Pathways for Future Sustainable Cities

Thesis submitted by

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CERTIFICATE FROM THE SUPERVISORS

This is to certify that the thesis entitled **"Pathways for Future Sustainable Cities"** submitted by **Smt. Swati Dutta,** who got her name registered on 25 February 2011 for the award of Ph. D. (Engineering) degree of Jadavpur University is absolutely based upon her own work under the supervision of **Prof. (Dr.) Suchandra Bardhan** and **Prof. (Dr.) Sanjukkta Bhaduri** and that neither her thesis nor any part of the thesis has been submitted for any other academic award anywhere before.

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Abstract

The emergent urban problems such as unprecedented population growth, urban sprawl, disparities between city core and its periphery, increasing traffic volume and congestion pose ever increasing challenges for our cities. It is generally seen that current trends and patterns of urbanisation point towards an uncertain future. Therefore, cities need to manoeuvre themselves to a position where they can improve life for people who flock to them and be environmentally sustainable.

It is found from the background studies that while the more conventional challenges of providing adequate housing, public transportation and other civic amenities to urbanising societies are recognised to some extent, the impact of India's urbanisation on the immediate environment of the human habitat has scope for further research and study. A general study of the urban morphology of our cities reveals that different configuration and types of built form and related population distribution characterize the urban form across the geographical extent of the city. Alternatively, it can be stated that density given by distribution of buildings, their typology and geometry, layout patterns, distribution / availability of open spaces, quality of infrastructure etc. varies from one locality to the other within the city. Thus, density gives rise to particular urban forms, land use and transit patterns in the city; and urban form and land-use along with transport system of a city are critical factors affecting urban environmental quality. Thus, it can be hypothesised that sometimes as a cause and sometimes as an outcome of urbanisation: Density impacts Urban Environmental Quality

The relationship between density and environmental quality is also found to be based on the concept of viable thresholds: at certain densities, the amount of development and number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable without putting a stress on the environmental carrying capacity. Hence, in order to provide a cleaner and sustainable environment to the city residents, it becomes pertinent to look at the urban environment at a micro scale, specifically the habitat of a neighbourhood / locality. In this context, the present thesis tries to understand the relationship between residential patterns observed in Indian cities and associated environmental quality at the neighbourhood level. The research hypothesis is formulated accordingly as – *Density impacts Environmental Quality in Residential Neighbourhoods.*

The scope is limited to the objective analysis of the physical aspects of the different residential neighbourhoods. This is grounded on the understanding that even though people evaluate their environments as they perceive, it is the physical aspect that provides a basis to objectively assess the quality of a place[1].

In order to comprehend the entire scenario, a detailed literature review is undertaken to understand the diverse types of urban processes and related environmental problems in different types of cities. Alongside, the terms density and environmental quality are defined and common measures adopted to describe the different types of density (People, Building and Spatial Density) and indicators to assess neighbourhood environmental quality (Crowding and Congestion, Nature and Use of Open Spaces, Shade and Ventilation, Temperature Variations, Average Noise Levels, Level of Cleanliness, Neighbourhood Walkability and Air Quality) are identified. The literature review reveals that studies taking into account physical aspects of the built environment and their impact on urban environmental quality are quite few especially in the Indian context and/or are sparsely reported, thus justifying the scope of the present work. Considering the significance of impacts, those responsible for poor environmental quality in residential neighbourhoods are acknowledged as the most urgent and greatest because of the immediate risk they present to their inhabitants' health and wellbeing. From these findings, finally, a set of variables as emerging from the literature review are identified to objectively measure the indicators of neighbourhood environmental quality.

Moving ahead, it is seen that much of the current sustainable cities debate focuses on the formidable problems of the world's largest urban agglomerations. However, it is predicted that in future majority of all urban dwellers will reside in smaller urban settlements of fewer than 500,000 residents[2]. This does not however mean that mega cities and larger metropolises would be neglected as they will continue playing a significant role in absorbing future anticipated growth, but for the foreseeable future metropolitan cities having population less than equal to half a million will hold the key to urbanisation[3]. Keeping this in mind, the research is primarily based on cities with 0.75 million ≤ population ≤ 1.5 million as it is known from literature and

[1] Alexander, E. (1993) Density Measures: A Review and Analysis. *Journal of Architectural and Planning Research*, 10 (3), 181-202.

[2] World urbanisation prospects: the 2003 revision data tables and highlights. New York, United Nations, 2004.

[3] Cohen, B. (2006) Urbanisation in Developing Countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society*, 28, 63-80.

background study that there is dearth of comprehensive database of Indian cities with population under 0.75 million[4,5].

The multiple case design is selected as the appropriate research strategy for the present study and subsequently, three rapidly urbanising cities namely - Amritsar, Chandigarh and Gurgaon (now Gurugram) with population size within the given range and situated in the same climatic zone (composite climate) are selected to explore and compare the residential patterns and neighbourhood environmental quality. A conceptual framework showing possible correlations between density variables and indicators of environmental quality is developed and an analytical model between the independent and dependent variables is proposed for the multiple hierarchical regression analysis. Three stages are identified beginning with i) the organisation of data, followed by ii) assessment of aggregated neighbourhood environmental quality (ANEQ) and formulation of the environmental quality index (EQI) and iii) culminating with the testing of hypothesis and best-to-fit analysis to identify optimum density ranges to maintain favourable environmental quality in different residential neighbourhoods of our cities.

A detailed study of eight neighbourhoods with different residential patterns from the three case study cities based on primary and secondary data is undertaken. The correlation coefficient analyses show that significant relationships (both positive and negative) exist between the density variables and indicators of neighbourhood environmental quality. While crowding and congestion generally increase with people density (R^2=0.466), people engage in different activities and greater social interaction happens in high density neighbourhoods (R^2=0.584). Other aspects like presence of sidewalks, streetlights, outdoor furniture, level of cleanliness, etc. determine peoples' desire to reside, walk and utilize spaces. Open spaces regulate the micro-climate (temperature) as shown by the negative correlation with R^2=0.182. Trees and vegetation also ameliorate noise and air pollution with average day time noise levels of 50dB and low $RSPM_{10}$ levels (80-100μg/m^3 against prescribed standard of 60μg/m^3) in some localities inspite of vehicular traffic. Both shade and naturalness increase the outdoor comfort conditions for the residents especially during the summer months as temperatures are more comfortable inside the locality (R^2=0.136). Good level of services and regular maintenance and upkeep of the

[4] World Wide Fund for Nature (WWF) (2010) Urbanisation and Sustainability in India: An Interdependent Agenda. *The Alternative Urban Futures Report 2010.*

[5] Indian Institute for Human Settlements (IIHS) (2011) Urban India 2011: Evidence. *Report of India Urban Conference 2011: Evidence & Experience (IUC 2011).*

neighbourhood ensure higher level of cleanliness as shown by the positive correlation with R^2=0.447 while proximity to daily needs, good condition of sidewalks with streetlights and open spaces helps in creating walkable neighbourhoods (higher scores between 3.5-5) – key factors for creation of sustainable cities.

The multi-criteria approach is adopted to assess the aggregated neighbourhood environmental quality (ANEQ). The approach helps to consider several density variables that can be controlled and modified during the planning and design phase to achieve better spatial quality of the designed space. The ‘Environmental Quality Index’ (EQI) and ‘Environmental Quality Profiles’ (EQP) formulated serve as tools to identify commonalities and differences in the indicators of environmental quality and justify the level of aggregated neighbourhood environmental quality (ANEQ) ascertained. The best-to-fit analysis and optimization technique enable identification of optimum values of the density variables that can be used as measures to attain favourable environmental quality in neighbourhoods with different residential patterns.

The study convincingly shows that all the measures of physical density (people, building and spatial density) have significant impact on neighbourhood environmental quality thus justifying their adoption for planning/design of new neighbourhoods or retrofitting/revitalization of existing neighbourhoods in rapidly urbanising Indian cities. The study also reinforces the need to promote contextual and participatory planning to cater to the needs and aspirations of the local people and enhance the environmental quality at the micro level. It helps in formulating several urban design guidelines for environmentally conducive development of residential neighbourhoods.

Finally, it is concluded from the research that the neighbourhood is a valid level of aggregation and a holistic approach incorporating social and economic factors along with physical factors is required for the assessment of environmental quality. The present research also provides immense possibility of advancing the derived methodology by future researchers to include cities of different sizes, classes, types, regions, etc. to derive case-specific solutions and suggest suitable measures to improve the neighbourhood environmental quality. Last but not least, the study can serve as a foundation for formulation of building or development control regulations for the planning and design of sustainable neighbourhoods with varying residential patterns suitable for different parts of a city.

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Chapter One

INTRODUCTION

The year 2008 was a milestone in the process of urbanisation that began several thousand years ago, but accelerated greatly in recent times. For the first time, there were as many people living in towns and cities as in rural areas. By 2050—when the world population is projected to reach over 9 billion—around 75% will be living in urban areas **(AGS, 2009)**.

Urbanisation has many causes and many faces. In underdeveloped countries, already about one billion people live in slums without basic necessities such as clean water and sanitation, and lacking secure tenure of the land they occupy. In rapidly industrializing countries such as China and India, urban growth is fuelled by economic development outstripping the capacity of cities to provide basic infrastructure. The results are traffic congestion, environmental pollution, increasing stress levels and acute health problems. At the other extreme, in some of the richest countries, a demand for larger houses and gardens is seen to produce vast areas of urban sprawl, with people using an ever denser transport network to commute long distances to their place of work. Huge megapolitan regions emerge in the process consuming small towns as they grow and causing fundamental changes to local, regional and global environments. In this context, visions of how cities will develop in future are quite diverse. With the urban populations of Asia and Africa set to double between 2000 and 2030 **(UNFPA, 2007)**, future urbanisation is predicted to be a largely developing world phenomenon[1]. India, projected to be an urban majority country[2,3] by 2040-45, is expected to be at the forefront of this massive socio-economic shift. It is believed that the manner in which the subcontinent responds to urbanisation over the next two to three decades shall define the social, economic and environmental future of not just the country, but given its size, also of the world.

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[1] According to United Nations Department of Economic and Social Affairs / Population Division; World Urbanisation Prospects: The 2003 Revision Population Database: In developed countries, 75 per cent of the population already lives in cities, compared to 35 per cent in developing countries. But the rate of urbanisation in developing countries is much higher – 3 per cent compared to 0.5 per cent in developed countries. Estimates show that by 2030, about 84 per cent of the population of developing countries will be living in cities.

[2] United Nations Population Division, World Urbanisation Prospects: The 2007 Revision Population Database.

[3] As per Census 2011, approximately 31 percent of India's total population or approximately 377 million people live in urban areas. Retrieved from http://censusindia.gov.in/2011-prov-results/paper2/data_files/india/Rural_Urban_2011.pdf

1.1 Background Study – Patterns of Urbanisation in Developing Countries

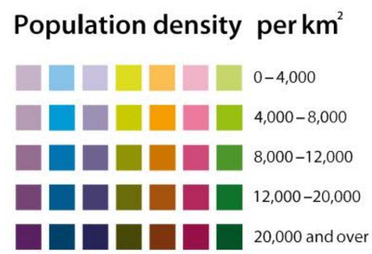
It is generally seen that current trends and patterns of urbanisation point towards an uncertain future. Therefore, cities need to manoeuvre themselves to a position where they can improve life for people who flock to them and be environmentally sustainable also. The different patterns of urbanisation found in developing countries are:

1.1.1 Peri-urbanisation or Suburban Sprawl and formation of City Regions: At present low- and middle-income countries are increasingly identified by the process of peri-urbanisation. In the peri-urban interface, the boundaries between the 'urban' and the 'rural' are continuously re-negotiated, and rather than being clearly defined are characterised by transition zones. These interfaces are affected by some of the most serious problems of urbanisation, including intense pressures on resources, slum formation, lack of adequate services such as water and sanitation, poor planning and degradation of farmlands. In most cases, planning regulations are weak or weakly enforced, and result in areas with complex patterns of land tenure and land use **(McGregor et al. 2006, Tacoli 2006)**. Although these areas provide a variety of activities and services for urban centres, they are generally beyond the legal and administrative boundaries of the cities, with the result that the process of urbanisation in most cases is unplanned and informal with frequent struggles over land use. Some scholars refer to these emerging urban configurations as 'city regions' emphasizing the fact that cities are growing not just in terms of population size, they are also changing their economic character and spatial form.

1.1.2 Low Density Urbanism or Restrictive Residential Enclave: Low-density urbanism on the other hand is a model equated with what is considered the destructive selfishness of the gated community and the environmentally disastrous results of low-density car-orientated suburbs, which are highly unsustainable and do nothing to support the traditional energy and vitality of urban life.

1.1.3 Urban Compaction and High Density: This refers to the compact city model which is often proposed for the sustainable development of our cities. However, in developing countries, cities generally have high densities and are characterised by high proportions of informal development lacking the infrastructure and urban management structures required to make the system work. Most of the people live in deplorable conditions with extreme compromises made on the standard of living. Any attempt at further densifying / intensifying these cities aggravates a range of problems like:

- Infrastructure overload,
- Housing shortage,
- Overcrowding and congestion,
- Air and noise pollution,
- Health hazards,
- Lack of public and green spaces and
- Environmental degradation



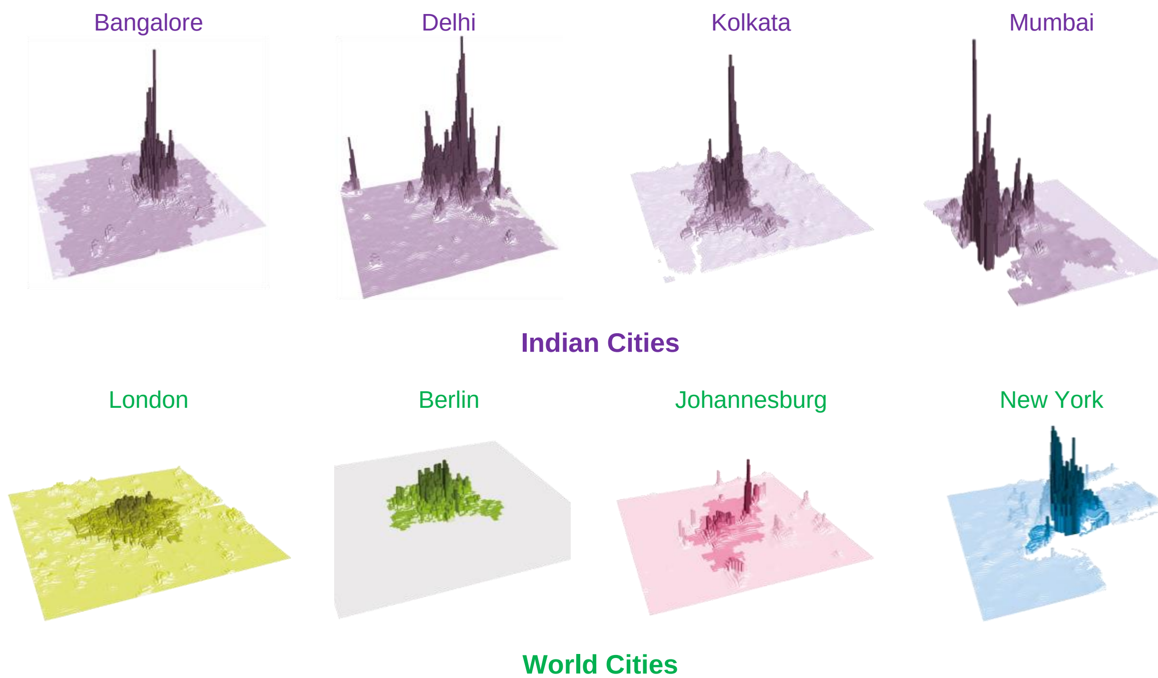


Figure 1.1: Urban Densities and Spatial Structure of Indian Cities compared with some World Cities

Source: Urban Age India, 2008 and Bertaud, 2011

As figure 1.1 illustrates, generally Indian cities have high density patterns as compared to the relatively dispersed and flat density pattern found in London, Berlin or Johannesburg. Mumbai is a typical example where within the city limits, the average density surpasses the mark of 27,000 people per km² (270pph) - a figure that rises to well above 50,000 people per km² (500pph) taking only the built-up area into account, a level higher than even the highest density peaks in

New York City's Manhattan area. Furthermore, it is not rare for the densest neighbourhoods of Mumbai to accommodate as many as 100,000 residents per km² (1000pph). Similarly Delhi – the capital city has a high average density of 9,340 people per km² (94pph approx.) inspite of its legacy of parks and other open spaces, as well as non-residential buildings and built forms that cannot be converted to residential uses.

1.2 Need of Study

The patterns mentioned above and the high rate of increase in the urban population creates many problems in our urban areas. Doubling and tripling of urban population practically in all major cities and towns and the consequent strain on the existing system gets manifested into an environmental chaos. Every major city of India faces the same proliferating problems of urban expansion, inadequate housing, poor transportation system, poor sewerage, erratic electric supply, insufficient drinking water supplies etc. An increasing number of trucks, buses, cars, three-wheelers and motorcycles – all spewing uncontrolled fumes, surging through haphazard city streets jammed with jaywalking pedestrians, rickshaw, cattle and goats are not an uncommon sight. The phenomena of accelerated urbanisation becomes the main culprit for bringing in problems like growth of dense and unplanned residential areas, increasing environmental pollution, non-availability of services and amenities, large amounts of solid waste generation and growth of slums **(Rahman et al. 2011)**. These conditions lead to the deterioration of the urban environment so fast that the sustainability of the cities is threatened. In metro cities, land and environment are especially under stress due to the pressure of rapid urbanisation. Population growth and in-migration of people, industrial growth, inefficient and inadequate traffic corridors, poor environmental infrastructure, etc. are the main factors that deteriorate the overall quality of the city. As the cities expand and population increases, the resources, which are limited, are shared. Housing, water supply, roads, drainage, transport, education, health services, police and fire services, etc. are not able to keep pace with the prevailing urban growth rate that leads to further degradation of the urban environment.

While the more conventional challenges of providing adequate housing, public transportation and other civic amenities to urbanising societies are recognised to some extent, it is felt that the impact of India's urbanisation on the immediate environment of the human habitat has scope for further research and study. This view is corroborated by independent research, which confirms that issues focussing on maintaining urban environmental quality do not figure very high on the agenda of city planners and local / national development authorities in India.

According to Urban Age, London School of Economics and Political Science (2008), 'Integrated City Making - Governance, Planning and Transport Detailed Report', only 12% of the respondents drawn from every level of Indian government and civil society point out environment as one of the three key challenges of urban India (as indicated in figure 1.2). The other key challenges include planning (47%), transport (41%), governance (32%), infrastructure (24%), migration (18%), housing (18%) and inequality (12%). Hence there arises a need to assess and maintain the environmental quality of our cities.

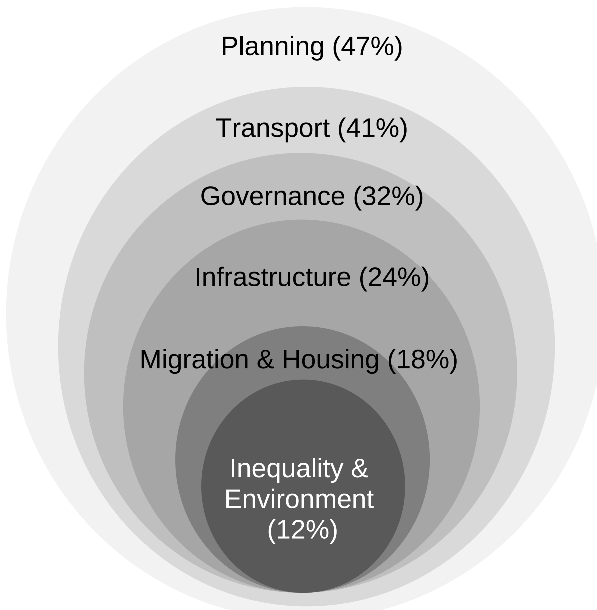


Figure 1.2: Key Challenges of Urban India

Source: Author's elaboration from Integrated City Making – Governance, Planning and Transport Detailed Report (2008) by Urban Age, London School of Economics and Political Science, 2012

While India can, and should draw a variety of lessons from the developed world that has already urbanised, it should base its tomorrow on fresh thinking and original ideas relevant to the local context. Hence there is a need to challenge mind-sets and provide practical solutions for our common urban future – a future that is not only economically stable or socially equitable but most importantly, environmentally sustainable **(WWF, 2010)**.

1.3 Area of Research

Land is one of the most contested and valuable of natural resources in urban areas. Change in land cover and modifications in land use account for one of the most significant changes in the environment due to human activity. At first glance, the issue of land and land use might appear superfluous to urbanisation as urban areas occupy less than 3% of the total land area globally **(Lambin, 2001)**, but the issue is extremely important for a number of reasons. It is well documented that the impacts of contemporary patterns of urbanisation on land and other resources far exceeds the actual extent of urban areas, as measured through ecological footprints and other tools. Moreover, there is already an indication that we may not be using land as efficiently as earlier, as the change in urban land use is faster than the rate of change in urban population **(Seto, 2011)**. Also, in almost all developing cities, the demand for urban land gets precedence over all other uses and results in loss of fertile croplands and ecologically sensitive areas **(Lambin, 2003)**.

While there are a few studies that measure land-use and land-cover changes for cities globally, there are only a handful of these for Indian cities. Generally, the patterns of urbanisation show that cities are sprawling. As they expand past their formal administrative boundaries, city densities lower over time as population growth rates lag behind the rate of the growth of built-up areas (as indicated in figure 1.3 and figure 1.4). This is hardly an unusual pattern when seen from a global perspective, but it does have obvious and possibly unfortunate consequences for urban governance, regional planning and the sustainability of our cities.

Most studies pertaining to causes and effects of urban expansion, nationally and internationally examine the issues at the citywide scale. They do not consider the issues at a smaller scale and understand the differences in patterns of urbanisation and its effect on the environment in different localities / neighbourhoods of a city. **Dowall and Monkkonen (2007)** examine urban densities in Chennai. The paper suggests that the city is growing both because of increasing density in inner city areas as well as expansion of city boundaries. Densities vary drastically from as low as 13 persons per hectare to more than 1000 persons per hectare in Chennai. Studying changes between 1971 and 2001 shows that the city has grown faster than predicted and density gradient of the city has flattened over the decades. The authors illustrating the case of Chennai point out that high density in central city is not because of high-rise buildings, but because of overcrowding. The above study points out that nature of density is also important vis-à-vis the measure of density. Similarly, the study by **Patel (2011)** is an attempt to set a framework on understanding densities and its relation to other factors that contribute to desirable urban living. The paper studies the interrelationships of six parameters: built up area per capita, public ground per capita, plot factor, floor space index, gross densities and net densities. It aims to arrive for a range of desirable values for a combination of these parameters while designing and planning an area between 20 and 200 hectares of land. The data is analyzed by plotting characteristics of select localities in Mumbai and New York. While this paper misses most sustainability aspects, it is one of the first attempts to answer the question of optimal densities in Indian cities.

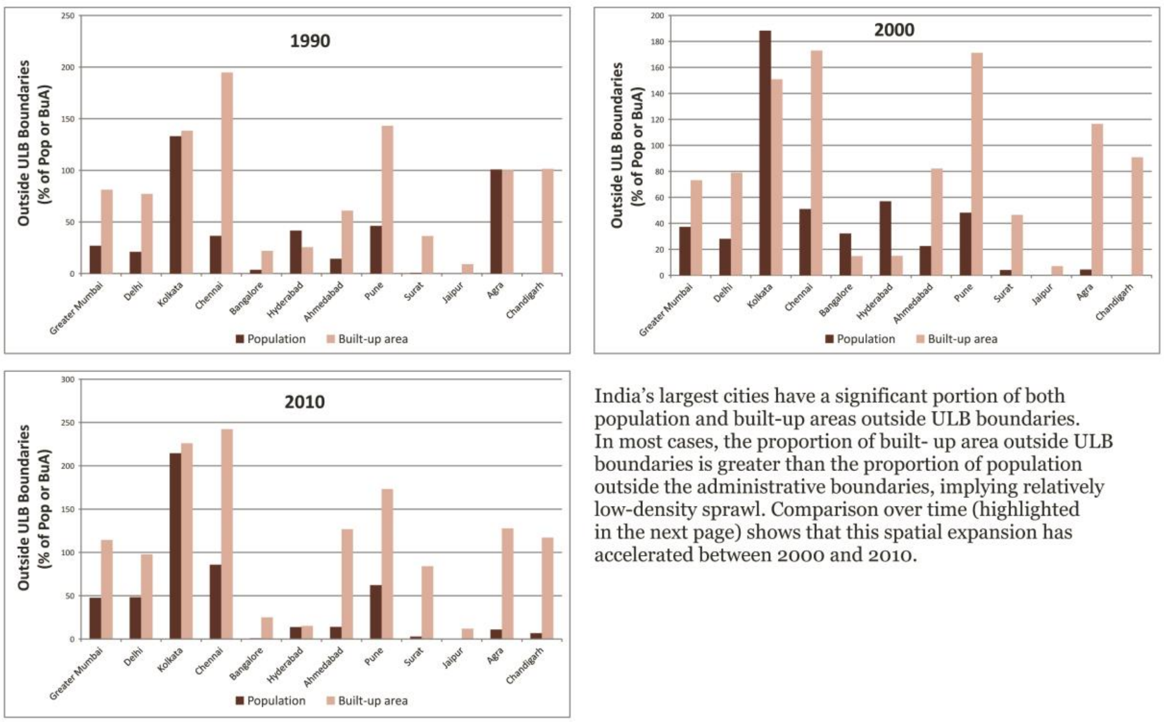
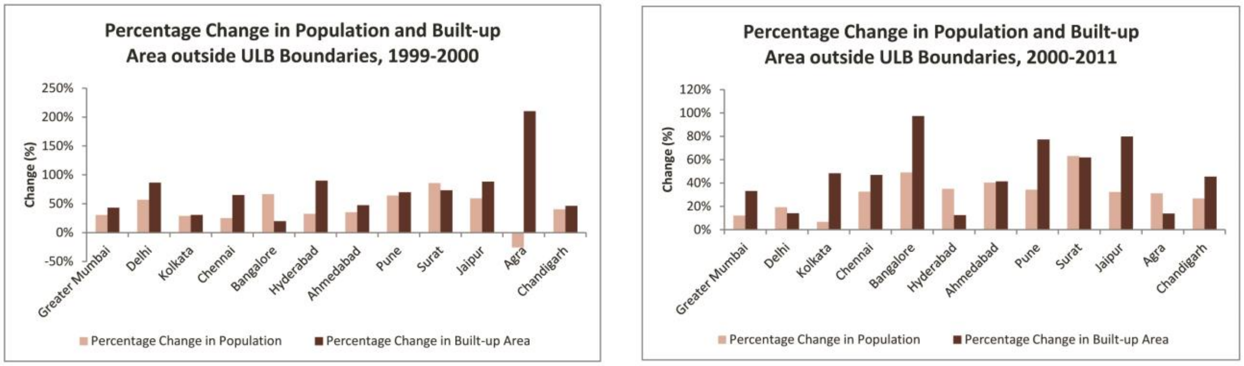


Figure 1.3: Population and Built-up Area - Outside ULB Boundaries in Indian cities

Source: H.S.Sudhira et al. (2004) and IIHS Analysis, 2011

Thus, most studies conclude that urban areas have a tendency to expand, and then gradually fill in and become contiguous (as indicated in figure 1.5a & 1.5b). However, very few studies intend to understand the effect of the physical development on the city's environmental quality, or the effect of a particular pattern of development within a particular land use. Questions like what are the different types of urban patterns identifiable? What is the nature of physical density? What is the distribution of people, buildings, open spaces etc. and resultant environmental quality are generally left unanswered.



Built-up area is growing faster than population in nearly all of the largest cities, especially between 2000-2011. In other words, lower-density sprawl is accelerating.

Figure 1.4: Urban Growth - Population versus Built-up Areas

Source: H.S.Sudhira et al. (2004) and IIHS Analysis, 2011

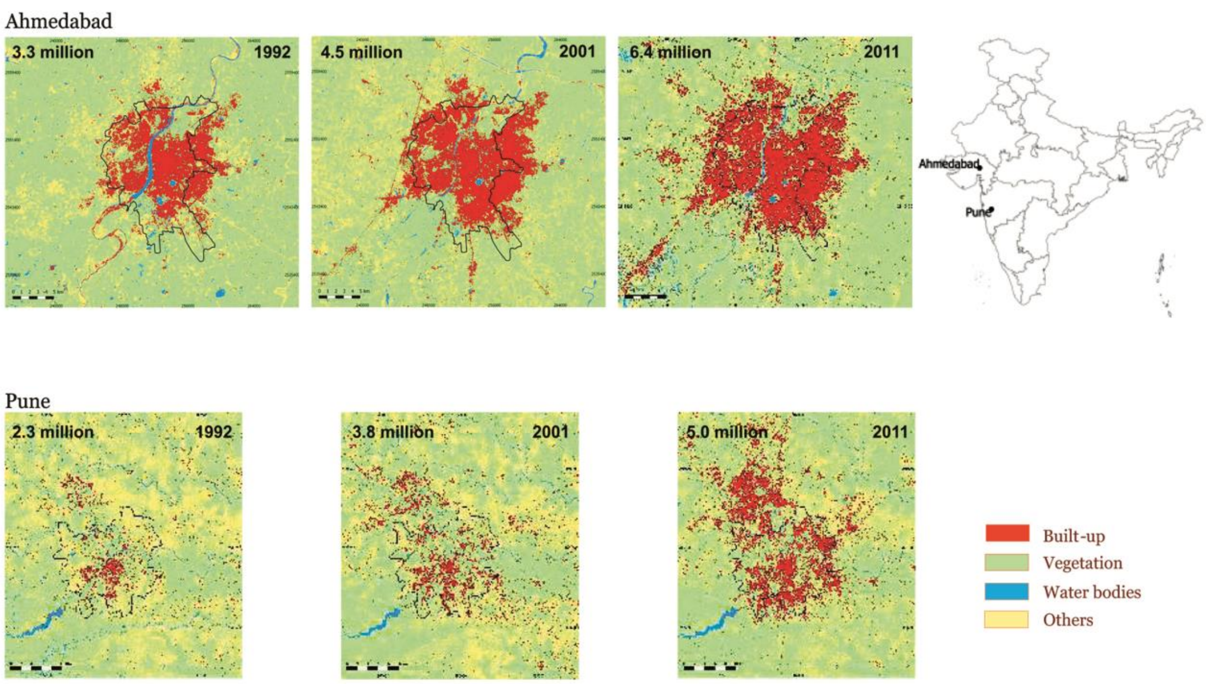


Figure 1.5(a): Change in Urban Built-up Area and Land Cover

Source: H.S.Sudhira et al. (2004) and IIHS Analysis, 2011

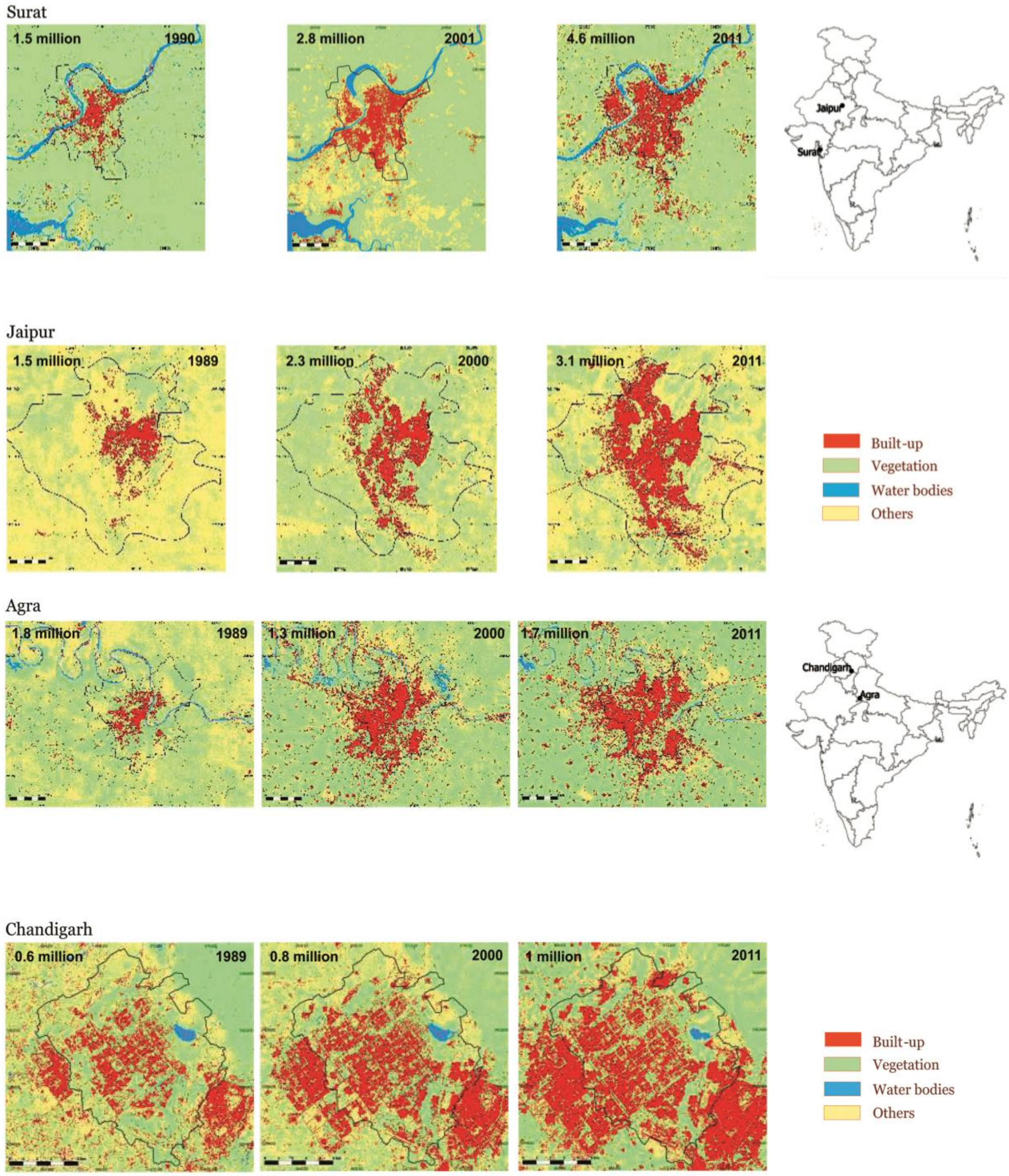


Figure 1.5(b): Change in Urban Built-up Area and Land Cover

Source: H.S.Sudhira et al. (2004) and IIHS Analysis, 2011

One of the reasons, as **Cadenasso (2007)** points out is that most land cover and land change methods are not adequate, as they do not capture urban heterogeneity well enough. These studies and corresponding analyses capture urban expansion, but not urban granularity at the block / neighbourhood level. Hence, a combination of tools may be required to answer the following questions:

- What are the environmental implications of different densities in different localities of a city, and?
- Can urban environment studies help in designing environmentally conducive neighbourhoods in our existing and upcoming cities?

Hence, a research on urban environmental quality with an objective analysis of the physical aspects of a residential locality can really prove useful in this regard. It can be used by residents to highlight and communicate concerns, wishes and positive aspects of their locality to fellow residents or decision makers (e.g. local authorities, planners, policy makers and organizations). The approach / method can also be used for the planning and design of new residential areas of the city.

1.4 The Research Hypothesis and Key Research Questions

Environmental Quality is an abstract concept resulting from both human and natural factors operating at different spatial scales. In urban areas the local scale is dominated by individual buildings, streets and trees, but regional scale influences may include the whole city and beyond **(Nichol and Wong, 2005)**. Hence, urban environmental quality is both objective and subjective in nature and in other words, spatial and physical features in addition to socio-economic factors affect the environmental quality.

Simultaneously, a general study of the urban morphology of our cities reveals that different configuration and types of built form and related population distribution characterize the urban form across the geographical extent of the city. Alternatively, as per **Cheng's (2010)** definition it can be stated that density given by distribution of people or buildings (people density), their typology and geometry (building density), layout patterns, distribution / availability of open spaces, quality of infrastructure etc. (spatial density) varies from one locality to the other within the city. Thus, density gives rise to particular urban forms, land use and transit patterns in the city. Further, it is also understood from various studies that urban form and land-use, and the transport system of a city are critical factors affecting urban environmental quality. Thus, it can be hypothesised that sometimes as a cause and sometimes as an outcome of urbanisation: Density impacts Urban Environmental Quality.

The relationship between density and environmental quality is also found to be based on the concept of viable thresholds: at certain densities, the amount of development and number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable without putting a stress on the environmental carrying capacity. In a wider sense, as **Carl, 2000** puts it, ‘Sustainable Cities are a matter of Density’.

Hence, in order to provide a cleaner and sustainable environment to the city residents, it becomes pertinent to look at the urban environment at a micro scale, specifically the habitat of a neighbourhood / locality. The present study is concerned with understanding the impact of different intra-city residential patterns on the neighbourhood environmental quality and search of an alternative approach for future sustainable growth of our cities. Accordingly the research hypothesis is:

Density impacts Environmental Quality in Residential Neighbourhoods

And the key research questions are:

1. What are the different residential patterns identifiable in rapidly urbanising Indian cities?
2. How does People Density measured by Population Density and Residential Density impact environmental quality in different residential patterns?
3. How does Building Density measured by FAR and Plot Coverage impact environmental quality in different residential patterns?
4. How does Spatial Density impact environmental quality in different residential patterns?
5. What are the optimum ranges of density for neighbourhoods with different patterns to maintain favourable environmental quality?

1.5 Aim and Objectives of the Study

The present study aims to understand the impact of density on environmental quality with change in the residential pattern of the neighbourhood. Accordingly the objectives are:

i. To identify different residential patterns and find representative neighbourhoods in the case-study cities.
ii. To disaggregate density and ascertain objective indicators that will help assess environmental quality at the neighbourhood level.

iii. To establish the association between density variables and indicators of environmental quality.
iv. To identify optimum density ranges for existing and upcoming neighbourhoods.
v. To arrive at guidelines to achieve environmentally conducive patterns of residential development for future sustainable cities.

1.6 Scope of the Study

One of the most enduring themes behind the search for more sustainable urban forms is that of the density of development. **Capello and Camagni, 2000** argue that "with the increase of residential density and the concentration of human activities within smaller built areas, it helps to exploit economies of scale for public services (e.g. schools, public buses and public utilities) and environmental resources (e.g. land, petrol and water). However, an excessive concentration of activities and proximity result in aggravated negative environmental externalities like traffic congestion, less privacy, poor access to natural agents (air, daylight, view, etc.) and overcrowding, which tend to outweigh the claimed benefits of urban compaction **(Burgess, 2000; Rudlin and Falk, 1999; Williams et al., 2000)**.

With this understanding, the present study tries to analyze the impact of different intra-city residential patterns on the neighbourhood environmental quality. The scope is limited to the objective analysis of the physical aspects of the different residential neighbourhoods. Accordingly, the study consists of reviewing, understanding, identifying and articulating the following aspects. Firstly, the patterns of urbanisation and its impact on the urban environment are reviewed followed by defining the two main aspects – Physical Density variables and indicators of Neighbourhood Environmental Quality and understanding the types and nature of impacts of Density on Environmental Quality. Next, eight neighbourhoods with different residential patterns are identified from the case study cities and coefficient correlation analysis is undertaken to assess the relationship between density and environmental quality. The study gives an opportunity to assess the aggregated neighbourhood environmental quality (ANEQ) using the multi-criteria approach and formulate the environmental quality index to generate environmental quality profiles that can serve as tools to identify commonalities and differences in the indicators of environmental quality for different neighbourhoods. Subsequently, the multiple hierarchical regression is used to test the research hypothesis and ascertain density values for optimum environmental quality using the best-to-fit analysis. Finally, the work helps in formulating some guidelines for environmentally conducive development of existing and upcoming residential neighbourhoods for our cities.

1.7 Limitations

While much of the current sustainable cities debate focuses on the formidable problems of the world's largest urban agglomerations, it is predicted that in future majority of all urban dwellers will continue to reside in smaller urban settlements of fewer than 500,000 residents (as indicated in figure 1.6). Thus, for the foreseeable future metropolitan cities having population less than equal to half a million will hold the key to urbanisation **(Cohen, 2006)**.

i. The research is limited to cities with 0.75 million ≤ population ≤ 1.5 million since it is known from literature and background study that there is dearth of comprehensive database of cities with population under 750,000 in a readily available format in India **(WWF, 2010 and IIHS, 2011).**

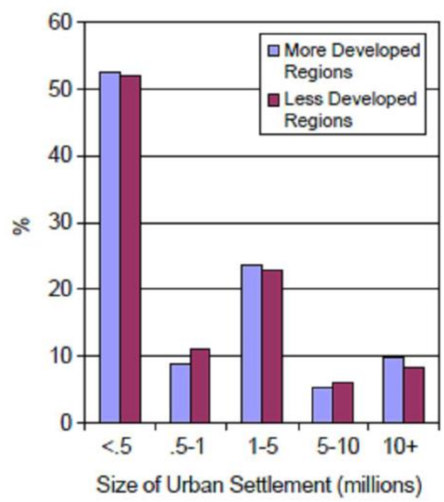


Figure 1.6: Distribution of urban residents by size of urban area, 2000

Source: World urbanisation prospects: the 2003 revision data tables and highlights. New York, United Nations, 2004

ii. Secondly, though the slum and squatter settlements pose a constant threat to the sustainable development of our cities, they are kept out of the scope of the present study. This is because of unavailability and paucity of data and poor physical conditions characterized by insecure land tenure, under serviced, unstructured and uncontrolled built environment rendering them unsuitable for taking measurements or carrying out field observations and visual surveys as an independent researcher.

iii. Thirdly, the study is limited to the objective analysis of the physical aspects of the different residential neighbourhoods. The investigation of people's perception to check the subjective values of an objective situation is presently kept out of the scope of the study. This is based on the argument given by **Alexander (1993)** that though individual cognitive factors provide a wider thinking on density as a concept, what determines density that is perceived by people is the physical form. **Acioly and Davidson (1996)** also contend that the size of the plot, the amount of plot that can be built up (plot coverage) and height of the building, floor area ratio etc. give the most visible aspect of density: the amount of space that is built. This is what designers determine in the design phase, which officials can control in planning through various development controls and building permissions.

iv. Fourthly, factors like the role of urban governance in the taxation and maintenance of municipal services and the resultant impact on environment quality and variations in socio-economic status of people and its effect on the type of facilities and amenities in a residential neighbourhood are also kept for future study and analyses.

Thus, the present research is focused towards understanding and suggesting ways to achieve environmentally conducive neighbourhoods – one of the key considerations for achieving long term sustainability as indicated in figure 1.7.

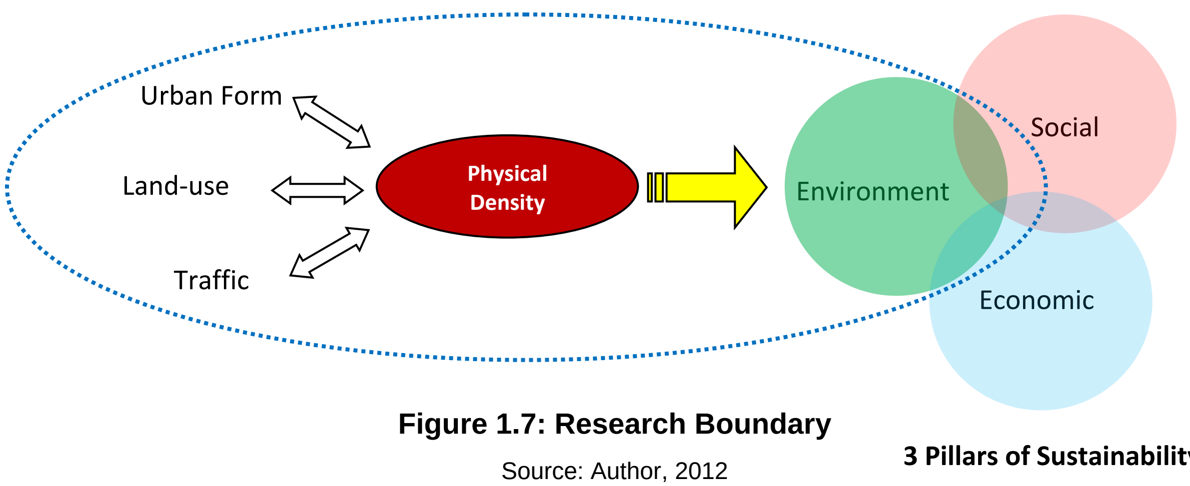


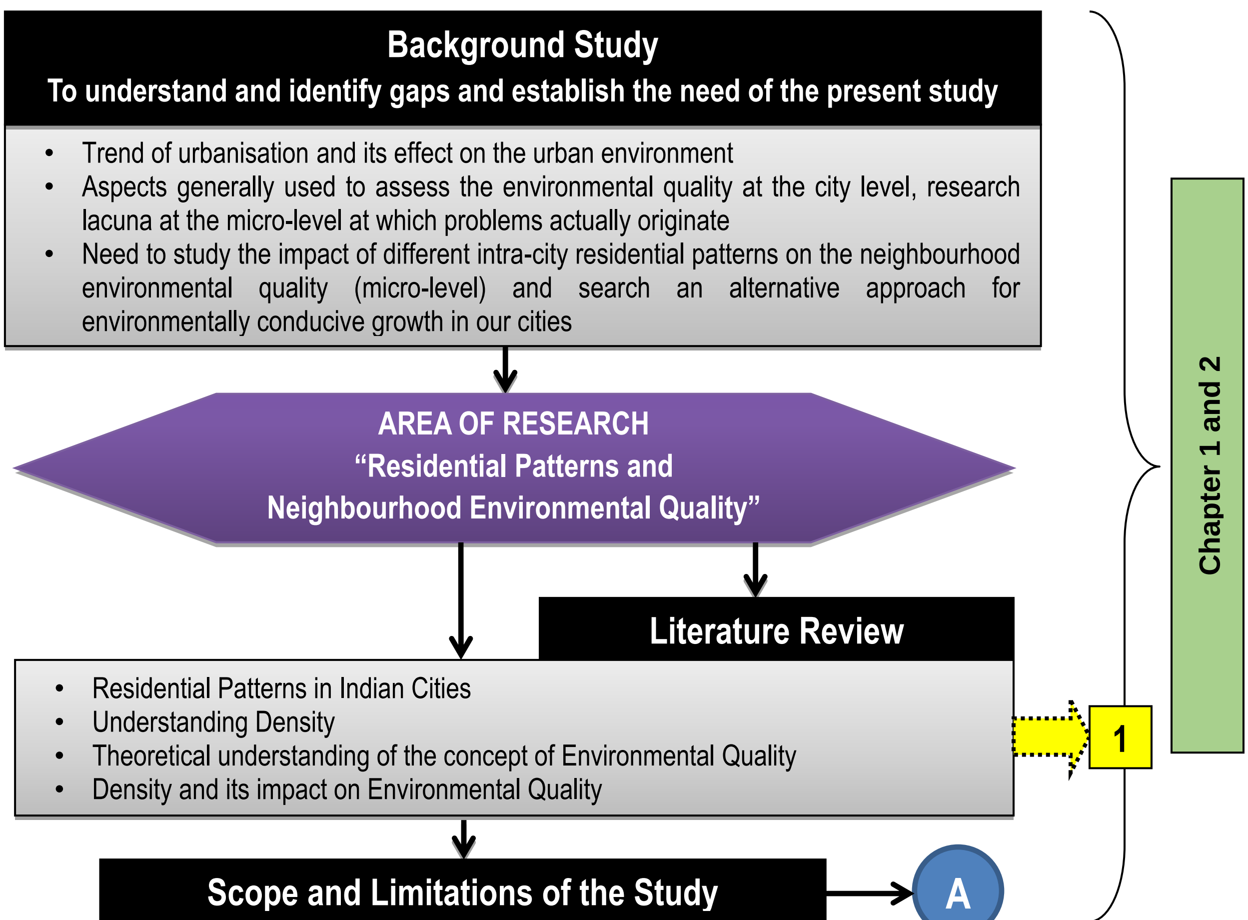
Figure 1.7: Research Boundary

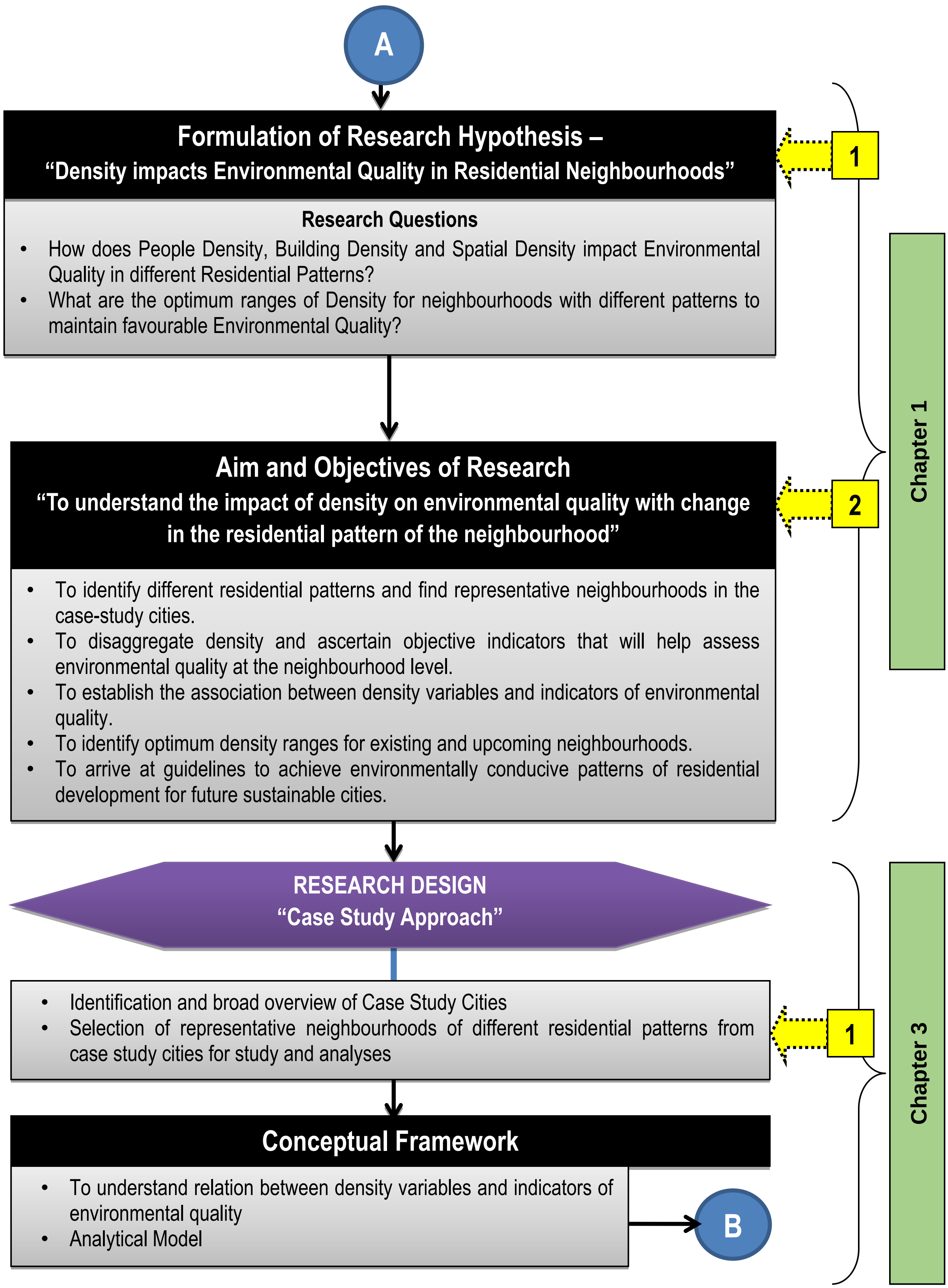
Source: Author, 2012

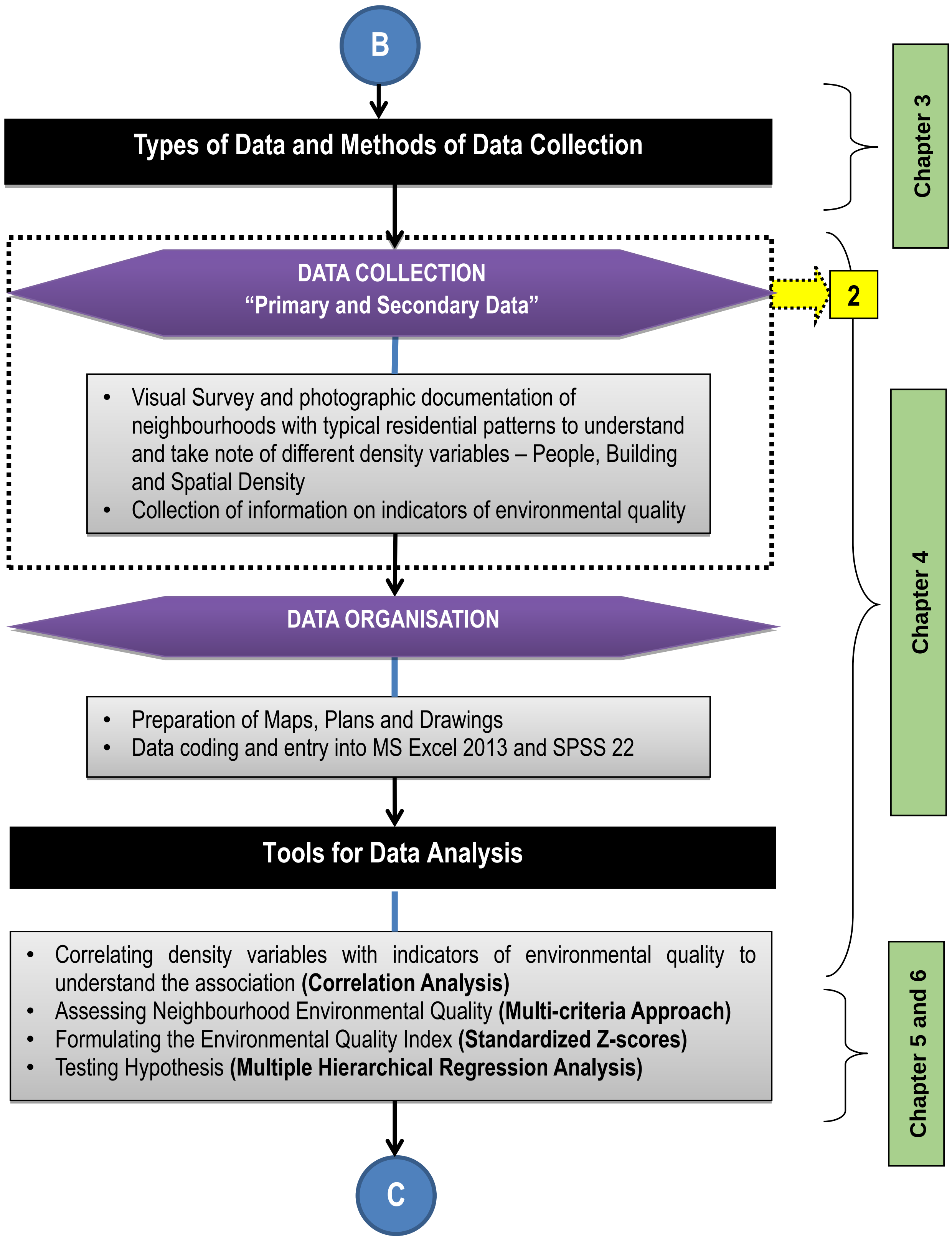
1.8 Research Methodology

Urban planners generally have very outspoken visions on environmental quality that contribute to livability **(e.g. Corbusier, 1935; Howard, 1898; Jacobs, 1961; Dantzig and Saaty, 1973)**.

Usually these visions are strongly conceptual, vary strongly in time (for an historic overview refer **Leidelmijer et al. 2002**), and can seldom be evaluated in practice. There is no coherent system to measure and evaluate aspects of, and trends in, environmental quality though concepts of urban environmental quality and related terms such as livability, quality of life and sustainability enjoy great public popularity and form a central issue in research programs, policy making and urban development **(Leidelmijer et al. 2002)**. Hence, in order to gain a detailed insight into the spatial components that influence environmental quality, several physical aspects of the urban form need to be evaluated from a new perspective. Accordingly, the **research methodology** (as indicated in figure 1.8) for the present study is detailed out as per the following stages:




A
Formulation of Research Hypothesis –
"Density impacts Environmental Quality in Residential Neighbourhoods"
Research Questions
• How does People Density, Building Density and Spatial Density impact Environmental Quality in different Residential Patterns?
• What are the optimum ranges of Density for neighbourhoods with different patterns to maintain favourable Environmental Quality?
1
Aim and Objectives of Research
"To understand the impact of density on environmental quality with change in the residential pattern of the neighbourhood"
• To identify different residential patterns and find representative neighbourhoods in the case-study cities.
• To disaggregate density and ascertain objective indicators that will help assess environmental quality at the neighbourhood level.
• To establish the association between density variables and indicators of environmental quality.
• To identify optimum density ranges for existing and upcoming neighbourhoods.
• To arrive at guidelines to achieve environmentally conducive patterns of residential development for future sustainable cities.
2
Chapter 1
RESEARCH DESIGN
"Case Study Approach"
• Identification and broad overview of Case Study Cities
• Selection of representative neighbourhoods of different residential patterns from case study cities for study and analyses
1
Conceptual Framework
• To understand relation between density variables and indicators of environmental quality
• Analytical Model
B
Chapter 3


B
Types of Data and Methods of Data Collection
DATA COLLECTION
"Primary and Secondary Data"
2
• Visual Survey and photographic documentation of neighbourhoods with typical residential patterns to understand and take note of different density variables – People, Building and Spatial Density
• Collection of information on indicators of environmental quality
DATA ORGANISATION
• Preparation of Maps, Plans and Drawings
• Data coding and entry into MS Excel 2013 and SPSS 22
Tools for Data Analysis
• Correlating density variables with indicators of environmental quality to understand the association (Correlation Analysis)
• Assessing Neighbourhood Environmental Quality (Multi-criteria Approach)
• Formulating the Environmental Quality Index (Standardized Z-scores)
• Testing Hypothesis (Multiple Hierarchical Regression Analysis)
C
Chapter 3
Chapter 4
Chapter 5 and 6

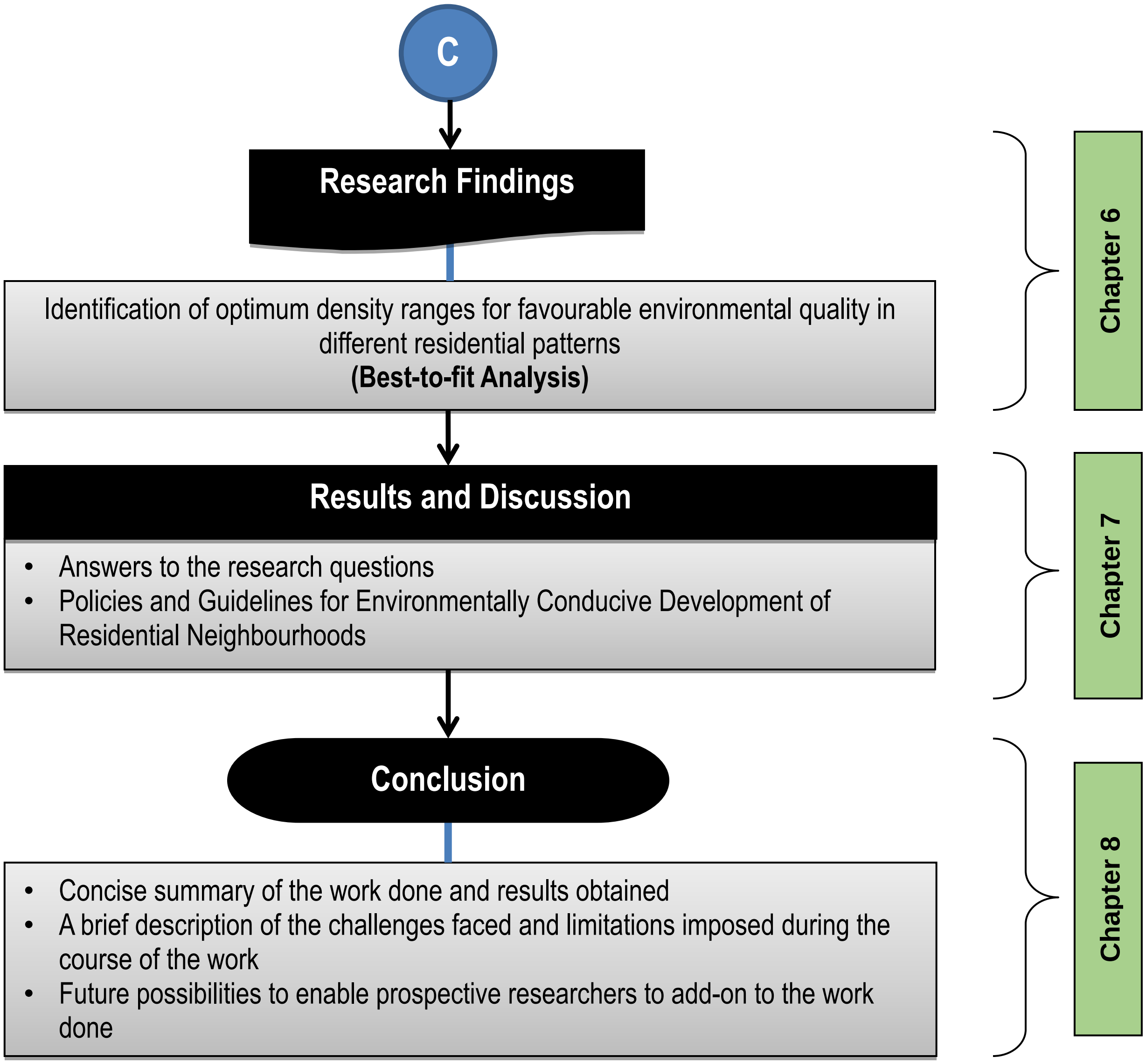


Figure 1.8: Research Methodology

Source: Author, 2012

1.9 Structure of the Report

This volume consists of eight chapters starting with an Introduction and finishing with Conclusion and Recommendations.

Chapter 1 – Introduction of the thesis begins with an over-view of the present trends of urbanisation and patterns of urbanisation in the developing countries and attempts to define the rationale of the present work and area of research. It subsequently defines environmental quality and its likely dependence on density and formulates the research hypothesis based on certain research questions. The key research questions help outline the Aim and Objectives of the thesis which is followed by the Scope and Limitations and a detailed Methodology for the present work.

Chapter 2 – Literature Review as the name suggests discusses the diverse types of urban processes and related environmental problems in different types of cities. It brings forth the key issue concerning environmentally sustainable development of cities in the wake of rapid urbanisation and shows the way to identify cities that hold the key to future urbanisation in India. Studies reveal that world over smaller cities/towns are going to accommodate larger number of people in near future and be the engines of economic growth and development. Following this, a thorough study to ascertain intra-city residential density patterns is undertaken. It is perceived that in order to understand the relationship between residential patterns characterized by built forms, distribution of dwelling units, population distribution, etc. and environmental quality, it is quintessential to study the local environmental problems at the neighbourhood level associated with different patterns found in Indian cities. Next, the terms density and environmental quality are defined and common measures adopted to describe the different types of density and parameters/indicators to assess environmental quality are identified. The literature review reveals that studies taking into account physical aspects of the built environment and their impact on urban environmental quality are quite few especially in the Indian context and/or are sparsely reported, thus justifying the scope of the present work. The chapter concludes with the discussion of impacts of increasing density on environmental quality. Considering the significance of impacts, those responsible for poor environmental quality in residential neighbourhoods are acknowledged as the most urgent and greatest because of the immediate risk they present to their inhabitants' health and wellbeing. Finally, the chapter ends with the identification of a set of variables as emerging from the literature review to measure the impacts. These form basis of the density-environmental quality correlation matrix and analytical model for further work as part of the research design.

Chapter 3 – Research Design elucidates the study design for the present work and identifies representative neighbourhoods from three case study cities namely - Amritsar, Chandigarh and Gurugram based on certain criteria as explained in the chapter to explore and compare the residential patterns and neighbourhood environmental quality. Next, density is disaggregated and indicators of environmental quality at the neighbourhood level are reinstated. A conceptual framework showing possible correlations between density variables and indicators of environmental quality is developed and an analytical model between the independent and dependent variables is proposed for the regression analysis. The chapter also gives a description of the types of data and methods of data collection to be adopted for the study and details out the various tools and stages of data analyses for subsequent work.

Chapter 4 – Study of Residential Neighbourhoods identifies eight neighbourhoods each representing a particular residential pattern from the three case study cities of Amritsar, Chandigarh and Gurugram and presents a detailed study of the same along with the study of the relationship between the different density variables and indicators of environmental quality. Traditionally formed Katra Dullo from walled city Amritsar is chosen as an example of low-rise high density neighbourhood whereas planned area Ranjit Avenue located outside the walled city is selected as an example of low rise medium density neighbourhood. Four neighbourhoods are selected from Chandigarh, namely, Sec-8, Sec-38W, Marble Arch, Manimajra and Sec-20, Panchkula. They are examples of low rise low density, low rise high density, medium rise medium density and medium rise high density neighbourhoods respectively. Finally, two gated communities are selected from Gurugram – World Spa and Uniworld City, both located in Sec-30 as examples of high rise low density and high rise high density neighbourhood. A detailed visual survey followed by organisation of primary and secondary data and study and analyses based on the conceptual framework and correlation coefficient analyses yield some valuable results.

Crowding and congestion increases with increase in people density. Also activity intensity increases with increase in people density and building density. Activity diversity shows an increasing trend with increasing residential density thus suggesting that more people engage in different activities and greater social interaction happens in high density neighbourhoods. Other aspects like presence and condition of sidewalks, streetlights, outdoor furniture, level of cleanliness, etc. determine peoples' desire to reside, walk and utilize spaces.

The arrangement of buildings and open spaces in a neighbourhood affect the radiation falling on the building surfaces, streets, roads etc. These in turn heat or cool the air temperature and have considerable effect on the micro-climate. The study also shows that there is significant association between building height to road width ratio and shade rating. Similarly, the presence of trees filter the sunlight, reduce air temperature by evaporation, protect smaller plants on the ground and reduce glare from bright overcast skies. Both shade and naturalness increase the outdoor comfort conditions for the residents especially during the summer months. The presence of vegetated open spaces also helps in ameliorating noise pollution in the neighbourhood.

It is also observed that proximity to daily needs, good condition of sidewalks and open spaces along with level of services helps in creating walkable neighbourhoods. As the cleanliness increases in the neighbourhood as a result of better services like efficient solid waste management, good storm water drains and proper sewerage system, people are encouraged to walk for their daily needs and short trips within and in the immediate surroundings of the neighbourhood.

Air quality is affected by the amount of roads, vehicles and congestion on roads, types of activities and appliances used, etc. More number of vehicles and smoke generating appliances imply more pollution and deterioration of air quality. Thus, the preliminary findings help to validate the conceptual framework and prompts to undertake the assessment of the aggregated neighbourhood environmental quality to formulate the environmental quality index for classification of the residential neighbourhoods.

Chapter 5 – Assessing Neighbourhood Environmental Quality details out the process of assessing the environmental quality at the micro-level using the multi-criteria approach. The multi-criteria approach helps to consider several density variables that can be controlled and modified during the planning and design phase to achieve better spatial quality of the designed space. The ‘Environmental Quality Index’ formulated serves as a tool to classify different neighbourhoods of the city according to the level of environmental quality. The illustrative maps are useful visual aids that help in bringing out heterogeneity at the block/neighbourhood level by identifying problems/issues at the micro-level. They represent and validate the conditions observed on site during the primary survey. The ‘Environmental Quality Profiles’ help to identify commonalities and differences in the indicators of environmental quality and justify the level of aggregated neighbourhood environmental quality (ANEQ) ascertained. The study also shows that significant relationships exist between density and neighbourhood environmental quality further propelling one to identify the most important density variables impacting environmental quality and test the research hypothesis for identifying optimum density values to maintain favourable environmental quality in neighbourhoods with different residential patterns.

Chapter 6 – Impact of Density on Environmental Quality tests the research hypothesis with the help of the multiple hierarchical regression (MHR) approach and conclusively shows that different density variables in varying degrees impact environmental quality in residential neighbourhoods. It thus proves the research hypothesis – '*Density impacts Environmental Quality in Residential Neighbourhoods*'. The regression coefficients or β weights give the relative importance of each of the significant density variables affecting neighbourhood environmental quality. The best-to-fit analysis and optimization technique enables identification of optimum values of the density variables that can be used as measures to attain favourable environmental quality in neighbourhoods with different residential patterns. The study convincingly shows that all the measures of physical density (people density, building density and spatial density) have significant impact on neighbourhood environmental quality thus justifying their adoption for planning/design of new neighbourhoods or retrofitting/revitalization of existing neighbourhoods in rapidly urbanizing Indian cities.

Chapter 7 – Summary, Findings and Recommendations presents a concise summary of the entire work with detailed discussion of each of the research questions. Based on the findings it is concluded that the neighbourhood is a valid level of aggregation for the assessment of environmental quality and certain recommendations are made for environmentally conducive development of residential neighbourhoods in rapidly urbanising present and future Indian cities. However, this is just a humble beginning and requires further studies and verification. Certain aspects are covered very briefly due to limitations in time, non-availability of proper/adequate data and integration mechanism.

The unresolved parts of the work are presented in **Chapter 8 – Avenues for Future Work** and it is expected that the future researchers would take up these partially-addressed challenges and supplement the work done in the course of this thesis.

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LITERATURE REVIEW

2.1 Introduction

Several studies indicate that majority of the cities around the world present a very similar pattern of urban development. All major towns and cities are found to be witnessing an explosive increase in urban population that strains the existing system and finally manifests into an environmental chaos (as indicated in figure 2.1).

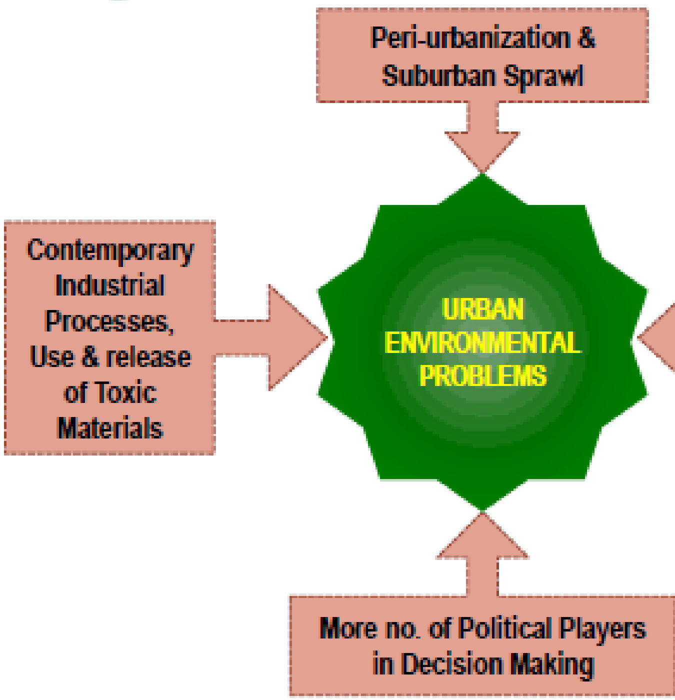

Figure 2.1: Urban Processes adding to Environmental Burdens

Source: Author's elaboration, 2013

It is often seen that low income or small cities with unplanned development have environmental problems that are localized, immediate and health threatening for the local residents because of the poor environmental quality within the city. The environmental problems in middle–income cities are somewhat city–wide or regional, while affluent or high income cities generally have fewer environmental problems and hence good environmental quality but because of their high rate of consumption and resource use pose a threat to environment and ecological sustainability at the global level. Also as cities transform from one level to another, the type of environmental problems they have to deal with change (as indicated in figure 2.2).

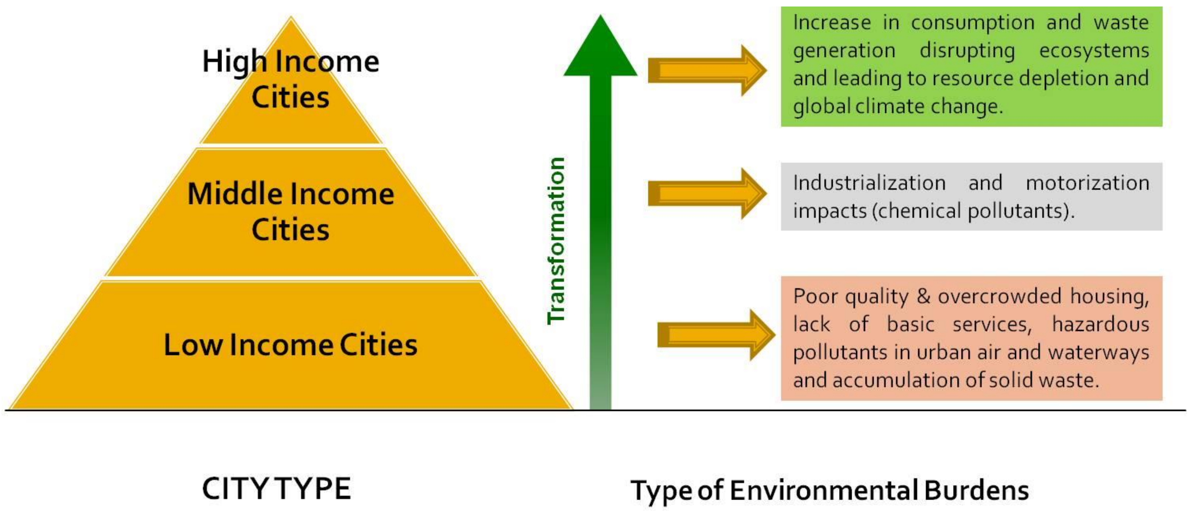

Figure 2.2: Environmental Issues in different types of Cities

Source: Author's elaboration from UNU/IAS Report – Urban Ecosystem Analysis: Identifying Tools and Methods (Piracha and Marcotullio, 2003)

The Indian scenario though somewhat similar for smaller cities is different in terms of the growth and development patterns and subsequent environmental problems faced especially by the larger cities. The low income (small and medium) towns continue to face local environmental problems as a result of lack of infrastructure and provision of basic services. The middle, upper middle and high income cities (larger cities and metropolises) on the other hand continue to grow undesirably in most cases accompanied by transformations and transgressions that adversely affect the city environment and its inhabitants[4]. As more and more people from small cities and rural areas migrate to these cities in hope of better jobs and comfortable lives, the city and its hinterland become an object to plunder for personal gains. The profiteering tendencies of the development authorities capped with political and bureaucratic jargon become responsible for the negative physical growth of the city. Zoning regulations and building byelaws are relaxed

[4] The poor live on $2 or less daily, low income on $2.01-10, middle income on $10.1-20, upper middle income on $20.1-50 and high income on more than $50; figures expressed in purchasing power parities in 2011 prices. People are grouped by the daily per capita income or consumption of a four person household.

Source: Pew Research Centre analysis of data from the World Bank PovcalNet database (Centre for Global Development version available on the Harvard Dataverse Network) and the Luxembourg Income Study database, (Kochhar, 2015).

to enable the private players to produce development of their liking. Land use changes are allowed without giving a thought to the impact that would follow. Lung spaces disappear from the city and ironically the city has hardly any green space left with most of the parks converted to other land uses, primarily the commercial uses and for utilities. Land prices shoot up as a result of profit oriented privatised urban development and the poor are completely alienated from the development process. With no choice left, they are forced to grab the nearest available open patch of land. Thus starts the proliferation and growth of slums and squatter settlements in the urban landscape **(Sandhu and Gill, 2010)**.

Away from the inner city, the periphery presents an equally dismal scene with the agricultural land fast converted to residential plots by both licensed and unlicensed private colonizers. The absence of appropriate periphery control and regulations result in unabated informal and chaotic developments on the fringe area leaving little scope for planned and orderly expansion in the future. Therefore, overall this type of unregulated growth and poor quality development results in bad water and air quality, unmanaged or mismanaged waste and increasing noise pollution because of increasing traffic especially in the already congested city. In several instances, controlling encroachment into public spaces and degradation of cultural and heritage sites also becomes a major problem. All these become a threat to the environment and people's lives and eventually cause deterioration of the urban environment. Therefore, it is important to note that growth and development patterns result in particular types of urban forms that have a definite impact on the urban environmental quality.

Thus, it is increasingly felt that the problems related to environmental quality in urban areas are very complex and require a systematic approach and careful analysis of all the relations between the parameters that are part of the urban environment. Several studies show that urban environmental problems have a local origin and should be addressed in cooperation with local stakeholders. Also, it is recognized that global environmental decay often manifests itself at a local level. This awareness has led to the formulation of the **Local Agenda 21** (1997)[5], in

[5] Agenda 21 is an action plan of the United Nations (UN) related to sustainable development. It was an outcome of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organisations of the UN, governments and key groups in every area in which humans directly affect the environment. The implementation of Agenda 21 was intended to involve action at international, national, regional and local levels. Some national and state governments have legislated or advised that local authorities take steps to implement the plan locally, as recommended in Chapter 28 of the document. Such programs are known as 'Local Agenda 21' or 'LA21'.

which a plea is made for local dedicated actions to reduce environmental decay and improve local socio-economic conditions. Hence, in order to provide a cleaner and sustainable environment to the city residents, it becomes pertinent to look at the urban environment at a micro scale, specifically the habitat of a neighbourhood.

2.2 Urbanisation in India

Urbanisation in India began to accelerate after independence, due to the country's adoption of a mixed economy, which gave rise to the development of the private sector. Population residing in urban areas in India, according to 1901 census, was 11.4%. This count increased to 28.53% according to 2001 census, and crossed 30% as per 2011 census, standing at 31.16%.

Presently with an urban population of **377mn – (approximately 30%) of 1.2billion as per Census 2011**, INDIA is about to embark on a period of rapid urbanisation with 60% urban population by 2030 as economic development shifts increasing numbers away from subsistence agriculture (as indicated in figure 2.3).

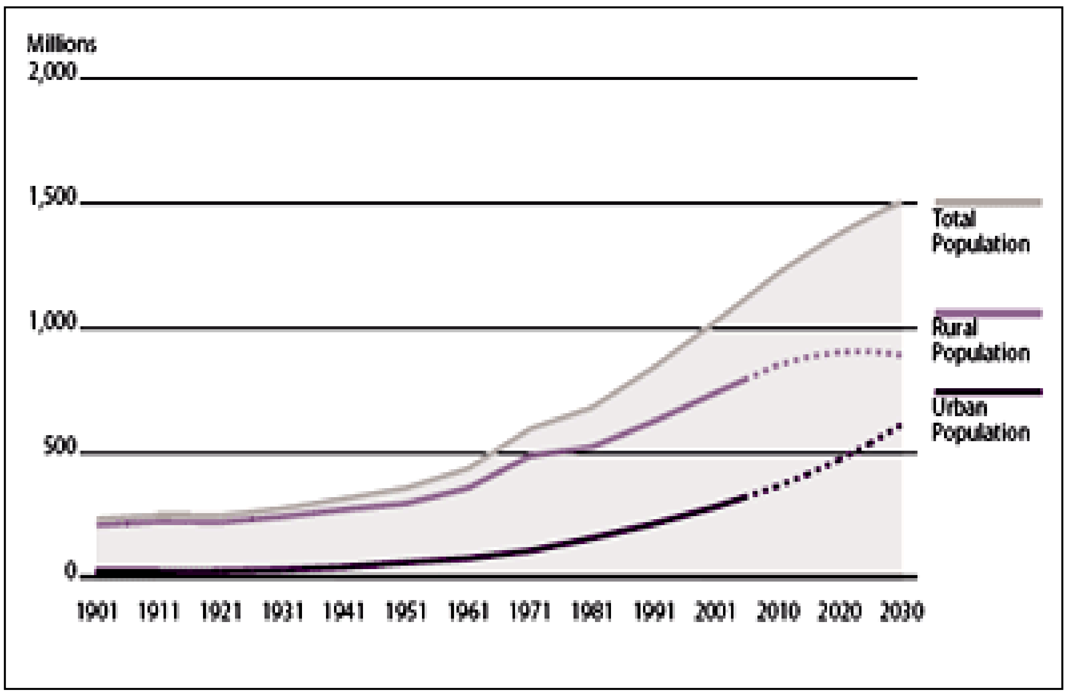

Figure 2.3: Population Growth in India

Source: United Nations Population Division, 2008

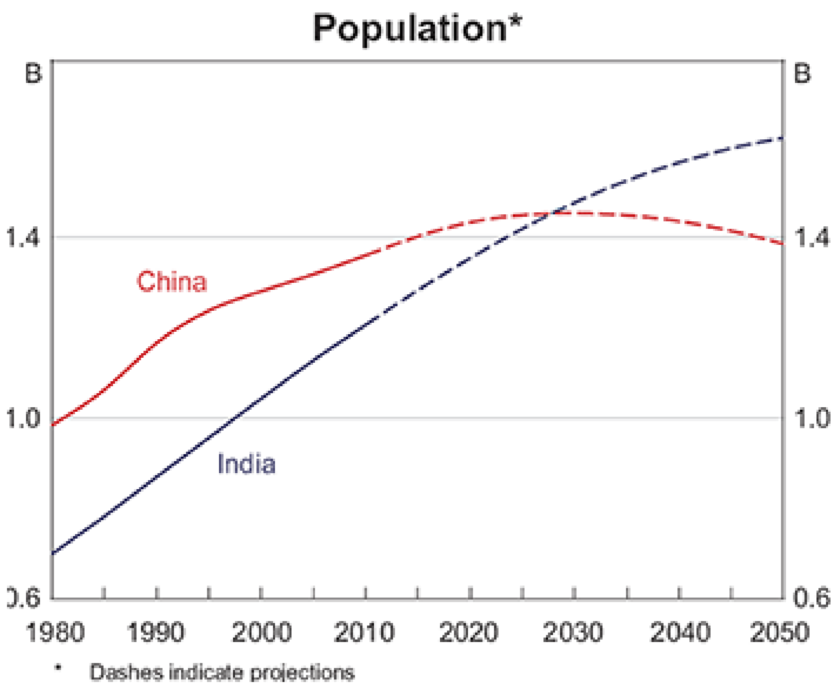

Figure 2.4: Population projections of India and China

Source: United Nations Population Division, 2008

China and India account collectively for almost 40 per cent of the world's population, with populations of 1.3 billion and 1.2 billion, respectively. Over the past three decades, India's population has grown at a much faster rate than in China. Projections from the United Nations suggest that while India's population will continue to grow, albeit at a somewhat slower pace than in the past, China's population will increase more slowly and eventually begin to decline around 2030 when India's population is expected to surpass that of China (as indicated in figure 2.4).

India has emerged as the world's second fastest growing economy (after China) in the first decade of the 21st century. This has happened due to:

- The change from the post-independence socialist development model with strong rural bias to a more open and varied economy.
- Spread of primary education – 51% in 1991 to projected 90% in 2020.
- Unprecedented shift of the small town middle class and rural population to the cities.
- Expected formation of around 13 Urban Agglomerations of more than 10 million people by 2025.

The explosive growth of Gurugram and Bangalore in the last ten years is only a foretaste of what we will witness in the next few decades. The key issue is then how does urban India deal with the influx of 343mn more people in an environmentally conducive way when it is already struggling with the existing population?

Also, it is important to note that most of India's urban centres are smaller towns. The 8000 urban centres identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only twenty percent live in million plus cities. Eighty percent of the urban population lives in cities and towns of population ≤ 1 million. Correspondingly, as the trends in urban and rural population growth in figure 2.5 indicate that less developed regions will show a much higher growth in urban population than more developed regions, the most meaningful approach in our case would be to expect the rapid growth of Class I (0.1 – 1 million) cities and put them centrally on the development agenda. This does not however mean that mega cities and larger metropolises would be neglected as they will continue playing a significant role in absorbing future growth, but for the near future cities with 0.1 – 1 million population will hold the key to urbanisation in India.

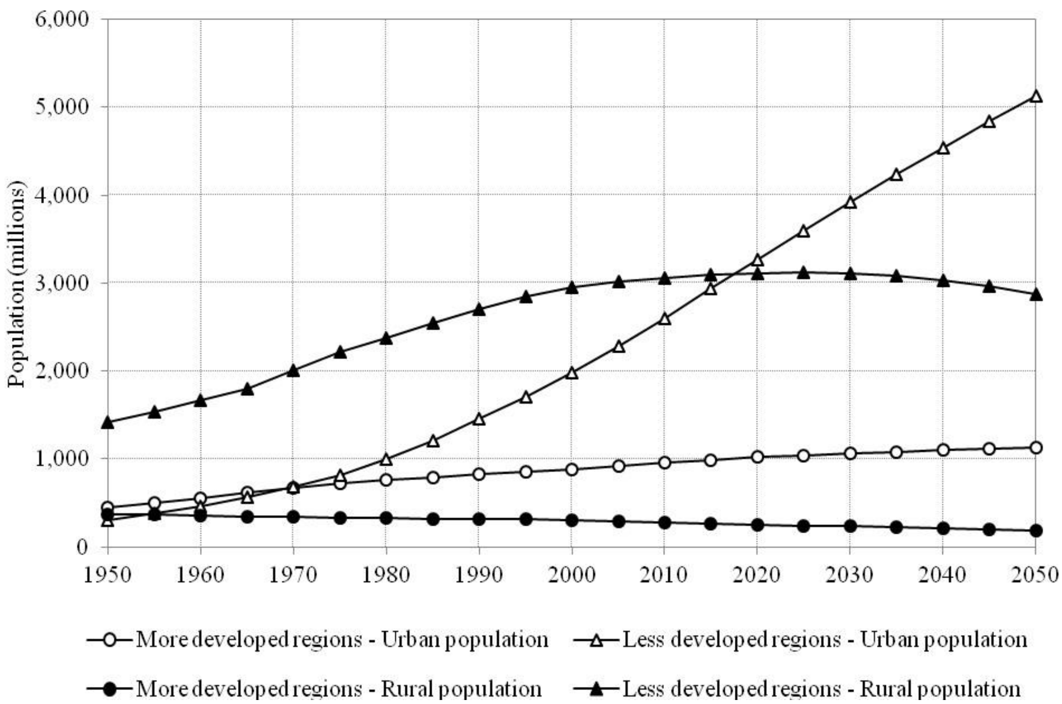

Figure 2.5: Trends in Urban and Rural Population Growth

Source: United Nations Population Division, 2012

2.3 Intra-city Residential Patterns in Indian Cities

By and large it is seen that patterns of urbanisation within a city differ from one location to another depending on local topography, land use regulations, socio-economic and cultural preferences of people and political and historical developments. It is also understood that these varying patterns of urban development from one place to another result in differences in levels of population density, concentration and mixing of residential or commercial uses, amount of open spaces and amount of intervening land devoted to non-urban uses **(Galster et al., 2001)**. This fact is best understood by carefully observing our Indian cities.

In most of the cases, the inner core or walled city in a traditional Indian city is found to be a compact city (low rise high density) largely designed for pedestrian use and cycle rickshaws supported by horse driven carts (Tongas) on certain marked routes. The entire built up mass is more or less a compact monolithic volume with small punctures for the purpose of light, ventilation and movement (as seen in plate 2.1). Domestic life revolves around an organically grown settlement pattern, closely knit to a physical density that permits the essential public open spaces in the form of streets and chowpals (public squares) and large courtyards. It is estimated that courtyards and pedestrian streets occupy nearly 30% of the area with the remaining area constituting the built up volume. The compact ground coverage of nearly 70% with ground plus two or three storey high buildings ensure that streets are shielded from the heat of the sun. Thus the pedestrian streets remain cool during hot summers and much cooling is also obtained by natural wind currents because of the particular orientation of the streets **(Kapadia, 2010)**.

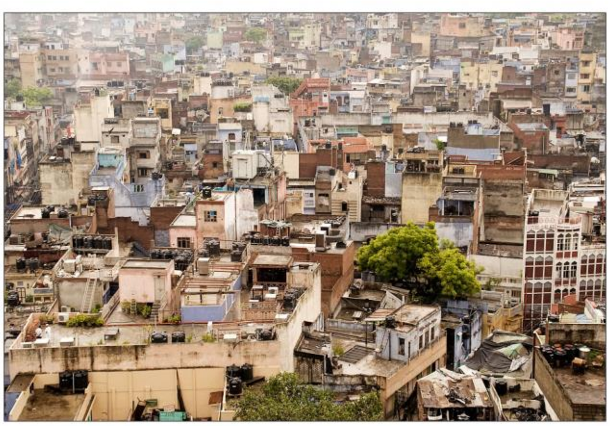


Plate 2.1: Compact Built-form in Old City Areas of Shahjahanabad and Ahmedabad

Source: www.google.com, 2013

Old parts of Shahjahanabad (Delhi), Jaisalmer, Jaipur, Ahmedabad, Vadodara, Amritsar and many other cities exhibit these characteristics. Being predominantly pedestrian entities, the towns ensure an interactive social community and since social, cultural and religious customs play a huge role in peoples' lives, they are seen expressed in special architectural details and in use of space at the residential and neighbourhood level **(Kapadia, 2010)**.

The city outside the walled area is dominated by the British annexes (low rise low density) in quite a few cases. While the indigenous or traditional city that grew around or alongside a fortress, royal palace or holy place or emerged from a village is irregular and amorphous in composition; the annexes (cantonment, civil lines and railway colonies) though in varying degree, are found to be much more organised with regular settlements that are spacious and sanitary (as seen in plate 2.2) with buildings far more clearly distinguished and grouped according to their functions **(Smailes, 1986)**.

Plate 2.2: Wide Avenues and Lush Green Open Spaces in Amritsar Cantonment

Source: Author, 2014

Leaving aside the British annexes, in most cases, newer parts of the city are found to have developed haphazardly around or along old areas as a result of accelerated industrialization and rapid urbanisation. High densities (medium rise high density or high rise high density) are found in and around commercial and industrial zones offering jobs to resident and migrant population, along transport corridors that promote easy accessibility to and from the place of work and so on and so forth (as seen in plate 2.3). The built forms are generally mid and high rise buildings, typically designed as heterogeneous and self-referential projects that rarely respond to their adjacencies, surrounding streets or their location within the city. The haphazard mushrooming of slabs and towers represent not only the denial of a coherent urban form and public realm, but the reduction of the very idea of city-making into an unchecked, rapacious capitalism in such cases **(Bharne, 2011)**.

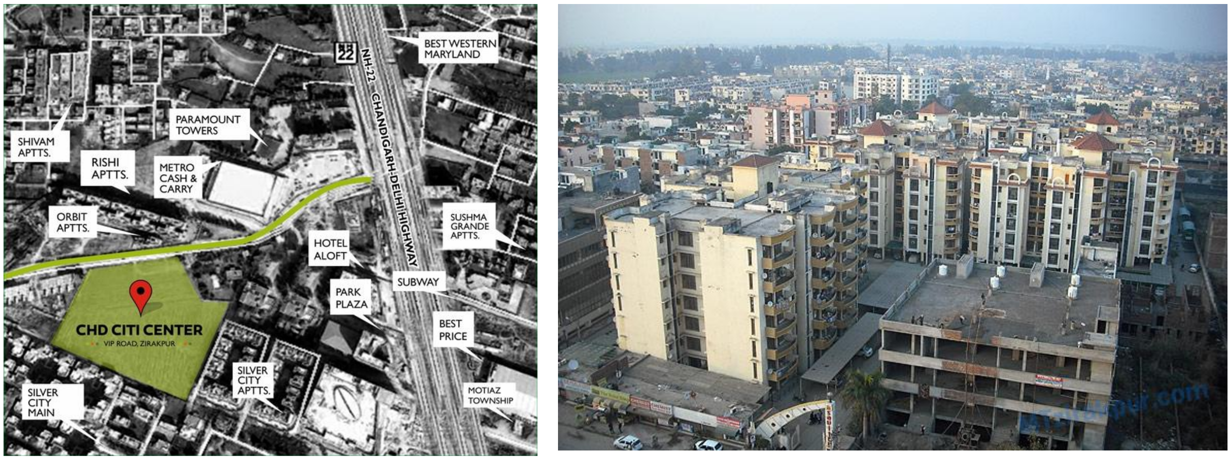

Plate 2.3: Haphazard Developments along Delhi-Chandigarh Highway

Source: www.google.com, 2013

Lastly, the residential development seen in most city outskirts are the gated communities dominated by high rise apartment blocks, community open space and shared facilities and amenities (as seen in plate 2.4). Though these communities themselves might be high rise high density enclaves but at the scale of the city, lying on the fringes they are generally part of a low-density car-orientated suburb, which is highly unsustainable and does nothing to support the traditional energy and vitality of urban life.

Plate 2.4: View of new upcoming residential projects along Bye-Pass, Amritsar

Source: Author, 2013

The urban form of the city is thus characterized by different configuration and types of built form and related population distribution across the geographical extent of the city. Alternatively, it can be stated that distribution of buildings, their typology and geometry, layout patterns, distribution / availability of open spaces, quality of infrastructure including links to the wider urban system etc.

vary from one locality to the other within the city. So, in order to understand the relationship between residential patterns characterized by built forms, distribution of dwelling units, population distribution, etc. and environmental quality, it becomes quintessential to study the local environmental problems associated with different patterns in a city.

2.4 Understanding Density

Density has been studied extensively from many perspectives including – physical, psychological, social and environmental perspective **(Breheny, 1992; Jelinek, 1992; Alexander, 1993; Churchman and Mitramy, undated; Acioly and Davidson; 1996; Rådberg, 1996 and Arenas-Gomez, 2002)**. In the field of planning, density has often been used to refer to the degree or intensity of development or occupancy. Conventionally, urban densities have been defined from two perspectives; of population and physical density. While population density has been referred to as the number of persons per unit ground area of development, physical density (sometimes referred to as objective density) has been examined as land use ratios. In housing and urban design, density has been measured in terms of floor area ratios or floor space index, plot coverage and dwelling units per specified area **(Alexander, 1993)**.

2.4.1 Measuring Physical Density

According to **Cheng (2010),** physical density is a numerical measure of the concentration of individuals or physical structures within a given geographical unit. Measurement of physical density is broadly divided into two categories: people density and building density. People density is expressed as the number of people or household per given area, while building density is defined as the ratio of building structures to an area unit. Common measures of people and building densities are outlined as follows.

2.4.1.1 Measures of People Density

- **Regional density** - Regional density is the ratio of a population to the land area of a region. Regional density is often used as an indicator of population distribution in national planning policy.
- **Residential Density** - Residential density is the ratio of a population to residential land area. This measure can be further classified in terms of net and gross residential densities based on the definition of the reference area. As per the **Model Building Byelaws 2016**

of the Town and Country Planning Organisation (TCPO), MoUD, Govt. of India, the residential density is expressed in terms of the number of dwelling units per hectare. Where such densities are expressed exclusive of community facilities and provision of open spaces and major roads (excluding incidental open spaces), these are considered as net residential densities. Where these densities are expressed taking into consideration the required open space provision and community facilities and major roads, these are gross residential densities at neighbourhood level, sector level or town level, as the case may be as indicated in figure 2.6. Incidental open spaces are mainly open spaces required to be left around and in between two buildings to provide lighting and ventilation.

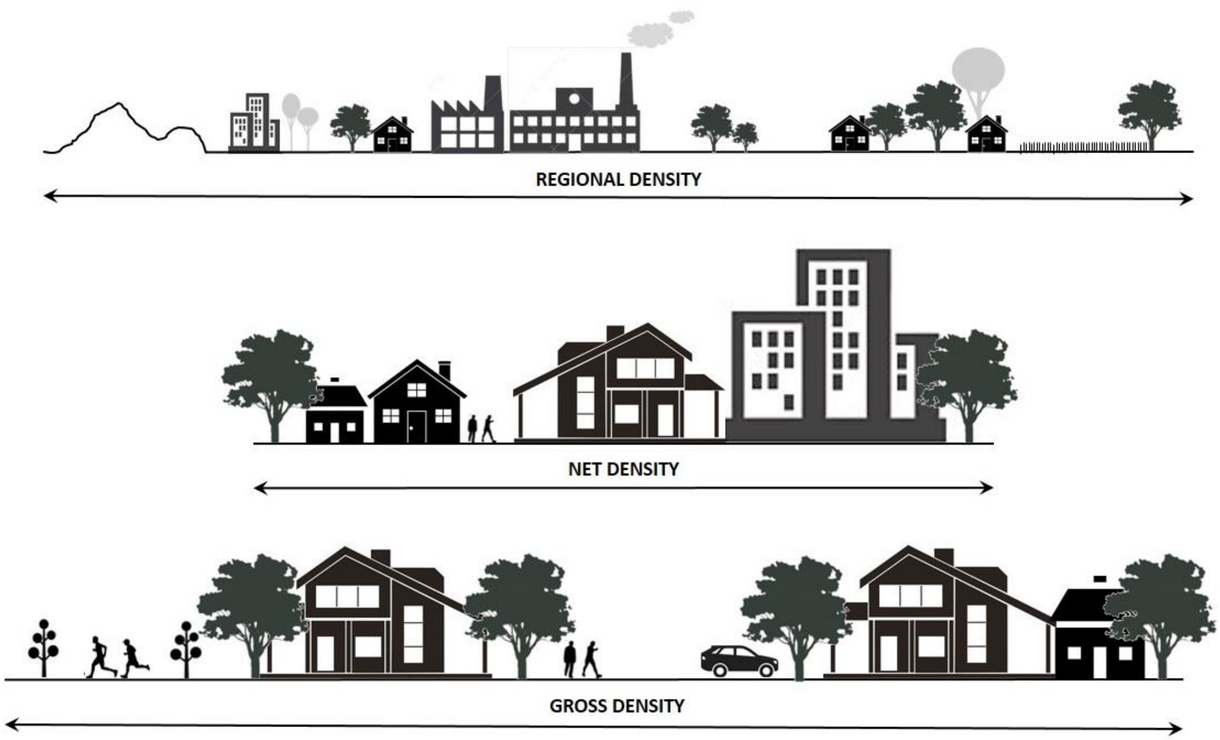

Figure 2.6: Measures of People Density

Source: Author's elaboration from Cheng's (2010) Study

- **Occupancy density –** Occupancy density refers to the ratio of the number of occupants to the floor area of an individual habitable unit. **Cheng (2010)** states that **Occupancy rate**, which is the inverse measure of occupancy density (i.e. ratio of floor area of individual unit to number of occupants), is commonly used as an indicator of space available for individual occupants. Higher occupancy rate means larger habitable area for individual occupants. Regulation of minimum occupancy rate is often used in building design to safeguard the health and sanitary condition of habitable spaces and thus ensure quality. The present study also considers built-up area per capita (BUA/Capita) to assess crowding – an important indicator of environmental quality.

2.4.1.2 Measures of Building Density

- **Plot Ratio (Floor Area Ratio) -** Plot ratio is the ratio of total gross floor area of a development to its site area. Site area refers to the total lot area of the development, which, in most cases, is precisely defined in the planning document. Since the definitions of both floor and site areas are relatively clear in the measurement, plot ratio is considered as one of the most unambiguous density measures. In planning practice, plot ratio is extensively adopted as a standard indicator for the regulation of land-use zoning and development control. Different plot ratios for different types of land uses are often specified in urban master plans as a provision of mixed land use. Furthermore, maximum plot ratio is often controlled in the master plan in order to govern the extent of build-up and prevent overdevelopment.
- **Site/Plot Coverage –** Site/Plot coverage represents the ratio of the building footprint area to its site/plot area. Therefore, site coverage is a measure of the proportion of the site area covered by the building. Similar to plot ratio, site coverage of individual developments is often controlled in urban master planning in order to prevent over-build and to preserve areas for greenery and landscaping. The **open space ratio**, which is the inverse measure of site/plot coverage, indicates the amount of open space available on the development site. However, the term is sometimes also expressed as area of open space per person and this measure is used by the planning authority to safeguard a reasonable provision of outdoor space for the population.
- **Building Density and Urban Morphology -** Building density has an intricate relationship with urban morphology; it plays an important role in the shaping of urban form. For instance, different combinations of plot ratio and site coverage manifest into a variety of different built forms. It describes the image of a residential area or in town row house area and helps in determining the patterns of land use and buildings (as illustrated in figure 2.7).

  Here, **Cheng (2010)** explains that as the buildings transform from single-storey buildings to a multi-storey tower the proportion of site coverage decreases. In a similar vein, urban developments of the same density can exhibit very different urban forms. Figure 2.7 shows three settlements with the same residential density of 75 dwellings per hectare, but in different urban forms: multi-storey tower, medium-rise buildings in central courtyard form, and parallel rows of single-storey houses. Intrinsically, the three layouts are different in many aspects; nevertheless, in terms of urban land use, the proportion and organisation of ground open space is of particular interest.

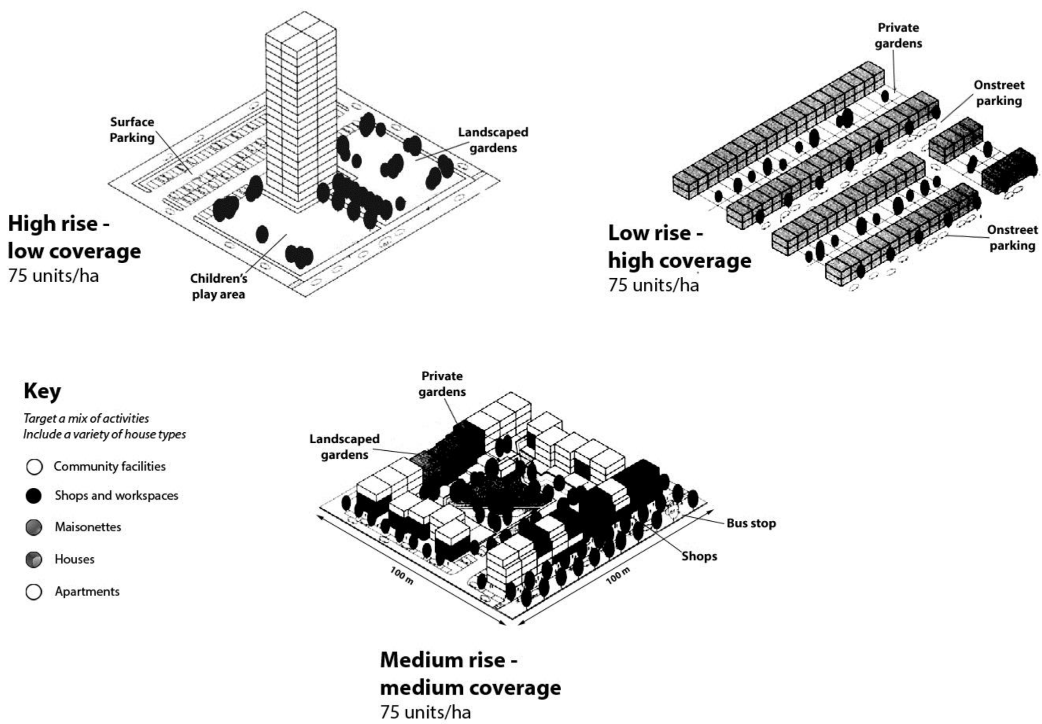

Figure 2.7: Relationship between density and urban form

Source: Moughtin, 2003

The high-rise layout creates large areas of open land that are suitable for expansive communal facilities, such as libraries, sports grounds and community centres. Nevertheless, without efficient land-use planning, these spaces can run the risk of being left over, not properly managed and end up producing problems. The proportion of open area resulted in the medium-rise courtyard form, although it is less than that of the high-rise layout. However, unlike the former, the courtyard space is enclosed and clearly defined. It can be shaped as the central stage of the community and, thus, encourages full use of space. The single-storey houses, on the other hand, divide open space into tiny parcels for individual uses. In this arrangement, the area for communal facilities is limited; nevertheless, residents can enjoy their own private open space.

2.4.1.3 Measures of Perceived Density

Perceived density is defined as an individual's perception and estimate of the number of people present in a given area, the space available and its organisation **(Rapoport, 1975).** Furthermore, perceived density not only addresses the relative relationships between individual and space, but also between individuals in the space. In order to distinguish between these two different aspects of perceived density, the concept of spatial density and social density were introduced.

- **Spatial Density -** Spatial density refers to the perception of density with respect to the relationship among spatial elements such as height to width ratio, spacing and juxtaposition. High spatial density is related to environmental qualities, such as high degree of enclosure, intricacy of spaces and high activity levels.
- **Social Density -** Social density describes the interaction between people. It involves the various sensory modalities, the mechanisms for controlling interaction levels such as spacing, physical elements, territorial boundaries, hierarchy, the size and nature of the group involved, its homogeneity and rules for behavior, in which all of these qualities affect the rates of social interaction **(Chan, 1999).**

In the urban environment, the perception of density has been found to be associated with the built form and certain urban features. **Rapoport (1975)** outlined the importance of a list of environmental cues, which are thought to have effects on perceived density; these hypothesized factors include building height, building height to space ratio, space openness, the number of people, the number of street signs, traffic, light level, naturalness of the environment and the rhythm of activity. Similarly, **Bonnes et al. (1991), Zacharias and Stamps (2004)** point out that spatial features such as street width, building height, building size and balance between built-up and vacant spaces can affect people's perception of density. However, **Flachsbart's (1979)** and **Zacharias and Stamps' (2004)** empirical study show that street shape and slope, building block diversity, architectural details and landscaping do not have significant effect on perceived density.

Mitramy and **Churchman** argue that in many studies, density is referred to as "high" or "low", without a definition of what is high or what is low. **Gewirtzman, Burt and Tzamir**

(2003) argue, most times people see low perceived densities as one of the characteristics of a high quality environment. Also, it follows from this argument that perceived higher densities characterise low quality environments. However, these studies are not able to build up a sufficient body of knowledge or a comprehensive theory about the meaning of density and its effect on the urban environment **(Mitramy and Churchman, undated)**.

By and large, research to date indicates that the perception of density is related to certain environmental cues; however, it is important to keep in mind that besides physical characteristics, individual cognitive and socio-cultural factors are also prominent, especially with respect to the notion of high density. There is not an explicit definition of high density; it varies from culture to culture and from person to person **(Cheng, 2010)**.

With this premise, the present study is limited to understanding the impact of the physical aspects of density – people density (population distribution and dwelling unit distribution), building density or built-form characteristics and spatial density on neighbourhood environmental quality. The various densities along with their measurement units are summarised as shown in table 2.1.

Table 2.1: Physical Density Variables

S.No	Type of Density	Measurement Units
1.	**People Density**	
(i)	Population Density	- Persons per hectare (pph)
(ii)	Residential Density	- Dwelling Units per hectare (DUs/ha)
2.	**Building Density**	
(iii)	FAR or FSI	- Ratio (expressed as 1, 1.5, 2, 3, etc.)
(iv)	Site/Plot Coverage	- Percentage (expressed as 30%, 40%, etc.)
3.	**Spatial Density**	
(v)	Height to Width Ratio	- Ratio (expressed as 1:1, 1:1.5, 2:1, etc.)
(vi)	Distribution of Open Spaces	- Percentage (expressed as 30%, 40%, etc.)
(vii)	Distribution of Roads and Sidewalks	- Road Length per hectare (m/ha) - % of Sidewalks
(viii)	Distribution of Services (domestic waste, drainage, sewerage, streetlights, etc.)	- Road Length attended/covered by waste collection and drainage system - No. of properties connected to the sewerage - c/c spacing of streetlights

Source: Author, 2014

2.4.2 People Density in Indian Cities

Indian cities occupy 10% of the world's total urban area and house more than one tenth of the world's urban population as indicated in table 2.2 **(Demographia, 2014)**. The quality of life in already strained cities is likely to degrade further, and the tremendous rate of urbanisation will have a significant environmental impact. The development of self-capability is a challenge, while the opportunity is in creating growth which is socially inclusive and environment friendly **(CII, 2010)**.

Table 2.2: Status of Urban India in relation to the World

Continent/Country	Average (Persons per Hectare)	% of World's Urban Area	% of World's Urban Population
World	43	100	100
Africa	70	11.2	10.3
North America	16	13.4	13.5
South America	57	7.7	8.5
Australia	14	0.7	0.7
Europe (EU)	28	9.3	7.4
Russia	32	4.2	2.6
Asia	70	51.3	56.0
India	120	10.1	10.6

Source: Demographia, 2014

A study by **Pandit (2016)** on relationship between urban density and transit oriented development (TOD) shows that the average densities in the 33 smart cities announced in the first year of Indian Smart Cities Mission varies from values as low as 10pph (Dharamshala) to values as high as 265pph (Chennai). Analysis of densities in these 33 cities reveal that even the 75th percentile is only 87pph (Bhagalpur) and the average density is 59pph. In metropolitan cities of India such as Mumbai and Chennai, densities are high and sufficient for transit, therefore requiring interventions in other aspects so as to improve the quality of the urban space. The second highest density in the smart cities of first year amounts to only 133pph (Surat), which is considerably lower than the highest density (Chennai).

Even though average densities are low in most of the Indian cities, their core areas have sufficient densities which can generate a demand for public transit system. In areas in the cities where the densities are low, re-densification together with improvements in urban space (non-motorized transport and pedestrian infrastructure, housing and urban design) become an important tool. TOD therefore is a tool to optimize densities to improve quality of life **(Pushkarev and Zupan, 1982)**.

Similarly, **Ray's (2012)** study on Sustainable Urban Form for Indian Cities advocates several aspects like mixed land use, strong public transport access with focus on pedestrian and cycle movement, horizontal and vertical randomisation of buildings coupled with low coverage and high FAR, conical massing, adoption of green building techniques, etc. She proposes medium to high density neighbourhoods with urban blocks of 100-200 hectares having 4-7 storeyed buildings and 40-80pph at the neighbourhood level.

On the other hand, as per **Dash's (2011) Times of India - The Economic Times Report**, the Town and Country Planning (TCP) Department, New Delhi, India has increased the density of population in case of group housing societies in Gurugram to 300ppa or 750pph as against the earlier standard of 250ppa or 625pph. Though this is much less than other cities for e.g. in case of Faridabad, for group housing areas the density of population is 400ppa or 1000pph. Haryana has already prepared the city's development plan as per new guidelines in case of plotted areas. In those cases the population density has been revised to 120ppa or 300pph as compared to 100ppa or 250pph earlier. The increase in density is a welcome sign as there is high residential demand in Gurugram because of the employment opportunities. The developers building high-rises can add more flats that will not only help create more housing facilities, but also put a check on the sky-rocketing property prices.

In the same way, the **Department of Housing and Urban Development, Govt. of Punjab** formulated a policy in **March 2014** to cater to the housing shortage in the state with an increase and rationalisation of density in various zones of Master Plans in the state. In order to save the scarce agricultural land and to encourage the vertical development, the density for residential plotted development and group housing projects were rationalized as given in table 2.3.

Table 2.3: Increase and rationalization of density in Master Plans in the State of Punjab

S.No	Residential Pattern	Approved Density	Proposed Density
1.	**Low Density Housing**	125-250pph	- **Plotted** 375-500pph - **Group Housing** 625-1125pph
2.	**Medium Density Housing**	upto 437.5pph	
3.	**High Density Housing**	>437.5pph & not exceeding 750pph	

Source: Draft Policy for Housing and Urban Development - Punjab, 2014

However, the proposed densities are not categorised as per the earlier residential patterns. They are just broadly divided into two groups – plotted and group housing. Also the density range of 500-625pph does not fall in either category thus creating a sense of ambiguity.

Delving further, studies indicate that the revised **Urban and Regional Development Plan Formulation and Implementation Guidelines (URDPFI) 2014** suggest 125-175pph as the developed area average densities for metropolitan cities of the country. However primary and secondary studies indicate much higher gross densities in the metro cities. Densities observed vary from as low as 95pph to as high as 798pph with an average density of 447pph across different case study cities.

Hence, the important question is – what is the basis of the suggested figures in the guidelines? Likewise, it is known that presently, urban India is home to 377 million people. It is expected to house 600 million people by 2031, an increase of 59% from 2011. India's urban housing shortage is around 19 million as indicated in table 2.4 **(Cushman and Wakefield, 2014)**. Thus, the present research seeks to find out a way for providing sufficient urban housing at optimum densities in an environmentally conducive way.

Table 2.4: Total Housing Shortage Projection

Housing Shortage	Units in Million
Urban Shortage in 2012	18.78
Rural Shortage in 2012	43.67
Additional Demand due to population growth in 2012-2017	26.33
Total Demand	**88.78**

Source: Cushman and Wakefield, National Housing Board (NHB), Ministry of Housing and Urban Poverty Alleviation (MHUPA)

2.4.3 Building Density in Indian Cities

There is a strong pitch to increase building density measured by permissible Plot Ratio / Floor Area Ratio (FAR) / Floor Space Index (FSI) in Indian cities considering the space crunch in the city. Higher FSI brings in more supply into the market, creating more homes. But vertical growth must be planned. Without the required infrastructural upgradations, higher FSI results in extra load on the facilities and services and degrades the environmental quality. It must be noted that

India lags behind in FSI norms compared to top cities of the world. Cities such as New York, Tokyo, Hong Kong and Shanghai offer FSI limits between 10 and 15. Comparatively in Mumbai, the permissible FSI ranges between 2.5 and 4 for redevelopment projects and between 1.33 and 4 for non-redevelopment projects.

Another important aspect to be understood is as **(Patel, 2011)** brings forth through his study is that higher FSI does not necessarily imply higher density. It actually depends on how much floor space each resident occupies or Built-up Area per Capita (BUA/Capita). In Mumbai a family averages about 5 people, living typically in an apartment of 25 sqm. That is 5 sqm per person. In Manhattan the apartment size is typically 1,000 sqft (about 90 sqm) and occupancy averages 1.7 persons. The average floor space there works out to 55 sqm per person. Each Manhattan resident occupies 11 times as much floor space as a Mumbai resident. So for the same plot area, FSI 11 will have 11 times the built-up floor area as FSI 1. But because of the space each family takes up, FSI 11 in Manhattan will have the same number of people as FSI 1 in Mumbai. Thus even though FSI values vary significantly, they do not imply the anticipated increased population density in case of Manhattan as compared to Mumbai. Rather it holds true otherwise. In addition, it is also important to understand that public ground area consisting of streets (carriageways and footpaths) and parks etc. available to each resident of the area or Public Ground Area per Capita (PGA/Capita) – also referred to as Open Space Ratio is also instrumental in establishing how good or bad the locality is. Increasing FSI and Site Coverage will bring in more people within the same area (until and unless there is considerable change in economic status and affordability and people can occupy larger flats) thus leading to increased impoverishment for all the older residents in respect of what each family enjoys by way of the infrastructure of schools, medical facilities, parks and playgrounds, as well as roads, water supply and sanitation **(Patel, 2014)**.

Studying and comparing FAR and building regulations for residential buildings across different cities in India shows that most of the cities have their own set of rules and regulations as considered appropriate w.r.t the population distribution, mix of housing, type of infrastructure etc. and future development strategies. The FAR norms of some of the important cities are shown in figure 2.8.

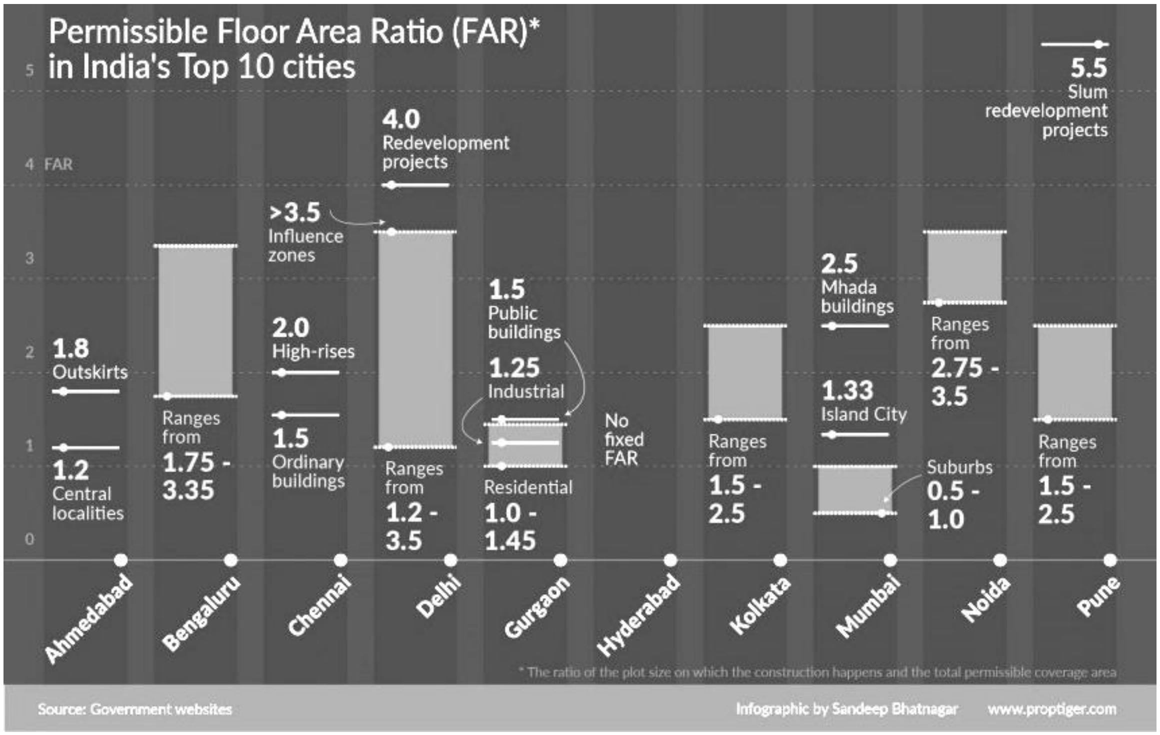

Figure 2.8: Permissible FAR in 10 Indian Cities

Source: Mishra, 2016

The FAR norms and building regulations w.r.t residential buildings in different Indian cities are summed up in table 2.5 and table 2.6. It is seen that within the Class I cities (population > 1, 00,000), Tier I cities have FAR ranging from 1.2 to 3.25 with exception of Delhi and Mumbai where FAR – 4 is permitted in redevelopment projects and low FAR ranging from 0.5 to 1 is assigned to the suburbs of Mumbai. Tier II cities (the cities under consideration for the present study) on the other hand have FAR ranging from 1 to 2 generally[6]. Plot coverage in both cases vary from 35% - 70% generally with few exceptions of higher plot coverage. Additional FAR can be purchased in certain cities like Gurugram. The intent is not to increase the number of families on a single plot but to increase the average size of the units. But for building the additional floor space as a result of the purchased FAR, one would incur considerable cost and try to accommodate more people to recover the cost of construction.

[6] Under the recommendation of the Sixth Central Pay Commission, the Compensatory City Allowance (CCA) classification was abolished in 2008. The earlier HRA classification of cities was changed from A-1 to X, *A*, *B-1* and *B-2* to Y and C and unclassified cities to Z. X, Y and Z are more commonly known as Tier-1, Tier-2 and Tier-3 cities respectively. Based on https://en.wikipedia.org/wiki/List_of_cities_in_India_by_population and https://en.wikipedia.org/wiki/Classification_of_Indian_cities, Tier 1 cities have generally population ≥ 4 million whereas Tier 2 cities have 0.75 million < population < 4 million. All other cities with population < 0.75 million are grouped as Tier 3 cities. [Accessed 18 September 2012].

Table 2.5: FAR norms and Building Regulations for Residential Buildings in Tier 1 Cities

<table>
<tr><th>S.No</th><th>City</th><th>Criteria</th><th colspan="2">Residential Pattern</th><th>Remarks</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Delhi</td><td rowspan="3">FAR norms are as per plot size and land use, not dependent on road width</td><td>Plotted Development</td><td>Group Housing</td><td rowspan="3">FAR decreases as plot size increases varying from 3.5 – 1.2

Max. FAR – 4 permitted in redevelopment projects in min. 4 hectares area</td></tr>
<tr><td>• Plot Coverage – 40% to 90%
• Setbacks & height regulations
• Max. no. of DUs on site to regulate density</td><td>• Standard FAR of 2 allowed on a min. plot area of 3000 sqm.
• No setback and height restriction</td></tr>
<tr><td colspan="2">Higher FAR permitted along MRTS corridor (500m on both sides)</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Bengaluru</td><td rowspan="2">FAR norms are as per plot size, land use, road width and ground coverage</td><td colspan="2">• Setbacks & height regulations
• No DU restriction on site to regulate density
• Integrated Townships with 40% residential land use
• Min. 40 hectares area
• FAR – 2.5
(18-24m road width)
FAR – 3.25
(>30m road width)</td><td rowspan="2">FAR increases with increasing plot size varying from 1.75 – 3.25</td></tr>
<tr><td colspan="2">150 m from the transit hub additional 0.5 FAR permitted along MRTS for plots abutting 60m or more on payment of fees</td></tr>
<tr><td>3.</td><td>Kolkata</td><td>FAR norms are as per plot size, land use and road width</td><td colspan="2">• Plot Coverage
60% upto plots of 200sqm
50% - plots of 500sqm or more
• Setbacks and height regulation
• No DU restriction on site to regulate density</td><td>Plots till 1500sqm have FAR – 2.5

FAR decreases as plot size increases further varying from 2.5 - 1.5</td></tr>
<tr><td>4.</td><td>Mumbai</td><td>Zone-wise uniform FSI</td><td colspan="2">• Max. no. of DUs on site to regulate density – 600DUs/ha and 267DUs for plots above 1 hectare
• Higher FSI for MHADA – 2.5 for vacant plots and 2.5 plus incentives for redevelopment</td><td>FSI varies from 0.5-1 in the suburbs and 1.33 in the Island city</td></tr>
<tr><td>5.</td><td>Chennai</td><td>FAR norms are independent of plot size and location</td><td colspan="2">• Plot coverage and plot frontage are stipulated
• Setback regulations as per abutting road widths</td><td>FSI is 1.5 for ordinary buildings and 2 for high-rise buildings</td></tr>
</table>

Source: Government Websites, Guturu (2016), www.timesofindia.indiatimes.com, www.hindustantimes.com

Table 2.6: FAR norms and Building Regulations for Residential Buildings in Tier 2 Cities

<table>
<tr><th>S.No</th><th>City</th><th>Criteria</th><th colspan="2">Residential Pattern</th><th>Remarks</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">Amritsar[7]</td><td rowspan="2">FAR norms are as per plot size, land use, ground coverage and not dependent on road width</td><td>Plotted Development</td><td>Group Housing</td><td rowspan="2">FAR decreases as plot size increases varying from 2 – 1.25</td></tr>
<tr><td>• Plot Coverage – 50% to 80%
• Setback regulations</td><td>• Standard FAR of 2 allowed
• Site Coverage – 50%
• Height regulations</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Chandigarh[8]</td><td rowspan="2">FAR norms are as per plot size, land use, ground coverage and not dependent on road width</td><td>• Plot Coverage – 35% to 70%
• Setbacks and height regulations</td><td>• Max. FAR of 1.2 allowed
• Site Area – min. 1 acre
• Site Coverage – 40%
• Max. no. of DUs on site to regulate density
• Height regulations</td><td rowspan="2">FAR decreases as plot size increases varying from 2 – 1</td></tr>
<tr><td colspan="2">• Outside Sectoral Grid – Integrated Housing on min. 25 acres with 40% Site Coverage and max. FAR – 2, Population Density – 625pph
• Height Regulations</td></tr>
<tr><td>3.</td><td>Gurugram[9,10]</td><td>FAR norms are as per plot size, land use, ground coverage and not dependent on road width</td><td>• Plot Coverage – 60% to 66%
• FAR – 1.8 to 1.98
• Max. permissible height – G+4</td><td>• FAR – 1.75
• Max. no. of DUs on site to regulate density
• No height restriction</td><td>Permissible FAR ranges between 1 and 1.65. Recently increased by 0.35 to 0.80. FAR decreases as plot size increases.</td></tr>
</table>

Source: Government Websites, www.timesofindia.indiatimes.com, www.hindustantimes.com

So, when FAR is increased, the load on the city's infrastructure increases with increase in population. Authorities charge extra for supporting the high population density and retrofitting of existing infrastructure. In an ideal condition, additional purchasable FAR is expected to raise

[7] Important Building Rules, Amritsar Municipal Corporation. Available at: http://amritsarcorp.com/inport.htm [Accessed 20 January 2012].

[8] Development Controls and Regulations, Chandigarh Master Plan-2031. Available at: http://chandigarh.gov.in/cmp2031/dev-control.pdf [Accessed 12 February 2015].

[9] Haryana Building Code, 2016 of Haryana Government. Available at: https://tcpharyana.gov.in/Policy/OfficeOrder/The_Haryana_Building_Code_2016.pdf [Accessed 12 June 2017].

[10] Policy regarding increase in FAR – 6.5.2016. Available at: https://tcpharyana.gov.in/Policy/Policy_Regd._Increase_in_FAR-6.5.2016.pdf [Accessed 12 June 2017].

additional capital for providing extra infrastructure. However, in real the situation is seldom so consequently leading to several problems and degraded urban environment **(Ramnani, 2016)**. Therefore, there is a need to reexamine the suggested values and identify range of density values for different types of residential patterns in our Indian cities that can accommodate more people in a favorable way and reduce the gap between the demand and supply of shelters in the type of cities under consideration.

2.4.4 Spatial Density in Indian Cities

Density has two main dimensions as discussed earlier – Physical Density and Perceived Density **(Cheng, 2010)**. The present study is primarily concerned with the physical aspects of density. However, it is known from empirical studies that perceptions of density sometimes affect the acceptable levels of physical density **(Dave, 2010 and Churchman, 1999)**. Hence, certain important parameters of spatial density like building height to street width ratio, proximity to daily needs, distribution / amount of open spaces, distribution / amount of roads, streetlights and level of services are studied.

Raman (2010) states that whatever density measures one may use to control or regulate development, the way in which it is manifested on the ground through design and layout changes the perception and experience of density. According to **Rapoport (1975),** in order to understand how density is experienced by people, other physical characteristics of the built environment such as space between buildings, open space ratio, building height, and layout etc. need to be considered. For e.g. the empirical analysis of six neighbourhoods of south-east England by **Raman (2010)** indicates that characteristics of social networks change enormously depending on density and layout (as indicated in table 2.7 and figure 2.9). Low-density neighbourhoods (around 25-30 dwellings per hectare) in street form are characterized by high level informal contacts and interactions while high-density neighbourhoods (160-270 dwellings per hectare) with complex spatial layouts have smaller but stronger social networks. Even though people feel they know fewer people in higher-density neighbourhoods, density of social activities is more in these neighbourhoods. The level of social interaction in outdoor public spaces at ground floor level is highest in medium density neighbourhoods (51-100 dwellings per hectare) as they are physically and visually more integrated with the other neighbourhood spaces. Thus the social environment is directly linked to the layout and built form or the spatial and physical characteristics of the urban neighbourhoods.

Table 2.7: Layout and Density of Case Study Neighbourhoods

S.No	Name of Neighbourhood	Layout Type	Residential Density (DUs/hectare)	Population Density (persons per hectare)
1.	New Marston, Oxford	Low rise, street form	25	68
2.	Thames Street, Oxford	Low and medium rise, street + Cul-de-sac	48	108
3.	Holy brook, Reading	Medium rise, street and courtyard form	108	176
4.	Parkview Estate, Thames mead	High and medium rise tower blocks	95	211
5.	Dalgarno Gardens, London	Medium rise gated community, blocks with staggered layout	162	485
6.	World's End Estate, London	High rise, tower blocks with podium	271	577

Source: Raman, 2010

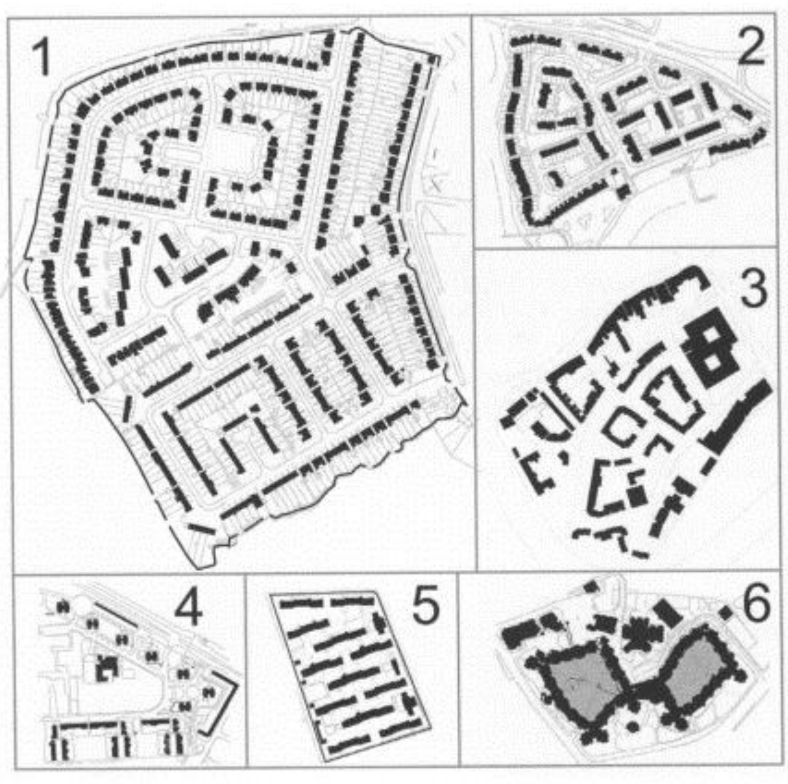

Figure 2.9: Figure ground drawings of six case study neighbourhoods

Source: Raman, 2010

Dave (2010) shows through the study of 11 case study neighbourhoods of Mumbai that both physical and perceived density have significant impact on the social, economic and environmental sustainability of the neighbourhood. While dense neighbourhoods are associated with less residential living space, less satisfaction with the amount of open spaces and parks, less road infrastructure per household, higher feelings of insecurity and vandalism especially during the night time, higher traffic congestion, problems of pollution and poor air quality; they have higher sewage pipes per hectare and more walking to work and shopping trips and greater use of public transport because of the proximity of transport nodes.

As far as the different physical aspects of spatial density are concerned, there are standard regulations of building height and abutting road width as per the building regulations of different cities. However, there are no regulations for street orientation for favourable wind movements and ensuing shade and ventilation. Architectural research and implementation in various projects by Charles Correa and B.V. Doshi help to understand the micro-climatic benefits achieved as a result of such consideration **(Correa, 1982 and Curtis, 1988)**.

The **URDPFI Guidelines 2014** recommend 1.2-1.4 hectares/1000 population or 12-14sqm/capita for community open spaces while it is seen that the open spaces have been constantly decreasing in metropolitan cities because of rapid urbanisation and increase in built-up areas. Mumbai has just 1.1 sqm of open space—gardens, parks, recreation grounds (RG) and playgrounds (PG)—per person **(Rajadhyaksha, 2012)**. In comparison London has 31.68 sqm per person while New York has 26.4 sqm per person. Chicago's 17.6 sqm per person also puts India's financial capital to shame. The poor green ratio in Mumbai translates into a terrible quality of life and poor environment. It also strikes a blow to Mumbai's reputation as a global hub.

Similarly, Jaipur has about 0.2 hectares/1000 population or 2 sqm of open space per person which is much less than the prescribed standards. According to the proposed Master Development Plan 2025, it is proposed to enhance the per capita open space to 8.80 sqm. For a population projected to grow to 6.5 million by the year 2025, even at the minimum scale, Jaipur will require to establish 58.50 sq.km of urban green space. From another perspective, overall, the people and planners will have to strive for regenerating at least one medium sized mature tree as desirable number per person in Jaipur, Rajasthan **(Pandit et al., 2009)**.

Considering distribution of roads, India has less than 0.07 kilometers of highways per 1000 people, as of 2010. This is among the lowest road and highway densities in the world. In contrast, United States has 21 kilometers of roads per 1000 people, while France about 15 kilometers per 1000 people – predominantly paved and high quality in both cases. India has less than 3.8 kilometers of roads per 1000 people, including all its paved and unpaved roads[11]. Lesser road length per capita implies higher traffic congestion, problems of pollution and poor air quality thus affecting the urban environment significantly.

Another important aspect related to roads, especially road safety are the provision of streetlights. The **Handbook of Service Level Benchmarking, Ministry of Urban Development, Govt. of India** lays down norms for number and spacing of streetlights to be adopted in the urban areas. In most cities, the street lights are installed and maintained by municipalities. Very little study or planning has gone into the illuminance required in different areas of streets, to address the needs of pedestrians and vehicular traffic alike. For instance, the lighting needs of vehicular traffic in high speed zones are different from low-speed high traffic zones. Likewise, lighting needs in road crossings are different from secondary roads. Then again, the lighting requirements of an area with vehicular traffic will vary from that of an area with high pedestrian traffic. A one-size-fits-all approach to street lighting results in inefficient deployment of power resources and ends up in wasteful use of electricity that could have been better utilized elsewhere. Street light planning is not just about luminosity but also the 'height' of the lighting mast, which in turn varies based on the requirements of that particular area. Due to a lack of 'area-wise' study, standard tenders are issued on a 'city-wise' basis, leading to high operational cost incurred on street lighting. Very often, one notices that the street lights stay on well past sunrise. This is because the lights are switched off based on a predecided time rather than lighting needs, which vary based on season and location of the city. There is a need for devising a well thought out way to prevent wastage of electricity. Perhaps, the government can think of implementing Automatic Street Light Control System using LDR (Light Dependent Resistor), which automatically switches off lights when sunlight fall on it. Poor maintenance of street lights is another problem faced by most citizens, leaving large areas without adequate lighting. The municipalities are hard pressed for funds and it is the citizens who have to face the brunt **(Debu, 2015)**.

[11] Indian Road network. Available at: https://en.wikipedia.org/wiki/Indian_road_network [Accessed 10 May 2017].

As per the **Handbook of Service Level Benchmarking, Ministry of Urban Development, Govt. of India** and **Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011**; several indicators are developed to ascertain the level of services in Indian cities. For solid waste management, the **cleanliness indicator**[12] measures length of roads attended by cleanliness service divided by the total length of the roads of the area; the **drainage indicator**[13] is given by total length of primary, secondary and tertiary drains (made of permanent material and covered) divided by total length of road network for managing storm water runoff while the **sewage indicator**[14] measures total number of properties with direct connection to sewage network divided by the total number of properties in the service area. The handbook lays down 100% as the minimum standards for the above mentioned indicators. However, the situation is quite poor in most of our rapidly urbanizing cities.

It is suggested as per the **National Action Plan on Solid Waste Management, 2015 by Central Pollution Control Board, New Delhi** that in a congested or thickly populated area, 350 running meters of road length and the adjoining houses may be given to each sweeper, whereas in medium density areas 500 to 600 running meter of the road length with adjoining houses may be allotted to a sweeper depending upon the density of population in the given area and local conditions. In low density areas even 750 running meter of road length can be given. Normally 150 to 250 houses coupled with the above road lengths may be taken as a yard stick for allotment of work to an individual sweeper. Studies indicate that generally cities have adequate number of sweepers to collect the solid waste from the households. For e.g. in Chandigarh there are 277 sweepers per 100000 population. This works out to around 1 sweeper for around 72-80 households which is within the norms **(Banerjea, 2005)**. The actual problem is of storing, transporting and disposing the solid waste that leads to insanitary conditions in our urban areas. Thus, efforts are required for adoption of advanced measures like sustainable urban drainage systems (SUDS), low impact development (LID) techniques, etc.

12 Cleanliness Indicator = Road length attended by primary-secondary waste collection / Total road length of the area
Here, as part of primary waste management, handcarts or wheel barrows are used for door to door collection of domestic waste and street sweeping (at least once a day) and for secondary stage waste collection container/community bins are installed at certain locations in a locality.

13 Drainage Indicator = Total length of primary, secondary and tertiary drains / Total length of road network
Here, drains should be of pucca construction and covered and road should have ≥3.5m carriageway.

14 Sewage Indicator = Total no. of properties with direct connection to sewage network / Total no. of properties in the service area
Source: Handbook of Service Level Benchmarking, Ministry of Urban Development, Government of India. Available at http://moud.gov.in/pdf/57f1ef81d6caeHandbook06.pdf [Accessed 10 March 2012].

Likewise, rapid urbanisation and urban sprawl in India is consuming the soft landscape, nature's absorbent for rainwater. And the man-made alternative, storm water drains along roads, face major deficits in urban locations. The ministry of urban development, for 2010-11, surveyed 13 states for various indicators in urban water and sanitation. One of these was storm water drainage. Here, coverage was defined in terms of the percentage of road length covered by the storm water drainage network; further, only those drains made of pucca (permanent) construction were considered. A total of 1,383 urban local bodies (ULBs) responded, of which 104 were municipal corporations in large cities. As many as 56 of these 104 large cities had coverage below 50% (a level termed by the ministry as needing "immediate action for improvement") and 93 had coverage below 75% ("caution for improvement") as indicated in figure 2.10.

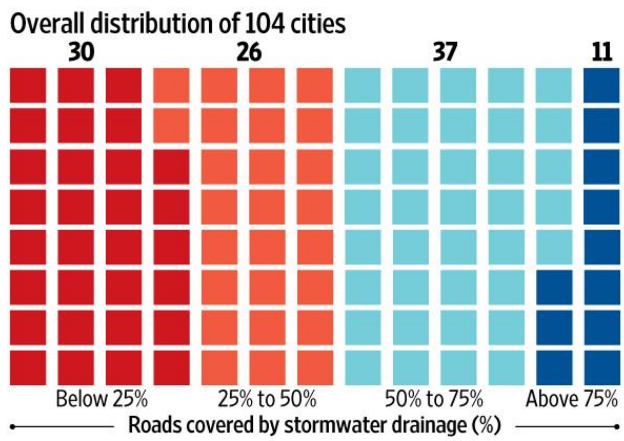

Figure 2.10: Percentage Distribution of Storm Water Drainage in Indian Cities

Source: Livemint E Paper, 2016

As per census 2011, at country level, there is no sewage facility in 48.9% households, while 33% households have only open sewage system[15]. Nearly 80% of the sewage generated in India flows untreated into its rivers, lakes and ponds, turning the water sources too polluted to use. Indian cities produce nearly 40,000 million litres of sewage per day, enough to irrigate 9 million hectares and barely 20% of this is treated. Almost half of the urban Indian population still depends upon groundwater sources for drinking, cooking and bathing which puts them at direct risk from the polluted water **(Times of India, 2013)**.

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15 Census of India 2011. Available at: http://www.censusindia.gov.in/2011census/Hlo-series/HH09.html [Accessed 13 June 2013].

Thus, the poor conditions of most of the spatial density parameters suggests that evaluation of urban neighbourhoods should become an increasingly important issue for planners, urban designers, residents and decision makers. The justification of the same can further be established from studies by **Rådberg (1996)** where he contends that great confusion in the field of quality and sustainability in urban planning stem from the fact that the theories are formulated on a very general and abstract level. He points out to the need of empirical observations, theoretical framework and systematic descriptive classification of the urban structure at the micro level in order to be able to process the accumulated information on existing urban environments and pave the way for better planning practice on both micro and macro levels of the urban structure.

2.5 Neighbourhood Environmental Quality

The term “neighbourhood” represents an intermediate urban scale, larger than a single building and its immediate surroundings but smaller than an entire town or city. It usually includes dwellings, infrastructure and community services. It is a scale in which multiple disciplines are involved, including environmental, mobility, accessibility, and infrastructure studies and their goals for optimization **(Delsante, 2016)**. The neighbourhood allows considering private and public spaces while the “home” and “city” mainly consider the former and latter, respectively **(Bonaiuto et al., 2003)**. Thus, it enables a classification of the urban system at an intermediate level for holistic understanding and local interventions at which problems actually originate.

As mentioned in Chapter 1, the literature study outlines that Environmental Quality is an abstract concept resulting from both human and natural factors operating at different spatial scales. *In urban areas the local scale is dominated by individual buildings, streets and trees, but regional scale influences may include the whole city and beyond* **(van Kamp et al., 2003; Pacione, 2003; Nichol and Wong, 2005)**. Thus, Environmental Quality is multi-dimensional, multi-faceted and multi-disciplinary in nature. Any assessment of the environment requires the integration and exploration of a variety of elements, thus one indicator alone cannot measure environmental quality. It is known that the concepts of urban environmental quality and related terms such as livability, quality of life and sustainability enjoy great public popularity and form a central issue in research programs, policy making and urban development **(Leidelmijer et al., 2002)**. However, there is hardly any clear, coherent or consistent system in place to measure or evaluate environmental quality, though many studies have urged for an integrated approach to the subject, incorporating both objective and subjective measures **(van Kamp et al., 2003 and Marans et al., 2000)**.

Over time, several researches have been conducted on the relationship between urban residents and their environment. **Bonaiuto et al. (1999)** studied the relationship between inhabitants and their neighbourhoods of residence in the urban environment of Rome from the environmental psychological view, and proposed two distinctive instruments. These instruments consisted of 11 scales for measuring the perceived environmental qualities of the urban neighbourhoods, with one scale measuring neighbourhood attachment. Other studies have been done to understand the social environment and its effect on residential satisfaction. **Tognoli (1987)** stated social ties bind people to a neighbourhood, provide social interaction, activity and support. Social relationships can even compensate for poor physical conditions to an extent, especially in disadvantaged areas. **Pacione (2003)** also addressed urban environmental quality and human wellbeing from a social geographical perspective, and presented a five-dimensional model for study of the quality of life. He examined the major theoretical and methodological issues confronting quality of life research. **Robin et al. (2007)** conducted a study among Parisians. At the end, seven principal dimensions, that were inclusive of potentially aversive situations encountered in the daily lives of city-dwellers emerged: feelings of insecurity, inconveniences associated with using public transport, environmental annoyances and concerns for global ecology, lack of control over time related to using cars, in civilities associated with sharing of the public spaces between different users, lack of efficiency resulting from the density of the population, and an insecure and run-down living environment.

Research on the physical environment has certainly confirmed the relationship between social class and the environmental quality of living environments **(Pacione, 2003)**. In general, the higher socio-economic groups are more likely to experience residential satisfaction. This is directly related to the sharp linear increase in residential quality with increasing social position **(Fried, 1982)**, and the mobility and choice available in residential environments. **Fobil et al. (2010)** assess the relationship between socio-economic conditions and neighbourhood environmental quality in Accra, Ghana. The results show wide variation in levels of association between the socio-economic variables and environmental conditions, with strong evidence of a real difference in environmental quality across the five socioeconomic classes with respect to (a) total waste generation, (b) waste collection rate, (c) sewer disposal rate, (d) non-sewer disposal and (e) the proportion of households using public toilets. Socioeconomic conditions are therefore important drivers of change in environmental quality and urban environmental interventions aimed at infectious disease prevention and control if they should be effective could benefit from simultaneous implementation with other social interventions.

Similarly, **Shieh et al. (2011)** study residential satisfaction in two neighbourhoods of Tehran based on (1) satisfaction with neighbourhood in terms of litter, malodor, lack of facilities, safety, pollution, crowding and noise; (2) satisfaction with dwelling w.r.t size, upkeep, facilities and costs; and (3) types of neighbours. The study shows dwelling size as the most significant attribute of residential satisfaction and points out that in addition to psycho-social, economic and physical attributes, attributes of the built environment are relevant attributes of environmental quality. Another study by **Discoli et al. (2014)** explores the theoretical and conceptual aspects of urban life quality (ULQ) in La Plata, Argentina. A model considering the interactions between basic services, infrastructure and environmental aspects is synthesized to identify habitants' satisfaction or dissatisfaction with the above mentioned aspects. The methodology allows evaluating qualitatively and quantitatively the basic needs of the habitants. Incorporating a set of dimensions that constitute components of every day and future life of a city, it helps in considering the possible actions for present and future planning.

The study by **Delsante et al. (2014)** considers medium density neighbourhoods in Lodi and Genoa, Italy with population densities ranging from 25-75pph for evaluation of urban environmental quality. The assessment is based on a specific set of 74 indicators **(Delsante, 2007)**, described through quantitative and qualitative variables. The study establishes that different sets of indicators can be created according to specific research aims, such as targeting different densities like high-density neighbourhoods or urban sprawl. Moreover, the proposed methodology is a meaningful tool for concisely evaluating urban environment quality as it is expressed with numeric values. It reduces subjectivity in the evaluation process and, most importantly, can be related to other data (e.g., environmental, health and well-being related). The study further states that even though there are some meaningful sets of indicators corresponding to neighbourhoods, there remains substantial opportunity for further research and experimentation **(Damen, 2014)**, especially in relation to various densities **(Lee and Chan, 2009)**.

In the Asian context, **Kimhi's (2005)** work on urban environmental quality emphasizes on the quality of the intra-urban environment by considering physical parameters for the state of Israel. It tries to address the question of how to increase residential densities in Israel's cities and prevent suburbanisation while still maintaining the quality of life. The principal recommendations are in the following domains: transportation, noise, air quality, the relationship between population density and open spaces and the quality of life in residential neighbourhoods, esthetics within the city, and environmental evaluation systems for buildings and the urban area. **Majumdar et al. (2007)** study the residents' perception of the different environmental aspects of Chittagong Metropolitan City, Bangladesh and conclude that degree of satisfaction varies with income groups and is dependent on quality of infrastructure and their appropriate management. The research is also able to create urban environmental quality maps of 41 wards of the city to show the spatial pattern of urban environmental quality for Chittagong Metropolitan City. Using remote sensing and GIS techniques, **Rahman et al. (2010)** study the quality of urban environment in the East district of Delhi, India which is experiencing very high urban growth with 98.75% urban population in 2001. Eight parameters which affect the urban environmental quality are selected, namely built-up area, open spaces, household density, occupancy ratio, population density, accessibility to roads, noise and smell affected area. The study shows that the quality of environment has degraded over the years. Most of the East district was in a better state of environment in 1982, but in 2003 things have changed. It also emphasizes encouraging public participation and involvement in planning and decision making process thus enabling improvement in the urban environmental quality.

In another study, **Patel (2011)** tries to clarify the interrelationships between six fundamental urban design parameters that affect the quality and character of any urban layout. These parameters are:

- built-up area per capita (BUA);
- public ground area per capita which includes streets and parks (PGA);
- plot factor (PF) - the ratio of land area given over to private development to land area available for public use;
- floor space index (FSI or FAR) - ratio of built-up area to buildable plot area;
- net density (ND) - population divided by the sum of all buildable plot areas;
- and, gross density (GD) - population divided by total area.

Mapping these six parameters in a chart shows the complicated trade-offs between one desirable feature and another, including combinations that show that higher densities do not necessarily mean small accommodation and inadequate public space – but they do mean high-rise, and there are severe limits on how high densities can go as seen in figure 2.11.

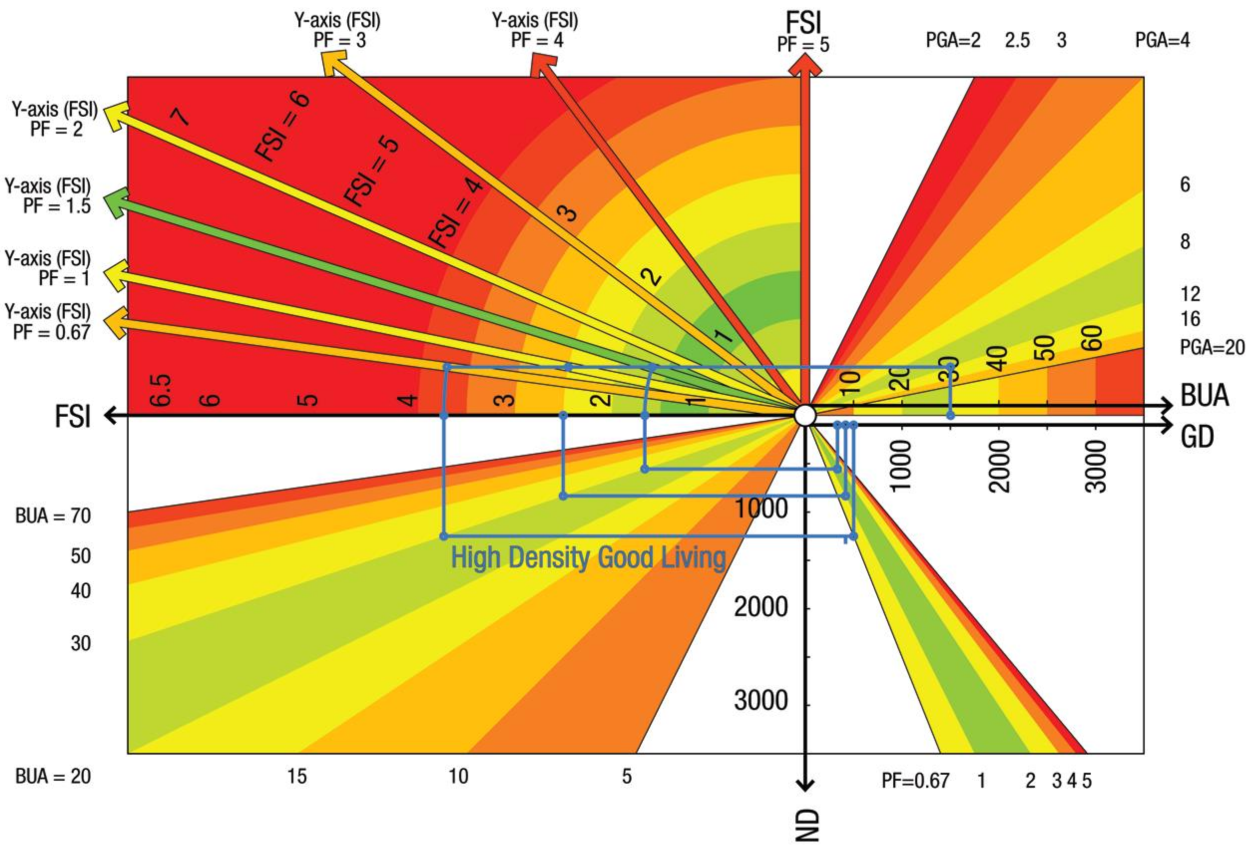

Figure 2.11: Net Density (ND) and Gross Density (GD) based on BUA, PGA, PF and FSI

Source: Patel, 2011

In terms of the six parameters, all concerned with the local environment, it is first agreed upon what is meant by good living conditions. If a comfortable BUA, say 30 square metres per capita, and a comfortable PGA, say 12 square metres per capita is considered, then it is observed that the horizontal line in quadrant 1 is fairly low. This is extended to the left into quadrant 2 and it intersects the radial lines of PF = 1.5, PF = 1 and PF = 0.67 at three different points on the horizontal, at higher and higher levels of FSI. (These three plot factors are equivalent to 60 per cent, 50 per cent and 40 per cent, respectively, of the total land area to be set aside for plots for construction.) The relevant arcs are taken down to the horizontal and lines are dropped vertically down to the radial in quadrant 3, which represents BUA = 30. At these intersection points, turning right to meet the net density vertical axis, net densities of 555, 833 and 1,250 persons/hectare respectively are achieved. Continuing into quadrant 4, and intersecting the inclined lines that correspond to the three different PFs, are turned up vertically to meet the gross density axis at values of 333, 417 and 500 persons/hectare. The FSIs for the three cases are 1.67, 2.5 and 3.75 respectively. So it is understood that in case we want good living conditions, one cannot go much beyond 500 persons per gross hectare.

The study also plots diagrams that show the values of these parameters for existing localities in New York, Mumbai (including Dharavi) and Delhi. Similarly other localities around the world can be represented as a diagram on this chart. Based on the net density and gross density values derived, favourable and unfavourable localities can be identified using this system and a detailed analysis may help in ascertaining preferred range of values for each of the parameters that can be adopted for future new developments or redevelopment of existing localities. The paper is one of the first attempts that tries to give objective values for the six parameters even though it misses out on many other aspects of environmental quality.

Thus, the literature review helps in understanding the various indicators/parameters[16] that are important to be considered for the assessment of environmental quality – physical, social, economic, geographical, psychological, etc. Additionally, one is able to comprehend several types of quality indexes[17] generated for classifying or ordering residential neighbourhoods based on livability or quality of life, quality of environment and/or people's perception of their residential environment (as indicated in table 2.8). It also helps in gaining knowledge about methods generally adopted for evaluating urban environmental quality at the neighbourhood level (as indicated in table 2.9). Finally, it also throws light on the fact that studies taking into account physical aspects of the built environment and their impact on urban environmental quality as compared to social, economic, geographical and psychological factors are sparsely reported and quite meagre in number thus justifying the scope of the present work.

[16] An indicator is a parameter or value that is derived from other parameters **(OECD, 1993)**. It selects, provides information or describes a phenomenon, environment or area.

[17] An "index" is defined as a number of indicators or parameters that are aggregated or weighted **(Delsante, 2016)**.

Table 2.8: Literature Review Summary:
Parameters/Indicators and Indexes of Environmental Quality

S.No.	Researcher	Premise of Study	Parameters/Indicators or Index
1.	**Tognoli, 1987** (US)	Social Environment and Residential Satisfaction	• Social Interaction • Activity Intensity • Support • Physical Condition of Neighbourhood
2.	**Bonaiuto et al., 1999** (Italy)	Relationship between inhabitants and their neighbourhood from environmental psychological perspective	11 indexes measure perceived environmental quality + 1 index measures neighbourhood attachment
3.	**Pacione, 2003** (Scotland)	Urban environmental quality and human well-being from social geographical perspective	Five dimensional model to study quality of life: Subjective & Objective Indicators and Social Groups at National, Regional and Local Levels
4.	**Robin et al., 2007** (France)	Social and Physical Environment and Residents' Perception	• Feeling of insecurity • Inconveniences with using public transport • Environmental annoyances • Time related to using cars • Sharing of public spaces • Lack of efficiency as a result of density of population • Run-down living environment.
5.	**Fried, 1982** (US) **and Pacione, 2003**	Socio-economic Factors and Urban Environmental Quality	Residential Quality, Choice of Residence and Type of Mode of Transport
6.	**Fobil et al., 2010** (Ghana)		• Total waste generation • Waste collection rate • Sewer disposal rate • Non-sewer disposal and • Proportion of households using public toilets
7.	**Shieh et al., 2011** (Iran)	Psycho-social, Economic, Physical and Built Environment Attributes and Residential Satisfaction	• Satisfaction with the Neighbourhood • Satisfaction with the Dwelling • Satisfaction with the Neighbours
8.	**Patel, 2011** (US and India)	Densities for Good Living Condition	Interrelationships b/w six urban design parameters – BUA/Capita, PGA/Capita, FSI, Plot Factor, Net Density and Gross Density
9.	**Discoli et al., 2014** (Argentina)	Qualitative and quantitative evaluation of the basic needs of the inhabitants for present and future planning	Basic services, infrastructure and environmental aspects are synthesized into a model to identify residents' satisfaction or dissatisfaction
10.	**Delsante et al., 2014** (Italy)	Assessing environmental quality for different densities	Set of 74 indicators divided into 4 domains – Architecture & Urban Design, Use & Accessibility, Landscape & Environment and Social & Community

Source: Author, 2017

Table 2.9: Literature Review Summary: Methods of Assessment

S.No.	Premise of Study	Methods Used for Assessment
1.	**Bonaiuto et al., 1999** Relationship between inhabitants and their neighbourhood from environmental psychological perspective	In order to reduce no. of factors, **Principal Component Analysis (PCA)** is run on 12 scales to establish significant factors and eliminate items not represented. Factor structures and indicator number confirm previous research.
2.	**Pacione, 2003** Urban environmental quality and human well-being from social geographical perspective	CASE STUDY 1 – Geography of Quality of Life (QoL) in Glasgow (nature, intensity and incidence of multiple deprivation) • **Principal Component Analysis** and **Cartographic Analysis –** Principal component was used to identify indicators of multiple deprivation and mapping scores revealed spatial expression of multiple deprivation in Glasgow.
		CASE STUDY 2 – Landscapes of Fear in the City (To study the nature and extent of fear of crime in male and female residents of a social housing estate on the edge of Glasgow) • **Interview Procedure** to rank neighbourhood problems, perceived risk from criminal activities and perceived dangerous spaces by gender. • Respondents' **Cognitive Maps** of Fear to identify specific danger areas within the estate.
3.	**Fobil et al., 2010** Improvement in urban environment for prevention of spread of Infectious Diseases	• In order to reduce no. of factors, **Principal Component Analysis (PCA)** is run on 39 variables to establish significant socio-economic factors affecting neighbourhood environmental quality and eliminate items not represented. 16 factors are considered after the PCA. • **Bivariate Analysis** and **Multiple Regression Techniques** were used to assess the relationship between area-based socio-economic status and neighbourhood environmental conditions.
4.	**Shieh et al., 2011** Psycho-social, Economic, Physical and Built Environment Attributes and Residential Satisfaction	• A **Multi-attribute** or **Multi-criteria Approach** is adopted to evaluate the environmental quality of residential neighbourhoods. • **Multiple Hierarchical Regression Approach** – Analyze relationship between dependent and independent variables. Estimation of 'regression weights' and 'model fit' for analysis of the concept of environmental quality.
5.	**Patel, 2011** Densities for Good Living Condition	Combination of 6 Urban design parameters - BUA/Capita, PGA/Capita, FSI, Plot Factor, Net Density and Gross Density plotted on **Graphical Charts**
6.	**Rahman et al., 2011** Environmental Quality of East Delhi	**Remote Sensing** and **GIS Techniques** to assess urban environmental quality changes between 1982 and 2003 based on eight parameters like built-up area, open spaces, density, etc.
7.	**Delsante et al., 2014** Environmental quality of medium density neighbourhoods	• Indicators are organized in a tree structure from single indicators to macro-indicators to indexes. • All indicators assigned numerical values and weighted to generate the **Environmental Quality Index**. • Indicators and macro-indicators are grouped into domains to differentiate them and avoid redundancy of information.

Source: Author, 2017

2.6 Density and its impact on Environmental Quality

As already mentioned in Chapter 1, the increase of residential density and the concentration of human activities within smaller built areas helps to exploit economies of scale for public services (e.g. schools, public buses and public utilities) and environmental resources like land, petrol and water **(Capello and Camagni, 2000)**. However, an excessive concentration of activities and proximity results in aggravated negative environmental externalities like traffic congestion, less privacy, poor access to natural agents (air, daylight, view, etc.) and overcrowding, which tend to outweigh the claimed benefits of urban compaction **(Burgess, 2000; Rudlin and Falk, 1999; Williams et al., 2000)**. In accordance with the research hypothesis and the key research questions it is therefore important to understand the types and nature of impacts density has on environmental quality. Table 2.10 lists down the types and nature of impacts increasing density (residential, building and spatial) has on the urban environment.

Table 2.10: Literature Review Summary -
Type and Nature of Impacts of Increasing Density

Type of Impact	Nature of Impacts	
	Positive Impacts	**Negative Impacts**
ENVIRONMENTAL IMPACTS	• Land occupation reduced • Reduction of urban sprawl • Reduction in travel distances • Increased feasibility of public transport • Reduced length of utility networks • Reduced solar gain due to mutual shading of buildings	• Exploitation of urban greens and open spaces • Danger of exhaustion of water source • Water Pollution • Increase in Traffic Volume • Increased Waste Generation • Dense urban form reduces access to natural/day light and ventilation • Reduced aesthetics due to overcrowding
	• Reduced carbon footprint • Reduced car dependence • Reduced demand for fuel • Less energy usage for infrastructure provision such as roads and pipelines	• Reduced level of service and increased travel time • Increase in Vehicular Pollution (Air and Noise) • Land and water pollution as a result of increased waste generation and insufficient infrastructure • Use of more energy intensive building materials for high rise construction • Higher GHG Emissions due to more lighting, ventilation and cooling requirements of high rise buildings

Source: Author, 2017

Table 2.10 (contd.): Literature Review Summary -
Type and Nature of Impacts of Increasing Density

Type of Impact	Nature of Impacts	
	Positive Impacts	Negative Impacts
SOCIAL IMPACTS	• Social Service Provision such as schools, hospitals etc. becomes feasible • Greater social interaction • Public surveillance of streets • Increased walkability	• Congestion and overcrowding • Rise in crime • Reduced hygiene leading to ill health • Loss of privacy
ECONOMIC IMPACTS	• Reduction in transportation costs • Reduction in construction costs in case of shared walls • Lower rents observed in dense residential areas • Service provision cheaper • Reduction in cost of living	• High rise development is cost intensive • Increased land prices • Overcrowding and reduced aesthetics may bring down real estate value
(blue) Direct Impacts		(grey) Indirect Impacts

Source: Author, 2017

It is observed that impacts can be broadly segregated into three types namely environmental, social and economic impacts. It is understood that all these impacts are a result of increasing densities whether people (population or residential), building or spatial density. Further, there are positive and negative impacts in each of the categories. A deeper understanding also enables one to comprehend that certain impacts are direct and others are indirect that is they accrue as a result of the direct impacts. This is significantly observed in the case of the environmental impacts in table 2.10 above.

2.6.1 Significance of Impacts

Even though all the listed impacts are significant, those responsible for the poor environmental quality in residential neighbourhoods have been acknowledged as one of the most urgent and greatest problems of our cities because of the immediate risk they present to their inhabitants health. This has also led to the plea in **Agenda 21** as mentioned earlier for dedicated actions at the neighbourhood level to reduce environmental decay and improve local socio-economic conditions. Accordingly, crowding and congestion; decay of parks and open spaces; air and water pollution; increasing waste generation; decreasing levels of cleanliness and failure of sewerage and drainage systems (services); decreasing sense of safety; increasing noise pollution; increasing temperature variations within and outside the locality; reduced natural light and ventilation are amongst the most significant impacts. This view can be further corroborated by several studies that directly show how these aspects of the environment affect child and family wellbeing **(Moore and Fry, 2011)**. While crowded living conditions have adverse impact on several child outcomes, housing quality affects their socio-emotional development. Similarly, there is evidence of the importance of parks and green spaces for child development - contact with nature may be as important to children as good nutrition and adequate sleep. Polluted air, water, etc. affect both cognitive and socio-emotional development while chronic exposure to noise in the forms of transportation, music, and other people has adverse effects on people's cognitive development (reading levels, long-term memory), psychophysiology (blood pressure, hormone levels and associated stress), mental health and motivation **(Evans, 2006; Huby & Bradshaw, 2006; Louv, 2005, 2011 and Wood, 2009)**.

Thus, as the present study tries to understand the impact of density on neighbourhood environmental quality it becomes necessary to take cue of the different ways of measuring the most significant impacts at the neighbourhood level as stated above so that environmental quality can be assessed with change in density.

2.6.2 Measurement of Impacts

All the impacts like crowding and congestion; air and water pollution; waste generation; levels of cleanliness and sewerage and drainage systems (services); noise pollution; temperature variations within and outside the locality; natural light and ventilation; etc. if carefully observed are measurable parameters. **In fact they can be considered as indicators that can be measured and aggregated to give objective values of neighbourhood environmental quality**. Thus, based on literature review, it is important to understand and identify the variables to measure these indicators so that they can be used for further study and analyses.

Population density is considered as the first attribute influencing the urban environment. More the number of people within a given area, the pressures on the environment are higher and the discomfort in the urban environment increases. The probability of increased degree of congestion also increases with higher population densities. In addition to population density, physical congestion can be measured through a number of variables like number of houses per unit area, number of vehicles plying on the road, concentration of activities etc. Hence, population density along with residential density, built-form characteristics like plot size, plot coverage, height, etc. and amount of open spaces help in determining built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita), paved road length per capita (PRL/Capita) and mobilization factor (M.F.)[18]. These parameters help in operationalizing and ascertaining the level of congestion or crowding (internal and external) – an important indicator of neighbourhood environmental quality.

Open spaces can be either in the form of parks and playgrounds, or some vacant spaces, or waste land or agricultural land and water bodies. In the residential neighbourhoods, parks and playgrounds provide lung space for the urban residents without which it is very difficult to live in a city with an environment affected by dust, pollution and other atmospheric hazards **(Malini, 1987)**. The trees and plants growing/grown in parks reduce the pollution amounts in the air, affect the micro-climate (cause temperature variations) by evaporative cooling and also serve as recreational sources for the locality. Similarly, the play-grounds besides providing sports opportunity for the residents also relieve congestion. The intention here is not only to classify and define open spaces, but rather to assess utilization levels and spatial qualities in these spaces. Specific variables include: the type of open space and its effect on the activity diversity and activity intensity of the space. While activity diversity refers to the number of different types of activities taking place in an open space, activity intensity refers to the number of users per square area (meters, hectares, etc.). Activity intensity as applied in this study implies the degree of utilization of space **(Lupala, 2001)**. More the diversity and better the utilization, higher is its contribution to the quality of the place. Further, condition of the open spaces in terms of maintained or unattended, encroached and percentage tree cover evaluate the environmental quality of the space.

Ventilation and presence of shade from plants is of vital importance to improve the micro-climate and enhance comfort living in cities with composite or semi-arid type of climate – one of the main climatic zones found in the Indian subcontinent. The outdoor environmental quality is primarily dictated by the degree of exposure to cross ventilation and shade from trees to buildings and outdoor spaces. Too compactly laid down houses have poor qualities in terms of facilitating cross ventilation. With regard to significance of shade trees, **Kyhn (1984)** notes that:

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[18] Defined as the number of exits from the area divided by total number of vias through the area. Source: Sarmento, R., Zorzal, F.M.B., Serafim, A.J. and Allmenroedr, L.B. (2000) Urban Environmental Quality Indicators. In: C.A. Brebbia, A. Ferrante, M. Rodiguez & B.Terra (Eds.), *The Sustainable City*. United Kingdom: WIT Press.

Shade trees filter the sunlight, reduce air temperature by evaporation, protect smaller plants on the ground and reduce glare from bright overcast skies. Thus, variables like street orientation, building height to road width ratio and percentage tree cover can aid in assessing ventilation, shade and temperature variations, if any.

As the densities increase in urban areas, the prevalent technology becomes incapable of catering to concentrated demands. Thus, slowly deterioration in the quality of services takes place or in other words the existing facilities and services fail to cater to the population pressure. The environmental quality can be evaluated with respect to the existence of certain specific services like sewerage and drainage, disposal of domestic waste, presence of street lights, condition of roads and sidewalks, types of open spaces etc. The assumptions in such cases is that each of the localities or census wards are closed units of study – the services considered are largely of local neighbourhood use and relevance; and inter-ward use of services is negligible. Big schools, hospitals, etc. are not considered because they are higher order services that are not tenable at the neighbourhood level. The condition of sidewalks and adequacy of streetlights and distance to daily needs is considered to ascertain the quality requirements for walking. These are important indicators of walkable neighbourhoods in present times and overall environment in the context of the present study.

Table 2.11: Indicators and Variables to Assess Neighbourhood Environmental Quality

Indicator	Measurement Variables			
Crowding and Congestion	BUA/Capita (Built-up Area per Capita)	PGA/Capita (Public Ground Area per Capita)	PRL/Capita (Paved Road Length per Capita)	Mobilization Factor
Nature and Use of Open Spaces	Type & Condition of Open Space	Tree Cover	Activity Intensity	Activity Diversity
Shade and Ventilation	Shade Rating - No. of hours of Shade in the Neighbourhood		Ventilation Score w.r.t. Orientation of Streets	
Temperature Variations	Mean Temperature Difference within and outside the Neighbourhood			
Average Noise Levels	At Entry Points	Inside the Locality	On Main Roads	
Cleanliness	Level of Cleanliness			
Neighbourhood Walkability	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights	Type & Condition of Open Space
Air Quality	NO_x	SO_2	$RSPM_{10}$	

Source: Synthesis of Milbrath and UNESCO, 1978; Rahman et al., 2011 and Literature Review

Air quality is the only indicator that is measured using NO_x, SO_2 and $RSPM_{10}$ values dependent on other variables like type and area of open space, percentage tree cover, vehicles on road, etc. and compared with national standards. These three pollutants among others are primarily considered as they are most noticeable sources of air pollution in residential areas **(CPCB, 2014)**. Similarly, noise levels are also compared with national standards as laid down for residential areas.

The indicators (as seen in table 2.11 above) examine the environmental quality in relation to inherent spatial qualities given by the density variables. Spatial quality as applied to this study refers to the basic pre-requisites for effective use of spaces. It refers to the necessary pre-conditions to evaluate utilizations of outdoor spaces and environmental quality within identified and selected urban types or residential patterns. The argument here is that irrespective of the context, there are basic planning and design requirements that facilitate environmentally conducive growth and utilization of spaces. If such requirements are missing, then utilization of spaces becomes poor or environmentally unfavourable.

2.7 Concluding Remarks

The chapter begins with a detailed description of the types of urban processes and related environmental problems in different types of cities. The literature review brings forth the key issue concerning environmentally sustainable development of cities in the wake of rapid urbanisation and shows the way to identify cities that hold the key to future urbanisation in India. Studies reveal that smaller cities / towns are going to accommodate larger number of people in near future and be the engines of economic growth and development.

The nature of the research problem and the need for understanding and classifying residential patterns and seeing its effect on environmental quality indicates that the approach in carrying out this study is both exploratory and causational. Keeping this in mind, a thorough study to understand and ascertain intra-city residential patterns is undertaken. Certain specific patterns are observed and it is concluded that in order to understand the relationship between residential patterns characterized by built forms, distribution of dwelling units, population distribution, etc. and environmental quality, it is quintessential to study the local environmental problems associated with different residential patterns found in different cities.

The chapter progresses to understand the term density and the common measures adopted to define the various types of density like people density, building density and perceived density. It also tries to understand the relationship of building density with urban morphology as it plays an important role in shaping the urban form. Population density in the context of Indian cities is studied thoroughly and it is found that though average densities are low in most of the cities, the core areas have high and sufficient densities that can generate a demand for public transit systems followed by other interventions so as to improve the quality of the urban space. Probing further it is seen that several efforts have been made by the town and country planning department and other government bodies of different states of the country to increase the density of population in case of plotted and group housing developments in an attempt to meet the challenges of providing quality housing in India's urban areas.

Moving further, FAR – an important measure of building density along with other building regulations like height, plot coverage, etc. are compared across different cities, both national and international. It is seen that most of the cities have their own set of rules and regulations as considered appropriate w.r.t. the population distribution, mix of housing, type of infrastructure and future development strategies. It is also understood that higher FAR/FSI does not necessarily imply high density. Density depends on the floor space occupied by each resident. However, it definitely implies high rise but there are several other factors to be considered as to the maximum height that can be built taking into account different residential patterns, needs and mindset of the people.

Next, the term spatial density is defined. Raman's (2010) and Dave's (2010) study indicate that the social environment is directly linked to the layout and built form or the spatial and physical characteristics of the urban neighbourhood. Information from different websites is gathered and several government documents and reports like URDPFI 2014, Handbook of Service Level Benchmarking of MoUD, Govt. of India, etc. are studied to find out the norms vis-à-vis the actual condition of the various parameters like amount/distribution of open spaces, distribution of roads, streetlights, sewerage and drainage services etc. that measure spatial density. It is observed that the standard of most of the parameters is below the suggested norms resulting in poor environmental quality in our rapidly urbanizing cities.

Following this, the term environmental quality is defined and the justification of studying it at the neighbourhood level is established. Subsequently, the various indicators/parameters and methods considered for the assessment of environmental quality are identified from the works of Tognoli (1987), Bonaiuto et al. (1999), Pacione (2003), Fobil et al. (2010), Shieh et al. (2011), Patel (2011), Rahman et al. (2011), Delsante et al. (2014) among many others. The literature review reveals that studies taking into account physical aspects of the built environment and their impact on urban environmental quality are quite few especially in the Indian context and/or are sparsely reported, thus justifying the scope of the present work.

The chapter concludes with the discussion of impacts of increasing density on environmental quality. Several impacts are identified based on the background studies and all of them are broadly categorized into three types – environmental, social and economic impacts. Further they are classified as positive and negative, and direct and indirect impacts. Indirect refers to the impacts that are caused as a result or accrue as a byproduct of the direct impacts. Considering the significance of impacts, those responsible for poor environmental quality in residential neighbourhoods are acknowledged as the most urgent and greatest because of the immediate risk they present to their inhabitants' health and wellbeing. Accordingly, crowding and congestion; decay of parks and open spaces; air and water pollution; increasing waste generation; decreasing levels of cleanliness and failure of sewerage and drainage systems (services); decreasing sense of safety; increasing noise pollution; increasing temperature variations within and outside the locality; reduced natural light and ventilation are identified as the most significant impacts.

Finally, the chapter ends with the identification of a set of indicators and variables that have all been sourced from the literature review to measure the neighbourhood environmental quality. These form the basis of the conceptual framework and analytical model for further work as part of the research design.

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RESEARCH DESIGN

3.1 Introduction

A detailed plan of how a research is to be completed is called a research design. It consists of the research approach, method of operationalizing the variables so that they can be measured, selecting a sample to study, collecting data for testing hypothesis and interpreting the results. Research design is needed because it facilitates the smooth sailing of the various research operations, thereby making research as efficient as possible and yielding desired research output by optimising resources. Research design also stands for advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analyses, keeping in view the objective of the research and the availability of staff, time and money. Research design, in fact, has a great bearing on the reliability of the results arrived at and as such constitutes the firm foundation of the entire edifice of the research work **(Kothari, 2004)**. The Research Design for the present study is as under:

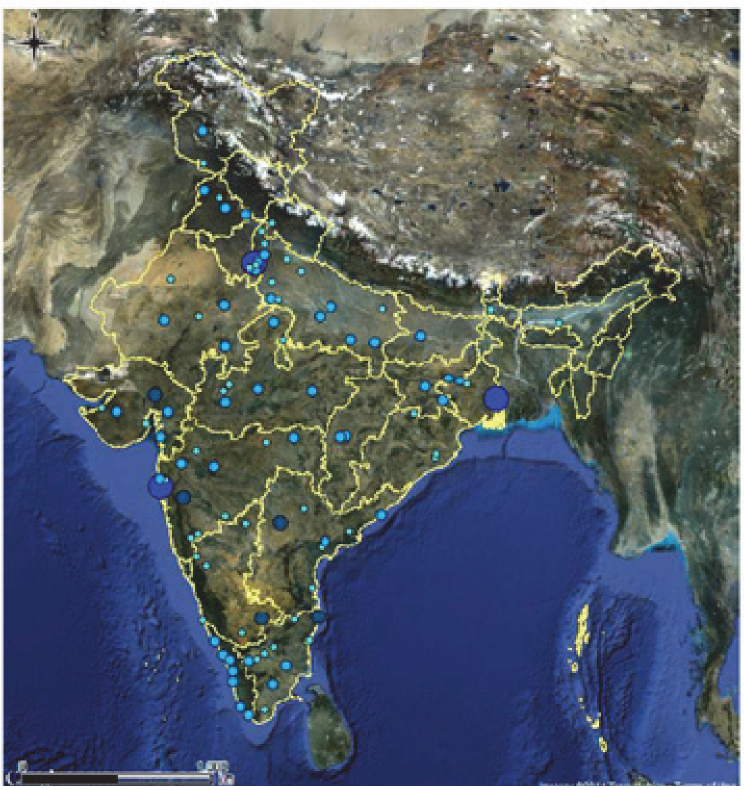
i. Establishing the Research Approach - The Case Study Approach
ii. Disaggregating Density
iii. Reinstating Indicators to assess Neighbourhood Environmental Quality
iv. Developing a Conceptual Framework showing possible correlations between Density and Environmental Quality
v. Constructing the Analytical Model to understand the impact of Density on Neighbourhood Environmental Quality
vi. Determining Types of Data required and Methods of Data Collection to be adopted
vii. Ascertaining the Tool(s) to be used for Data Analyses

3.2 The Case Study Approach

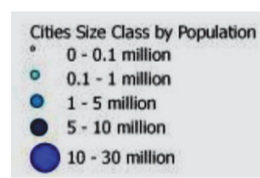
The **Case Study Approach** is based on the assumption that the cities being considered are typical of cases of certain type so that, through intensive analyses, generalizations may be made that can be applicable to other rapidly urbanizing cities in the Indian context. This research employs a multiple case design. One of the advantages of multiple case designs is the fact that they are more compelling and considered robust than single case designs **(Yin, 1994)**. Yin points out further that multiple case studies have been considered when a comparative study among cases is envisaged. Since one of the aims of this study is to explore and compare the residential patterns and the associated environmental quality, a multiple case study design is considered as an appropriate strategy to explore in detail variations in environmental quality with variations in densities.

3.3 Identifying Cities for Assessing Neighbourhood Environmental Quality

India is well endowed with cities spread evenly across the country. Historically, cities in India have been located in areas with adequate water and on popular trade routes. Like other countries, cities have had bulk of the economic wealth and have been 24-hour market places. The high concentration of people living in the cities has brought variety of resources, products and services to our cities **(Bhandari, 2006)**.



In 2011, there were 3 cities with population greater than 10 million and 53 cities with population greater than 1 million. Over 833 million Indians lived in 0.64 million villages but 377 million lived in about 8,000 urban centres.



Map 3.1: Urban India – 2011
Source: IIHS Analysis[19] of Census data, 2011. (Satellite Map, Google Inc.)

[19] Urban India 2011: Evidence – A book produced by Indian Institute of Human Settlements (IIHS) for the India Urban Conference Evidence and Experience (IUC 2011) comprising of a series of events designed to raise the salience of urban challenges and opportunities in the on-going debate on India's development.

Over the years the megacities have occupied significant mind, media and policy space in terms of urbanisation in India. Post-Independence also urbanisation in India has been dominated by the largest cities. However, with time, these cities have grown in size but quality of life has been severely compromised. The fact, however, is that most of India's urban centres are smaller towns. The 8000 urban centres / townships identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only twenty percent live in cities of 10 million or more. Eighty percent of the urban population lives in cities and towns of population ≤ 1 million (as shown in map 3.1). Hence, the most meaningful approach in our case is to anticipate the rapid growth of these cities and put the Class I (0.1 – 1 million) cities centrally on the development agenda. The graph in figure 3.1 below also shows this fact that in the 20th century the rapid growth of the largest metropolitan cities has slowed down, whereas the smaller cities are expanding.

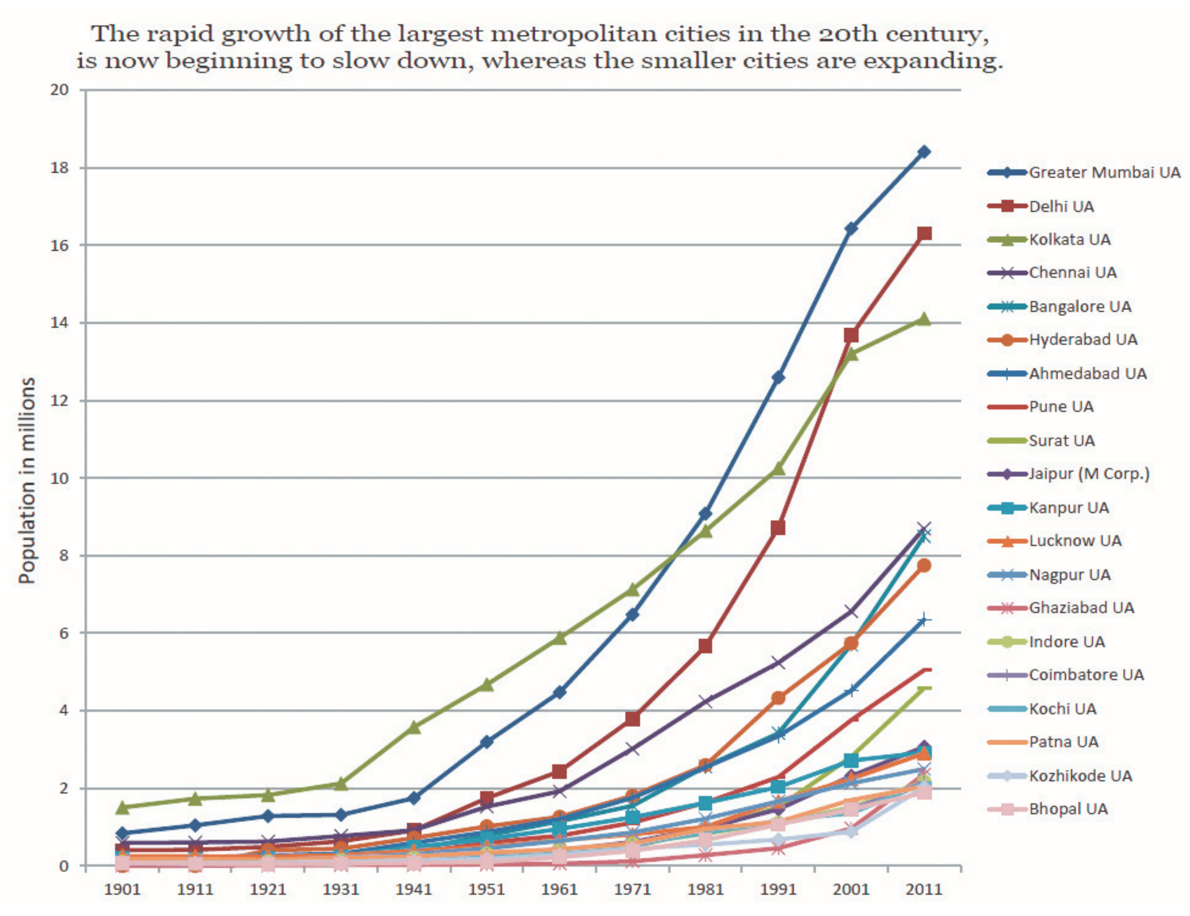


Figure 3.1: Largest 20 Urban Agglomerations by Population – 2011

Source: IIHS Analysis[19] based on Census of India, 2011

Further considering the contribution to the Gross Domestic Product (GDP) or output of the country, it is seen as indicated in figure 3.2 that while the top 10 and 53 million plus cities account for 15% and 31% of the GDP; and hold 8% and 13% of the population respectively, the top 100 cities with 16% of the population and having approximately 47 cities in the 0.1 – 1 million population range contribute 41%-43% to the GDP thus additionally justifying their potential as key cities for future urbanisation in India.

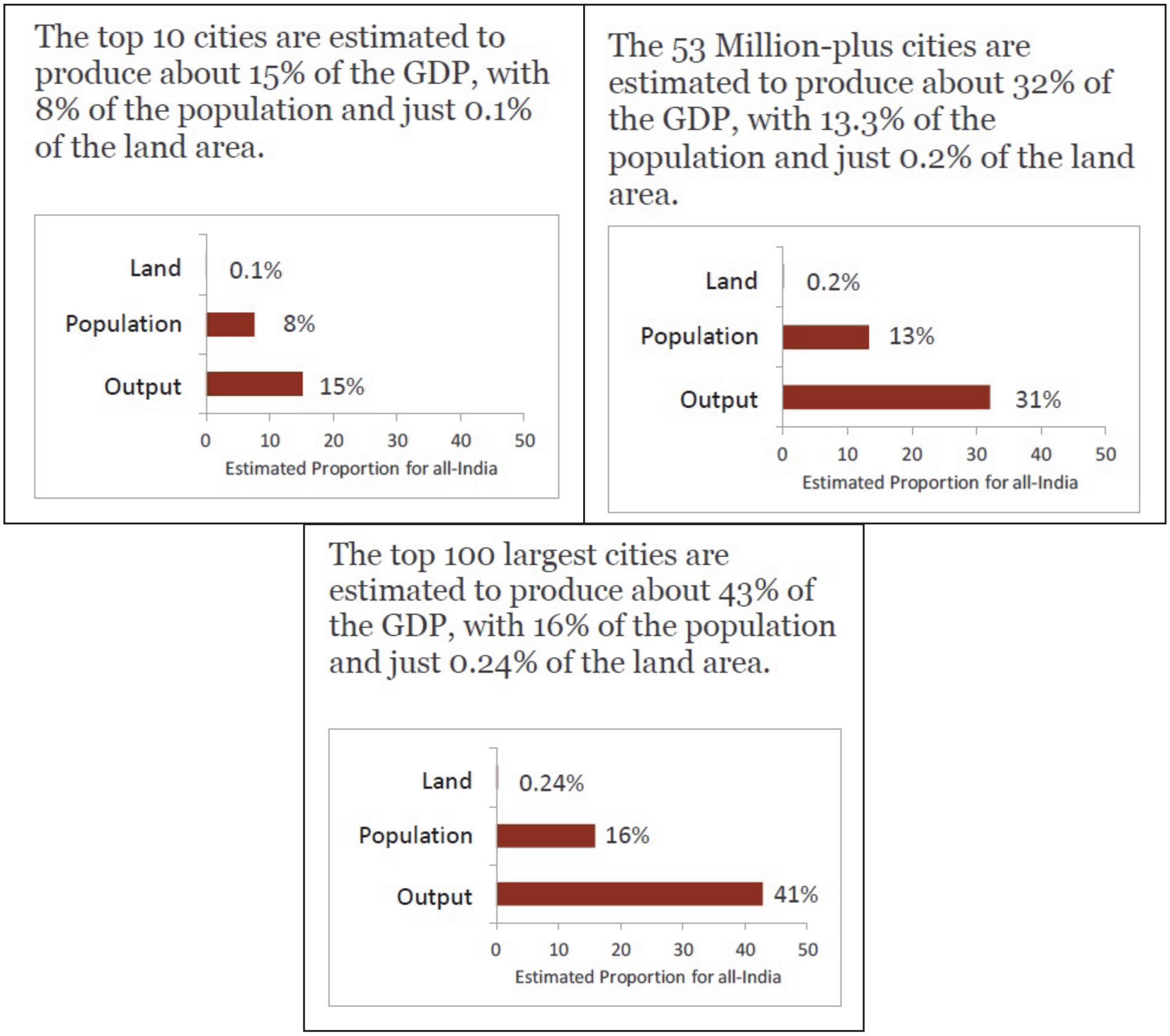


Figure 3.2: Estimates of Land Covered, Distribution of Population and Economic Output across cities of various sizes

Source: IIHS Analysis[19] based on Census of India, 2011

In order to gain a detailed insight into the components that influence environmental quality and develop a methodology that can assess, monitor and potentially forecast developments of environmental quality in our cities, it is necessary to first identify some cities that hold the key to future urbanisation in India. As per literature review, the main criteria for selecting the cities are:

1. The cities should be emerging centres of economic activity.
2. They should be located between other urban centres and well connected.
3. In near future, these cities should create better opportunities for citizens living in and around them.
4. Some out of them should be cities that are budding and have the potential to turn into much larger centres.
5. They should be steadily gaining the necessary scales in terms of population and market size.

Based on the criteria listed and a study by an economic research firm, Indicus Analytics, all potential cities are divided into three categories as shown in table 3.1.

Table 3.1: Potential Cities that hold the key to future urbanisation in India

Sibling Cities	Upcoming Cities	Budding Cities
A collection of smaller cities clustered around each other and highly dependent on the mother city.	Cities that in the recent past have come onto their own as important regional and economic centres.	Cities that have the potential to turn into much larger centres in the near future.
1. Centres that are siblings of larger cities such as Gurgaon and Noida (Delhi), Panchkula and Mohali (Chandigarh). 2. Kolkata's siblings in North 24 Parganas such as Baranagar, Barasat, Dum Dum, Kamarhati, Panihati and Salt Lake City. 3. Mumbai's siblings in Thane district such as Dombivli, Bhayandar, Navi Mumbai, Thane, Ulhasnagar and Virar. 4. Chennai's siblings in Thiruvallur district such as Ambattur, Avadi and Tiruvottiyur.	1. Goa, 2. Vijayawada and 3. Thiruvananthapuram These cities have become important regional or state centres of economic activity. As they progress, they will create opportunities for citizens living in them and their surrounding areas.	1. Capitals of states and UTs, such as Chandigarh, Gandhinagar, Srinagar and Shillong. 2. Industrial centres such as Durg-Bhilai and Bokaro. 3. Historically important cities such as Udaipur and Mysore. 4. Religious cities such as Amritsar, Varanasi and Ajmer.

Source: Author's elaboration from – The Diversity of top 100 cities of India by Indicus Analytics, An Economic Research Firm, 2006

All the above-mentioned cities are grouped into three population categories as shown in table 3.2. It should be noted that some cities with just over 1 million population are included since they feature as potential cities according to table 3.1 above.

Table 3.2: Population of Potential Case Study Cities

Population	**0.1 – 0.49 million**	Shillong – 0.14 million
		Gandhinagar – 0.2 million
		Chandigarh's Siblings: Mohali – 0.15 million, Panchkula – 0.2 million
		Kolkata's Siblings: Salt Lake – 0.22 million, Baranagar – 0.25 million, Barasat – 0.3 million, Kamarhati – 0.34 million, Panihati – 0.38 million and Dumdum – 0.4 million
		Chennai's Siblings: Tiruvottiyur – 0.25 million, Avadi – 0.3 million and Ambattur – 0.47 million
		Durg – 0.27 million
		Bokaro – 0.4 million
		Udaipur – 0.45 million
	0.5 – 0.74 million	Mumbai's Siblings: Ulhasnagar – 0.5 million
		Ajmer – 0.54 million
		Bhilai – 0.6 million
		Delhi's Siblings: Noida – 0.65 million
	0.75 – 1.5 million	Thiruvananthapuram – 0.75 million
		Mysore – 0.88 million
		Vijayawada – 1.05 million
		Chandigarh – 1.05 million
		Amritsar – 1.13 million
		Srinagar – 1.2 million
		Varanasi – 1.2 million
		Goa – 1.4 million
		Delhi's Siblings: Gurugram – 0.88 million
		Mumbai's Siblings: Bhayandar – 0.8 million, Navi Mumbai – 1.1 million, Vasai Virar – 1.22 million, Kalyan Dombivli – 1.25 million and Thane – 1.8 million

Source: List of most populous cities in India according to Census 2011 – Wikipedia, the free encyclopedia

Three cities namely **Amritsar, Chandigarh** and **Gurugram** are selected for the study purpose out of the several cities listed in Table 3.2 above. It is observed that all the three cities have been growing constantly as indicated in table 3.3. The average decadal growth rate has been 2.3%, 11.4% and 10.24% respectively. The steep rise as seen in figure 3.3 in comparison to figure 3.1 further establishes the fact that these cities are expanding rapidly and hold the key to future urbanisation in India.

Table 3.3: Population Growth in Case Study Cities

Name of City	1951	1961	1971	1981	1991	2001	2011
Amritsar	336,114	390,055	454,805	594,844	708,835	1,011,327	1,133,000
Chandigarh	24,261	119,881	257,251	451,610	642,015	900,635	1,054,686
Gurugram	18,613	37,868	57,151	100,877	121,486	239,684	876824

Source: District Gazetteers and Census of India 1971, 1981, 1991, 2001 and 2011

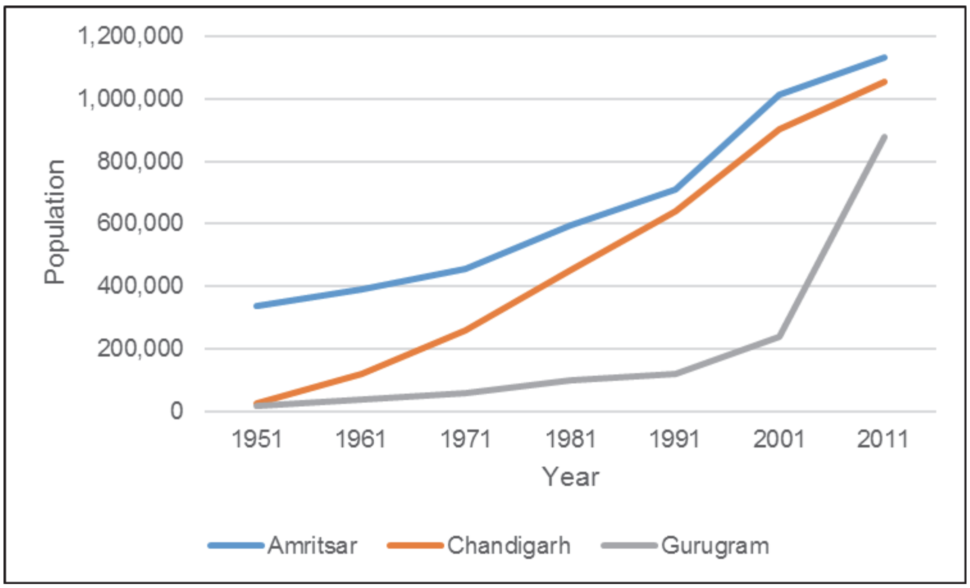


Figure 3.3: Growth of Case Study Cities by Population

Source: District Gazetteers and Census of India 1971, 1981, 1991, 2001 and 2011

The city of **Amritsar** situated in north-western part of the state of Punjab is recognized as one of the budding cities of India. It is a ***historic city*** that has attained the status of a global city due to it being a major pilgrimage/tourist destination and has also emerged as one of the youngest metropolitan cities of India. The present population of the city is 1.13 million (as per census 2011). Amritsar has imprints of all types of settlement patterns and associated densities. There are important differences between the older habitations in the core of the city – walled city of

Amritsar (1665 – 1849) with post-colonial (1947 onwards) settlements outside the walled city and in and around the periphery of the city.

Chandigarh is a city and a union territory in the northern part of India that serves as the capital of the states of Punjab and Haryana. The city of Chandigarh was the first planned city in India **post-independence** in 1947 and is known internationally for its architecture and urban design.[20] The master plan of the city was prepared by Swiss-French architect Le Corbusier. Most of the government buildings and housing in the city were designed by the Chandigarh Capital Project Team headed by Pierre Jeanneret, Jane Drew and Maxwell Fry. The city was reported to be the cleanest in India in 2010, based on a national government study[21] and the territory also headed the list of Indian states and territories according to Human Development Index **(Meghalaya Human Development Report 2008 and Chhabra, 2010)**. The present population of the city is 1.05 million (as per census 2011). The metropolitan of Chandigarh-Mohali-Panchkula collectively forms a Tri-city, with a combined population of over 2 million.[22] This is the first smoke-free city in India **(WHO, 2011)**. The roads in Chandigarh are lined by trees and it has the third highest forest cover in India at 8.51% following Lakshadweep and Goa **(Walk through India, 2016 and Thakur, 2014)**.

Gurugram is a leading financial and industrial city of India, situated in the National Capital Region near the Indian capital New Delhi in the state of Haryana. Located 32kms south-west of New Delhi, Gurugram has a population of 876,824 (as per Census 2011). Witnessing rapid urbanization, Gurugram has become the city with the third highest per capita income in India **(Julka, 2011)**. Historically known as *Guru Gram*, the city's economic growth story started when the leading Indian automobile manufacturer Maruti Suzuki India Limited established a manufacturing plant in Gurugram in the 1970s **(Kumar and Mishra, 2012)**. Today, Gurugram is center for more than 250 Fortune 500 companies[23]. The housing type in the city consists largely of attached housing, though a large number of multi-dwelling units, like apartments, condominiums and high rise residential towers are getting popular as seen in plate 3.1. Some inhabitants in the city live in slums in shanty houses lacking proper sanitation, safe water

[20] [Online] Available at: https://en.wikipedia.org/wiki/Chandigarh [Accessed 12 March 2015].

[21] *India's cleanest: Where does your city stand?* Rediff.com News, 13 May 2010. [online] Available at: http://www.rediff.com/news/slide-show/slide-show-1-chandigarh-cleanest-of-all/20100511.htm [Accessed 26 July 2012].

[22] [Online] Available at: https://en.wikipedia.org/wiki/Panchkula [Accessed 12 March 2015].

[23] [Online] Available at: https://en.wikipedia.org/wiki/Gurugram [Accessed 20 May 2015].

supply, electricity, hygienic streets or other basic human necessities. Gurugram has a complex park system managed by Haryana Urban Development Authority but most parks are small and ill-maintained.

Plate 3.1: View of residential projects along NH-8, Gurugram

Source: www.google.com, 2013

The **Table 3.4** sums up the important criteria considered for selecting the case study cities. In addition ease of accessibility to the three cities (within 1-5hrs as author is based in Panchkula – Chandigarh's satellite town) has been an important decisive factor.

Table 3.4: Identification of Case Study Cities

Criteria	Amritsar	Chandigarh	Gurugram
1. Category	**Budding City**	**Upcoming City**	**Sibling City**
2. Population	**1.13 million**	**1.05 million**	**0.88 million**
	All have population in the range 0.75 million – 1.5 million (as per census 2011)		
3. Typology	**Historic City**	**First Planned City**	**Millennium City**
	Being from different time periods, several residential patterns and their associated environmental quality can be evaluated and compared to arrive at generalized and meaningful conclusions.		
4. Climate Zone	**Composite**	**Composite**	**Composite**
	Same climate zone will ensure consistency and comparability of the physical aspects of the built environment for environmental quality assessment.		

Source: Author, 2015

3.4 Identifying Case Study Neighbourhoods

Amritsar, Chandigarh and Gurugram are selected as the case study cities since they are from different time periods and have imprints of all types of urban patterns and associated densities. There are important differences between the older habitations in the historic city of Amritsar with newer settlements in Amritsar, post independent planned interventions in Chandigarh and modern residential areas in the millennium city of Gurugram.

For detailed investigation, to begin with a matrix based on two critical factors namely building height and gross population density is generated and eight neighbourhoods are identified from the three case study cities as indicated in table 3.5 and figure 3.4. Each neighbourhood represents a particular type of residential pattern commonly found in Indian cities with 0.75 million ≤ population ≤ 1.5 million. The common patterns found are low rise low density (LRLD), low rise medium density (LRMD), low rise high density (LRHD), medium rise medium density (MRMD), medium rise high density (MRHD), high rise low density (HRLD) and high rise high density (HRHD).

Table 3.5: Case Study Neighbourhoods

HEIGHT \ DENSITY	LOW	MEDIUM	HIGH
LOW	**Sector 8, Chandigarh**	**Ranjit Avenue, Amritsar**	**Sector 38W, Chandigarh (Planned)** **Katra Dullo, Amritsar (Organic)**
MEDIUM	No Identifiable Neighbourhood	**Marble Arch (Manimajra), Chandigarh**	**Sector 20 (Panchkula), Chandigarh**
HIGH	**World Spa, Sector-30, Gurugram**	No Identifiable Neighbourhood	**Uniworld City, Sector-30, Gurugram**

Generally, G+3 storied structures that do not require elevators are considered low-rise. The International Building Code (IBC 2000) and the Building Construction and Safety Code, NFPA 5000TM-2002, Paragraph 3.3.28.7 of the Life Safety Code®, 2006 edition, define high-rise

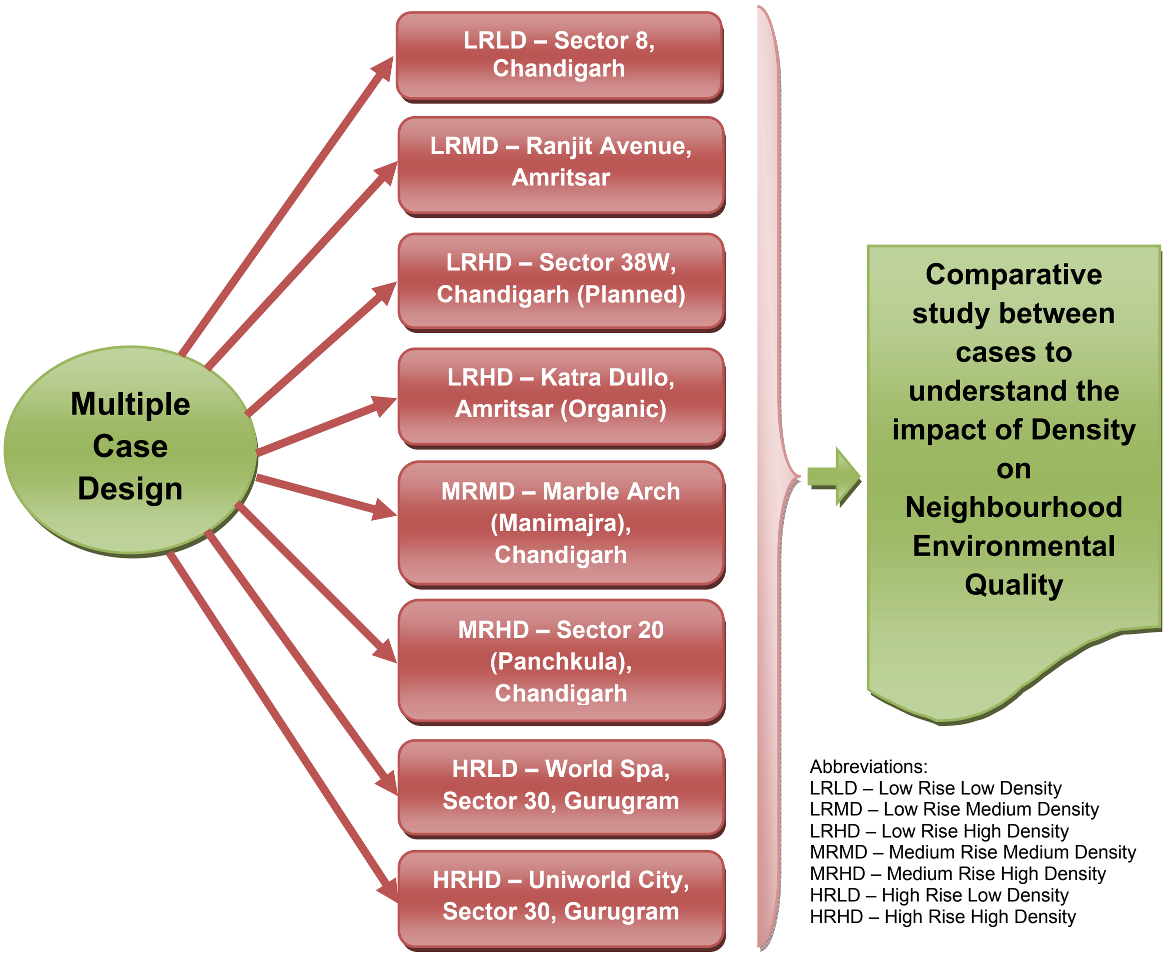


Figure 3.4: The Case Study Approach for Research

buildings as buildings 75 feet (23m approximately) or greater in height measured from the lowest level of fire department vehicle access to the floor of the highest occupiable storey. Also buildings with more than 8 stories or 24m in height with mandatory provision of diesel generators in case of an electricity failure are considered high rise as per the National Building Code 2005 Fire Safety and Fire Protection Norms. Therefore, from the above two definitions, buildings having 5-8 stories are considered as medium rise structures for the present study as seen in table 3.6 and plate 3.2.

Another aspect that is worth noticing is that over the years (from historical to modern to post-modern times) the residential patterns show a changing trend from low rise low/medium/high density to medium and high rise medium/high density. This is also the case for the three case study cities under consideration as seen in figure 3.5.

Table 3.6: Neighbourhoods grouped according to Height of residential buildings

Neighbourhood	No. of Storeys	Range	Rise
Sector 8, Chandigarh	G, G+1, G+2	≤G+3 storeys	Low
Ranjit Avenue, Amritsar	G, G+1, G+2		
Sector 38W, Chandigarh	G+2		
Katra Dullo, Amritsar	G, G+1, G+2, G+3		
Marble Arch (Manimajra), Chandigarh	G+4	5-8 storeys	Medium
Sector 20 (Panchkula), Chandigarh	G+5, G+6, G+7		
World Spa, Gurugram	G+12, G+16	>8 storeys	High
Uniworld City, Gurugram	G+12, G+13		

Source: Primary Survey, Author, 2012

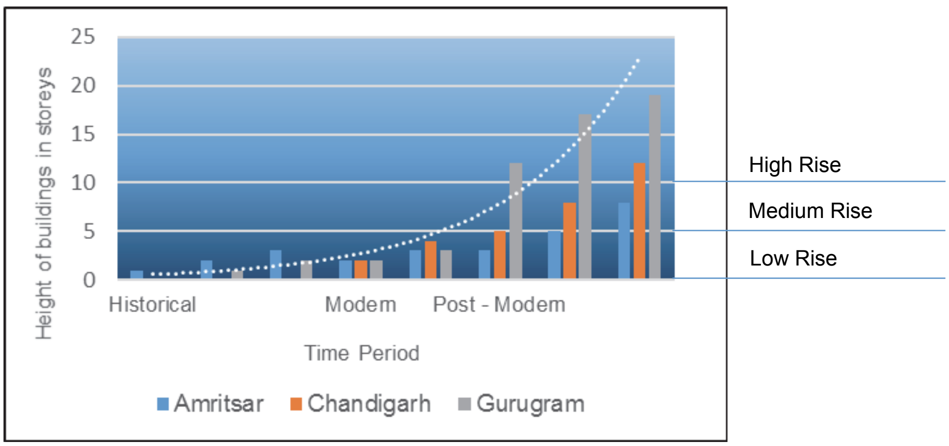


Figure 3.5: Growing Trend towards Medium and High Rise Residential Patterns

The population density is categorised as low density with <200pph, medium density with 200 to<400pph, high density with 400 to<600pph and very high density with ≥600pph as listed in table 3.7. This is based on the gross population densities observed in different neighbourhoods.

Table 3.7: Neighbourhoods grouped according to Gross Population Density

Neighbourhood	Gross Population Density (pph)	Range	Level
Sector 8, Chandigarh	95	<200pph	Low
World Spa, Gurugram	178		
Ranjit Avenue, Amritsar	256	200 to <400pph	Medium
Marble Arch (Manimajra), Chandigarh	345		
Sector 38W, Chandigarh	441	400 to <600pph	High
Sector 20 (Panchkula), Chandigarh	540		
Katra Dullo, Amritsar	641	≥600pph	Very High
Uniworld City, Gurugram	735		

Source: Primary and Secondary Data, 2012

Katra Dullo, Amritsar

Ranjit Avenue, Amritsar

World Spa, Gurugram

Uniworld City, Gurugram

Sector-8, Chandigarh

Sector-38W, Chandigarh

Marble Arch, Manimajra

Sector-20, Panchkula

Plate 3.2: Residential Neighbourhoods in Case Study Cities

Further, the study considers gross residential densities because of the paucity of net density values and comparability issues with gross values generally given in different government documents, reports etc. in our scenario. Also in case of old/core areas of the city, it becomes a challenge to calculate net densities as the boundaries are not clear. Since the streets are irregular and other spaces (excluding incidental spaces) are not well-defined, it becomes still more difficult to calculate net density values that are conventionally biased to formal settings with well-defined streets and spaces **(Lupala, 2001)**.

Additionally it is found that urban planning controls are sometimes focused on the net density of a particular site. Yet such measures are of little use in understanding how cities work because they do not include the public space of streets and parks. The gross density is always lower than net density and it is the one that matters in debates over urban density. While people might be packed in on a particular site, the street network of a car-based city tends to keep them apart. Hence, net density is not always considered an effective measure of urban density **(Dovey, 2016)**. Here, the residential density is categorised as low density with <50DUs/ha, medium density with 50 to<100DUs/ha, high density with >100DUs/ha as indicated in table 3.8. This is based on the gross residential densities calculated for the different neighbourhoods.

Table 3.8: Neighbourhoods grouped according to Gross Residential Density

Neighbourhood	Gross Residential Density (DUs/hectare)	Range	Level
Sector 8, Chandigarh	17	<50DUs/hectare	Low
Ranjit Avenue, Amritsar	36		
World Spa, Gurugram	44		
Marble Arch (Manimajra), Chandigarh	65	50-100 DUs/hectare	Medium
Sector 38W, Chandigarh	76		
Sector 20 (Panchkula), Chandigarh	98		
Uniworld City, Gurugram	147	>100DUs/hectare	High
Katra Dullo, Amritsar	149		

Source: Primary and Secondary Data, 2012

3.5 Disaggregating Density

The next stage consists of disaggregating density and constructing the conceptual framework to show possible correlations between the density variables and indicators of environmental quality. The central question is how density can be disaggregated into a number of independent variables that affect environmental quality and hence test the hypothesis – Density impacts Environmental Quality in Residential Neighbourhoods.

'Density' is broadly disaggregated into eight attributes under three heads to point out all significant physical aspects of the neighbourhood. The three heads and eight attributes based on the literature review **(Cheng, 2010)** are namely:

1. People Density
   i. Distribution of People or Population Density, and
   ii. Distribution of Buildings or Residential Density
2. Building Density (Built-form Characteristics)
   iii. Floor Area Ratio (FAR), and
   iv. Site/Plot Coverage
3. Spatial Density
   v. Height to Width Ratio,
   vi. Distribution of Open Spaces,
   vii. Distribution of Roads, Sidewalks etc., and
   viii. Distribution of Services

As per the hypothesis 'Environmental Quality' is the dependent variable that is assumed to differ significantly with change in residential pattern. The indicators of environmental quality that are expected to vary are identified on the basis of discussion in Chapter 2, 2.6 Density and its Impact on Environmental Quality, page no. 61 as follows:

i. Crowding and Congestion
ii. Nature and Use of Open Spaces
iii. Shade and Ventilation
iv. Temperature Variations
v. Average Noise Levels
vi. Level of Cleanliness
vii. Neighbourhood Walkability, and
viii. Air Quality

3.6 The Conceptual Framework

After this, a conceptual framework showing possible correlations between density variables and indicators of environmental quality is devised as shown in table 3.9. The conceptual framework basically tries to indicate the probable correlations between the density variables and indicators of neighbourhood environmental quality. While the black dots represent assumed significant associations between the independent and dependent variables, the gray dots represent associations that may or may not be significant between the two set of variables. The assumptions are based on the literature review and the pilot study conducted on two neighbourhoods of Amritsar. The same is validated during further case study analyses. The basis of the different assumptions (A1 to A8) can be summarized as follows:

A1. Population density is considered as one of the first attributes influencing environmental quality. The probability of crowding and congestion both internal and external increases with higher population densities. Population density along with residential density, built-form characteristics like FAR, plot coverage, height, etc. and amount of open spaces help in determining built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita), paved road length per capita (PRL/Capita) and mobilization factor (M.F.) that are instrumental in ascertaining the level of crowding and congestion.

A2. Research has found naturalness (vegetation) and openness as a principal component of neighborhood attachment **(Bonaiuto, Fornara and Bonnes, 2003)** and as a factor affecting use of space, sense of safety, and informal social contact among neighbors **(Kuo and Sullivan, 1998)**. Though the present study does not include residents' perception or social characteristics of the neighborhood as it is more concerned with understanding the association between physical characteristics with neighbourhood environmental quality, it proposes to verify the associations between population density, residential density, built-form characteristics and distribution/amount of open spaces with nature and use of open spaces. It is believed that there is a positive correlation between people density and use of open spaces. Also FAR, plot coverage etc. are bound to have an association with the nature of open spaces – private/public and their intensity of use at the neighbourhood level. Level of cleanliness especially in terms of solid waste storage and disposal will also have an impact on the nature of open spaces.

Table 3.9: The Conceptual Framework

Density Variables	Environmental Quality Indicators							
	Crowding & Congestion	Nature and use of Open Spaces	Shade & Ventilation	Temp. Variations	Noise Levels	Level of Cleanliness	Neighbourhood Walkability	Air Quality
Population Density	●	●			○	●		●
Residential Density	●	●	●	●	○	●		●
FAR, Plot Coverage	●	●	●	●	○			
Height to Width Ratio			●	○			○	
Distribution of Open Spaces	●	●	●	●	●		○	○
Distribution of Roads and Sidewalks	●				●		●	●
Distribution of Services		○				●	●	○

● Assumed Strong Correlation ○ Assumed Weak Correlation Empty Cells – No Apparent Correlation

Source: Author's elaboration based on Literature Review and Pilot Study

A3. The outdoor environmental quality is primarily dictated by the degree of exposure to cross ventilation and shade to buildings and outdoor spaces. Climate is discussed in much architectural research advocating the compact built forms **(Correa, 1982 and Turner, 2003)**. Densely developed places in hot-arid and composite climates consume less energy for cooling by blocking out strong sunshine and providing shade to adjoining buildings, streets and public places **(Correa, 1982)**. With this understanding it is assumed that residential density, built-form characteristics and amount of open spaces will have direct association with shade and ventilation in the neighbourhood.

A4. Shaded and well ventilated neighbourhoods will have some temperature differences within and outside the locality. Therefore, the same shall be verified with respect to residential density, built-form characteristics, height to width ratio and amount of open spaces.

A5. Noise is regarded as a pollutant under the Air (Prevention and Control of Pollution) Act, 1981. It has been defined as unwanted sound. There are two major settings where noise occurs, viz., community noise and industrial noise. Major sources of community noise are automobiles, construction work, loudspeakers, recreational activities, fireworks, etc. In the present study, outdoor noise levels are assumed will vary with the amount of roads and type of traffic in different parts of the neighbourhood. It is also understood that indirectly noise will be affected by people density, built-form characteristics and amount of open spaces. More people and dwelling units will imply more vehicle population thus generally causing more noise. On the other hand more open spaces with vegetation and greenery will absorb sound and decrease the noise levels.

A6. Services and facilities generally deteriorate with increasing population and residential density. This will have an impact on cleanliness in the neighbourhood. Thus people density and distribution of services will have direct association with level of cleanliness.

A7. The condition of sidewalks, provision of streetlights (in terms of spacing and condition, other parameters being assumed constant) ensuring safety even during late evening hours and distance to daily needs is considered to ascertain the quality requirements for walking. In addition, sometimes good open spaces like parks and gardens are also helpful in encouraging people to walk. Thus, distribution of sidewalks, services and number of open spaces (occasionally) and height to street width ratio affecting shade and ventilation are expected to show positive correlation with walkability.

A8. Finally, air quality (parameters considered as per NAAQM Status and Trends 2014-15) is assumed will vary with the distribution of roads negatively and positively with open spaces and naturalness. It might show some association with level of cleanliness because of foul smell from littered garbage and open drains, household and street dust, etc.

3.7 The Analytical Model for Assessing Environmental Quality

Based on the conceptual framework and the research hypothesis, a bottom-up model is proposed to understand the impact of density on neighbourhood environmental quality. The model shows the top-level attribute environment quality of a neighbourhood represented by i) Crowding and Congestion, ii) Nature and Use of Open Spaces, iii) Shade and Ventilation, iv) Temperature Variations v) Noise Levels, vi) Quality requirements for Walking, vii) Level of Cleanliness and viii) Air Quality. Each of these is further disaggregated into a series of variables that can be objectively measured. The bunched/grouped variables help to understand and see at a glance the particular type and number of variables affecting each of the indicators of environmental quality as shown in figure 3.6.

This study is further designed on the basis of a **multiple hierarchical regression (MHR) approach**. The multiple regression analysis is generally used for prediction. It is a statistical technique to understand the impact of two or more predictor or independent variables (i.e., lower-level attributes) on a single criterion or dependent variable (i.e., higher-level attribute). Normally, it is used to assess the extent to which the observed variance in the dependent variable is explained by the observed variance in the independent variables, also referred to as the **'model fit'**. These specific properties of multiple regression analysis, estimation of the 'regression weights' and assessing the 'model fit' shall be used for the analysis of the concept of environmental quality **(Van Poll, 1997)**.

The variables that characterize density and are assumed to have an impact on the neighbourhood environmental quality as per the model can be put as:

$EQ_i = f(PD_i, RD_i, FAR_i, PC_i, HWi, OS_i, RSW_i, S_i)$ ………………………….…………………...(1)

Assuming that a linear function exists between the variables, the equation can be written as:

$EQ_i = \beta_0 + \beta_1 PD_i + \beta_2 RD_i + \beta_3 FAR_i + \beta_4 PCi + \beta_5 HWi + \beta_6 OSi + \beta_7 RSW_i + \beta_8 Si + \varepsilon_i$……….....…(2)

Where:

EQ_i = is the environmental quality of neighbourhood i

PD_i = refers to the population density of neighbourhood i

RD_i = refers to the residential density of neighbourhood i

FAR_i = refers to the floor area ratio of neighbourhood i

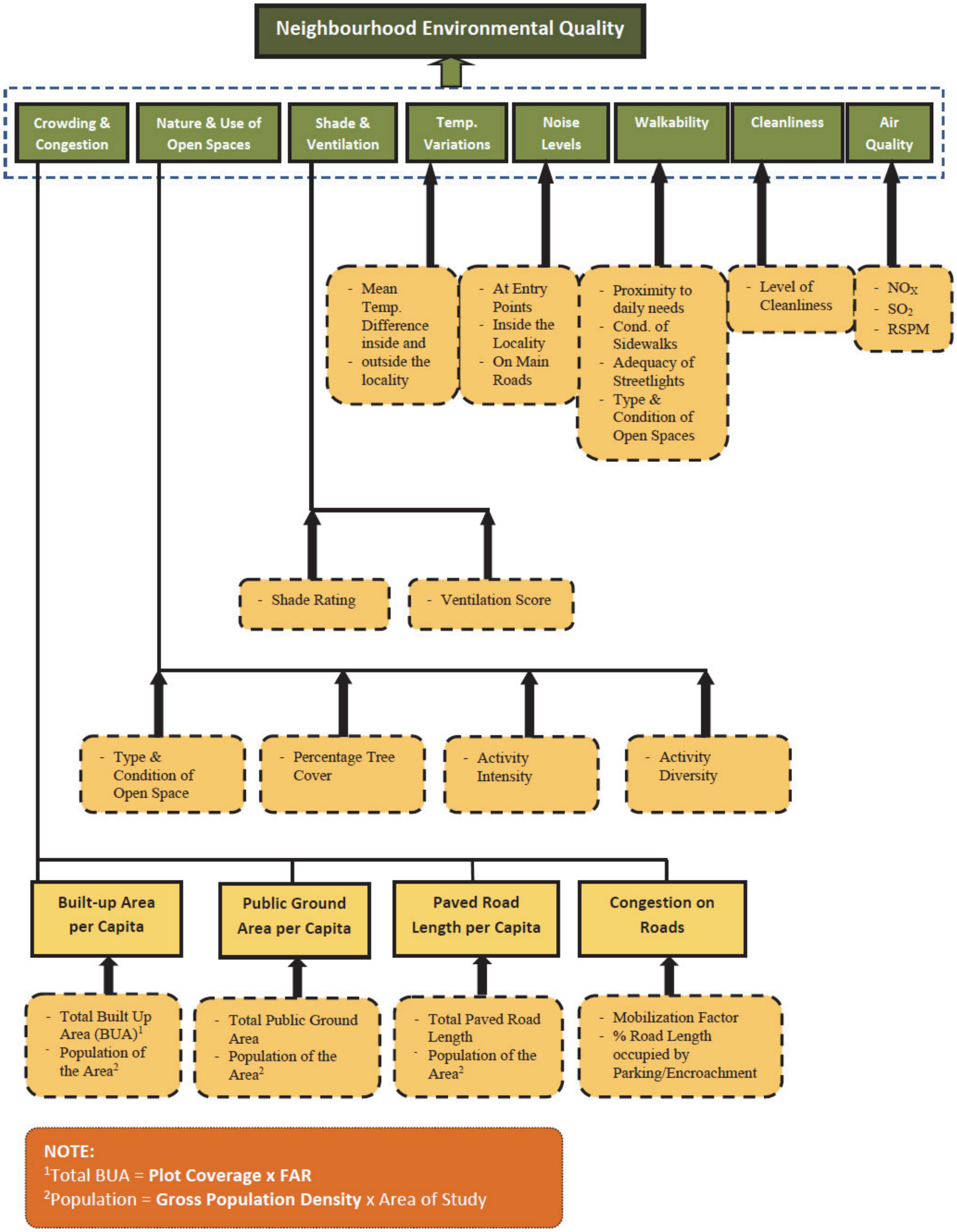


Figure 3.6: The Analytical Model

Source: Author's Elaboration, 2014

PC_i = refers to the plot coverage of neighbourhood i

HW_i = refers to the height to width ratio of neighbourhood i

OSi = refers to the distribution of open spaces in neighbourhood i

RSW_i = refers to the distribution of roads and sidewalks in neighbourhood i

S_i = refers to the distribution of services in the neighbourhood i

β_0 = refers to the constant

β_i = refers to the standardized regression weights to be estimated and

ε = refers to the error term

The multiple regression approach shall also be used **to assess the so called 'standardized regression weights' (β's)**. In the present study, this is a very important property, since the 'β - coefficient' will be used to indicate the relative importance of a lower-level attribute and help in assessing which variable of density significantly impacts the environmental quality. In addition, the comparative analysis of the environmental quality of different neighbourhoods having varying densities will help in identifying desirable density ranges to maintain favourable environmental quality and arrive at guidelines to achieve environmentally conducive patterns of residential development in our cities.

3.8 Types of Data and Methods of Data Collection

There are two approaches to gathering information about a situation, person, problem or phenomenon. Sometimes, information required is already available and need only be extracted. However, there are times when the information must be collected. Based upon these broad approaches to information gathering, data are categorized as:

- Secondary data and
- Primary data.

Information gathered using the first approach is said to be collected from **secondary sources**, whereas the sources used in the second approach are called **primary sources**.

For the present study, data is gathered from both primary and secondary sources as indicated in figure 3.7. Primary sources included detailed field studies, visual surveys and photographic documentation of the case study localities with the help of base maps prepared from Google Earth images. Observation is employed as a primary method to study house forms, plot sizes, configuration and plot characteristics, types of roads, sidewalks and open spaces and their uses, etc. Additionally, unstructured interviewing through focus group interviews, narratives and oral histories is also resorted to, to extract information. Data collection through unstructured interviewing is extremely useful in situations where either in-depth information is needed or little is known about the area. The flexibility allows eliciting extremely rich information. Information about certain aspects of the neighbourhood is also gathered through an interview schedule consisting of close-ended and open ended questions as listed in Annexure 1. Close-ended questions produce factual information whereas open-ended questions help in seeking general opinions, attitudes and perceptions.

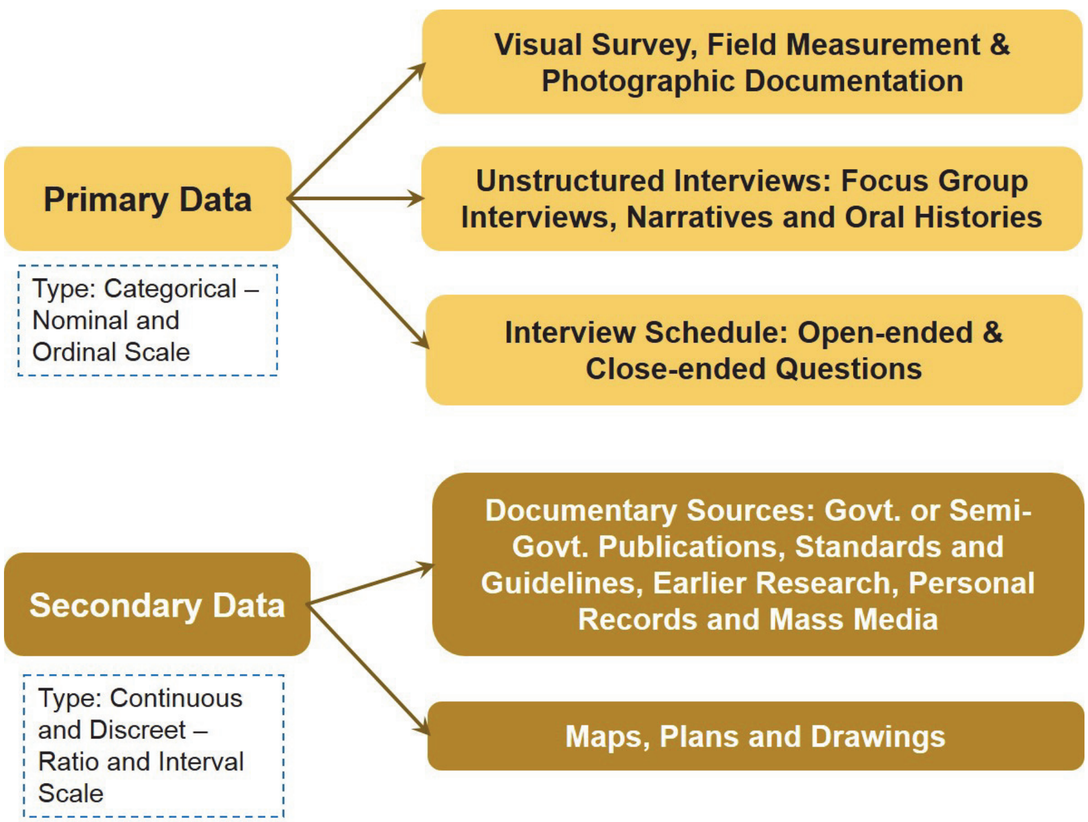


Figure 3.7: Types of Data and Methods of Data Collection

Source: Author's Elaboration, 2014

Certain mechanical instruments like the Temperature and Humidity Data logger and Smartphone Android Applications like deciBel as shown in plate 3.3 are used to record Ambient Temperatures and Noise Levels in different places within and in immediate surroundings of the neighbourhood. The ambient temperatures are measured in different places of the neighbourhood at 1.5m (5'-0") street level and terrace level approximately.

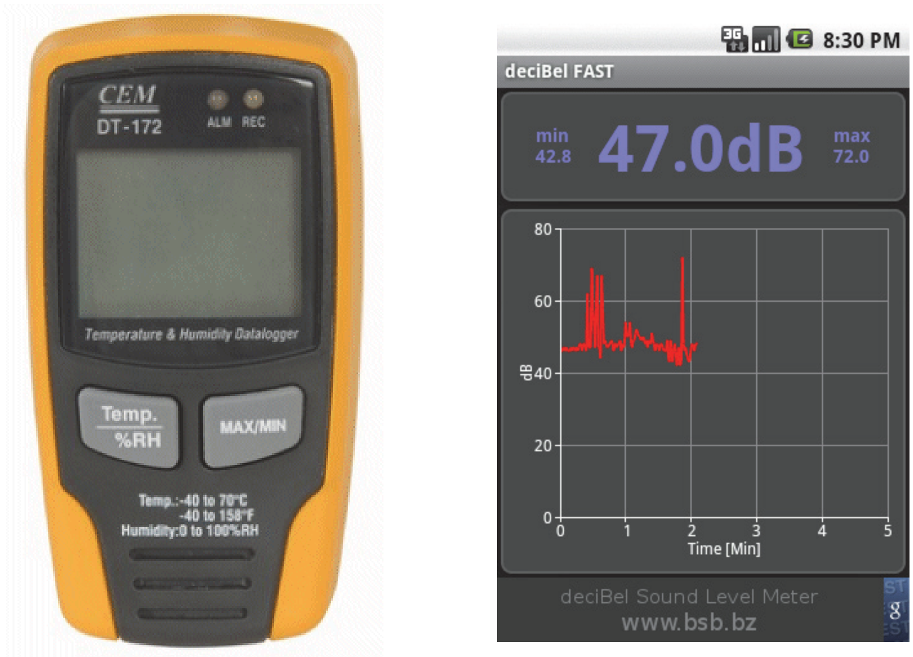


Plate 3.3: RH Temperature Data logger and DeciBel Android Application

Source: Author, 2013

The secondary data consisting of general information about the city of Amritsar, historical significance, growth and evolution of the city, land-use, gross population density across the wards, housing condition, environment, level of infrastructure, etc., is gathered from several documentary sources like the **Draft Master Plan Amritsar 2010-2031**, **City Development Plan Amritsar 2025**, The State of Cities in North-Western India: A Case of Selected JNNURM Cities - Study Focus City: Amritsar **(Sandhu and Teotia, 2013)** and earlier research done by post graduate students of Guru Nanak Dev University (GNDU), Amritsar. Maps, plans and drawings in the form of blueprints from the Municipal Town Planning Department, Amritsar; Amritsar Improvement Trust help in validating the visual surveys and observations made during the primary data collection and preparation of the final maps of the neighbourhoods under consideration. Several other reports available on the internet and articles from journals give first-hand information on several aspects of the city like Status of Sewerage Project **(MCA, 2007)** to Tourism Potential and Tourist Infrastructure **(Singh and Singh, 2007)** to Analysis of Historical Areas, Lifestyle, Values and Culture in Amritsar **(Singh, 2011)**. Similarly for Chandigarh and Gurugram in addition to site visits and primary data collection, documents like **Chandigarh Master Plan (CMP) 2031**, Alternative Urban Future Report – Urbanisation and Sustainability in India: An Interdependent Agenda **(WWF, 2010)**, books like Documenting Chandigarh: The

Indian Architecture of Pierre Jeanneret, Edwin Maxwell Fry, and Jane Beverly Drew, Vol. 1 **(Joshi, 1999)**, newspaper articles **(Polanki, 2012)**, websites etc. are referred for secondary data.

3.8.1 Calculation of Sample Size

Another important aspect of empirical studies and in particular for cause and effect studies is to calculate the sample size for data collection to derive statistically significant and meaningful estimates. The formula (from statistics) for determining the sample size is as follows:

$$\eta = (Z\sigma/E)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,

η = sample size

Z = z-boundary of interval probability

σ = standard deviation

E = standard error of mean

In this case Z is taken as ±1.96 considering 95% confidence interval and σ and E are taken from the pilot study conducted for two neighbourhoods of Amritsar as indicated in table 3.10. The values are: σ=0.349 and E=0.071. Substituting the values in equation 3,

$$\mathbf{n} = [(1.96 \times 0.349)/0.071]^2 = 92.8 \approx \mathbf{93}$$

Therefore, n = 93 or 93 samples atleast should be considered for the study. In the present study, each neighbourhood is divided into a number of study units to determine the impact of density on environmental quality. On an average 5 households per study unit from amongst total 64 study units are surveyed for primary data collection. Thus the total sample size equals 64 x 5 = 320 households which is more than the minimum sample size required and hence adequate for carrying out different statistical analyses.

After the data collection, based on the detailed visual survey land-use maps of all the neighbourhoods are prepared. Also, the study units as mentioned above are drawn on the maps of each neighbourhood. Simultaneously the raw data is sorted and tabulated in Excel Sheets as given in Annexure 2 for further study and analyses.

Table 3.10: Descriptive Statistics of ZAEQ – Amritsar as part of Pilot Study

Statistics		
ZAEQ - Katra Dullo & Ranjit Avenue, Amritsar		
N	Valid	120
	Missing	0
Mean		.0000
Std. Error of Mean		.07123
Median		-.0556
Std. Deviation		.34894
Variance		.122
Skewness		-.102
Std. Error of Skewness		.472
Kurtosis		-1.591
Std. Error of Kurtosis		.918

Source: Author, 2015

3.9 Tools for Data Analysis

Analysis means the computation of certain indices or measures along with searching for patterns of relationship that exist among the data groups. Analysis, particularly in case of survey or experimental data, involves estimating the values of unknown parameters of the population and testing of hypotheses for drawing inferences. Analysis may, therefore, be categorized as descriptive analysis and inferential analysis. Inferential analysis is often known as statistical analysis. While descriptive analysis is largely the study of distributions of one variable, inferential analysis consists of correlation analysis that studies the joint variation of two or more variables for determining the amount of correlation between two or more variables or causal analysis which is concerned with the study of how one or more variables affect changes in another variable. It is thus a study of functional relationships existing between two or more variables. This analysis is also termed as regression analysis.

In modern times, with the availability of computer facilities, there has been a rapid development of multivariate analysis which may be defined as “all statistical methods which simultaneously analyze more than two variables on a sample of observations” **(Sheth, 1971)**. The most common analysis in this category is the multiple regression analysis. This analysis is adopted when one dependent variable is presumed to be a function of two or more independent variables. The objective of this analysis is to make a prediction about the dependent variable based on its covariance with all the concerned independent variables. Thus, inferential analysis is concerned with the various tests of significance for testing hypotheses in order to determine with what validity data can be said to indicate some conclusion or conclusions. It is also concerned with the estimation of population values. It is mainly on the basis of inferential analysis that the task of interpretation (i.e., the task of drawing inferences and conclusions) is performed.

With this understanding the forthcoming work is suitably divided into three stages of analyses and subsequent derivation of results and conclusions as shown in figure 3.8. The first stage consists of collection and assimilation of primary and secondary data and preliminary findings based on comparison with threshold values. The second stage consists of ascertaining the standardized aggregated environmental quality (ZAEQ) of the neighbourhoods and formulation of the environmental quality index. The third and final stage envisages carrying out multiple hierarchical regression analysis to ascertain the significant density variables affecting neighbourhood environmental quality followed by testing of hypothesis and best-to-fit analysis to identify desirable density ranges to maintain optimum environmental quality in different residential neighbourhoods.

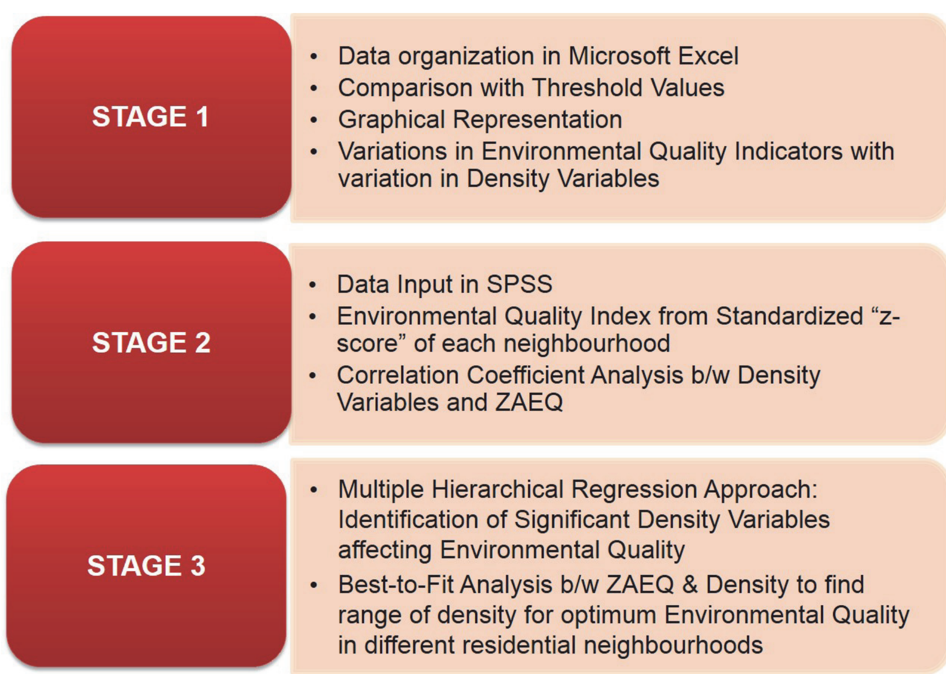


Figure 3.8: Stages of Data Analysis and Tools for Data Analysis

Source: Author's Elaboration, 2015

3.10 Concluding Remarks

The present chapter explains the research design for the present work and identifies several representative neighbourhoods from the three case study cities to explore and compare the residential pattern and neighbourhood environmental quality. The multiple case design is selected as the appropriate research strategy for the present study. Next, density is disaggregated and indicators of environmental quality at the neighbourhood level are identified. A conceptual framework showing possible correlations between density variables and indicators of environmental quality is devised and an analytical model based on the assumption that a linear function exists between the dependent and independent variables is proposed for the regression analysis. The chapter also gives a description of the types of data and methods of data collection to be adopted for the study and details out the various tools and stages of data analyses for subsequent work. Three stages are identified beginning with the organisation of data, followed by assessment of neighbourhood environmental quality and formulation of the environmental quality index and culminating with the testing of hypothesis and best-to-fit analysis to identify desirable density ranges to maintain favourable environmental quality in different residential neighbourhoods of our cities.

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Chapter Four

STUDY OF RESIDENTIAL NEIGHBOURHOODS

4.1 Introduction

The assessment of environmental quality at the neighbourhood level with respect to the density variables is the most important part of the present research. As per the case study approach several localities from the three cities namely – Amritsar, Chandigarh and Gurugram are identified to assess and compare the neighbourhood environmental quality with change in residential patterns. Before assessing the neighbourhood environmental quality, the detailed study of each of the neighbourhoods is taken up. The detailed study includes:

i. Brief overview of Amritsar
   - Choice of Residential Neighbourhoods
   - Detailed Study of the Neighbourhoods

ii. Brief overview of Chandigarh
   - Choice of Residential Neighbourhoods
   - Detailed Study of the Neighbourhoods

iii. Brief overview of Gurugram
   - Choice of Residential Neighbourhoods
   - Detailed Study of the Neighbourhoods

iv. Data Organization

v. Comparative Analysis and Preliminary Findings

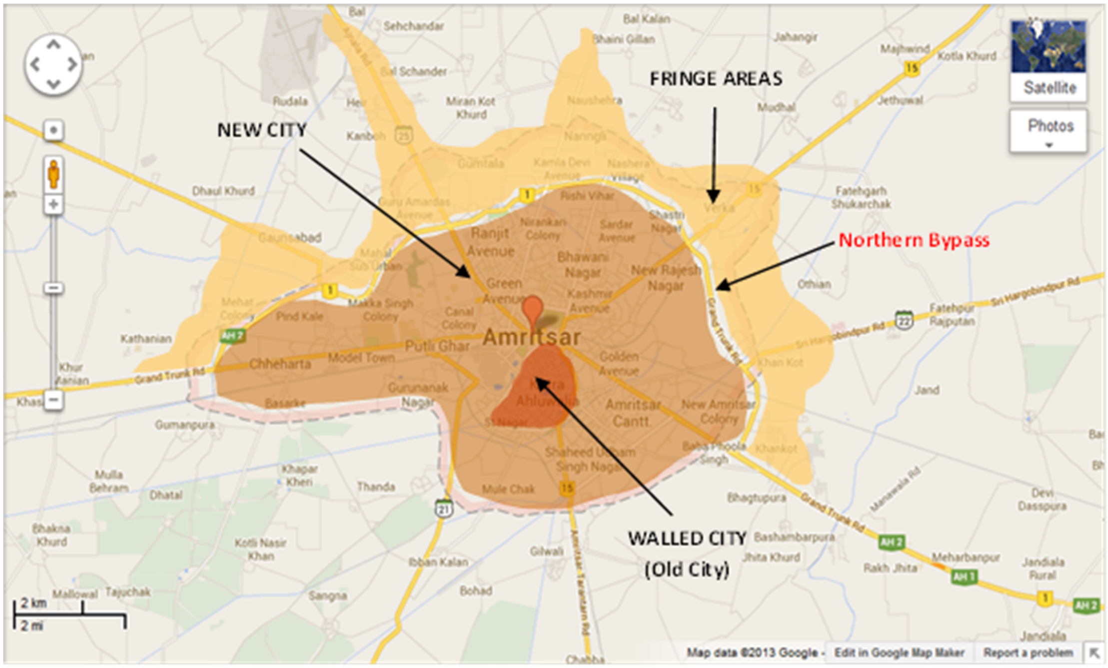
vi. Concluding Remarks

4.2 Brief overview of Amritsar

To begin with, the city of Amritsar is divided into three zones as indicated in map 4.1 and subsequently two neighbourhoods are considered for the study as indicated in map 4.2. The three zones are as described below:

a) Walled city forming the core of the city,
b) New and more cosmopolitan areas beyond the walled city and up to the northern bypass, and
c) Fringe areas comprising of newly developed and developing areas beyond the bypass as shown in the map of Amritsar.

Based on the reconnaissance survey, it is observed that the housing existing in the walled city area of Amritsar is in dilapidated or poor condition. It is characterized by age-old buildings with an average building height of G+3, 100% ground coverage with no setbacks and narrow access roads with poor mass space relationship. These areas have high intensity of development as seen in plate 4.1 **(Master Plan Amritsar 2010-2031 and Malhotra, 2013)**.

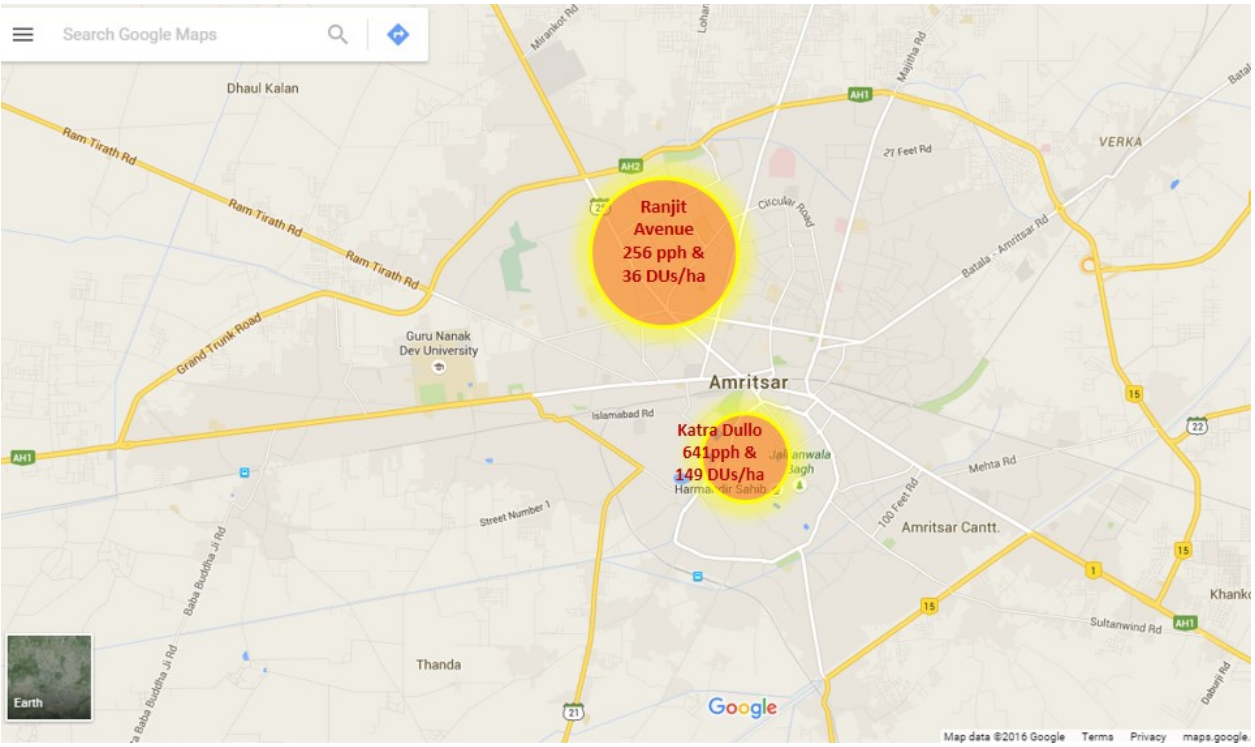


Map 4.1: Zones identified in Amritsar City

Source: www.google.com, 2013

Plate 4.1: Poor housing condition, poor mass space relationship, mesh of wires and high intensity of development in walled city Amritsar

Source: Master Plan Amritsar 2010-2031



Map 4.2: Location of Katra Dullo and Ranjit Avenue in Amritsar City

Source: www.google.com, 2013

On the contrary, the area outside the walled city and within the northern by-pass is characterized as medium density built up area with medium to good housing condition as seen in plate 4.2. The houses have 60% - 80% ground coverage depending on the plot size with mainly front and side setbacks and average building height is G+1.

Plate 4.2: Planned housing areas in Green Avenue and Ranjit Avenue, Amritsar

Source: Master Plan Amritsar 2010-2031

The peri-urban area that is outside the northern bye pass is characterized by low-density development with new approved housing colonies coming up. Increasing concentration of planned housing efforts are observed in the north of the city which has further aggravated the difference in quality of life and urban environment between the northern and southern half of the city **(Master Plan Amritsar 2010-2031)**.

4.2.1 Choice of Residential Neighbourhoods

The area of the chosen localities varies from 6 hectares to more than 100 hectares. They are selected in a way such that they are walkable and one can see and feel their distinguishing character as one moves in and around them. Also they are big enough for their particular type so as to reveal meaningful averages for comparative analysis. In Amritsar, no neighbourhood is selected from the fringe areas (as indicated in Map 4.1) identified in the city as the housing colonies are still under construction and hence uninhabited. The similar residential density patterns are considered later while studying the city of Gurugram. It is worth mentioning here that Amritsar is part of the National Heritage City Development and Augmentation Yojana (HRIDAY) scheme of Ministry of Housing and Urban Affairs, Government of India launched in 2015 to preserve and revitalise the heritage city's soul and reflect its unique character by encouraging aesthetically appealing, accessible, informative and secure environment. The scheme supports development of core heritage infrastructure projects which include revitalization of urban infrastructure for areas around heritage assets identified / approved by the Ministry of Culture, Government of India and State Governments. These initiatives also include development of water supply, sanitation, drainage, waste management, approach roads, footpaths, street lights, tourist conveniences, electricity wiring, landscaping and such citizen services. It is also part of Atal Mission for Rejuvenation and Urban Transformation (AMRUT, 2015) by the same ministry and having thrust on aspects mentioned above in all parts of the city in addition to heritage precincts/areas. In line with the above, the present study looks at almost all of the above mentioned aspects to assess neighbourhood environmental quality and pave the way for future sustainable development in Class-I Indian cities.

4.2.1.1 Brief Background of the Case Study Neighbourhoods of Amritsar

- **Katra Dullo**, Ward No. 5 is selected as a representative locality within the walled city. It lies in the north-western part of the walled city. The locality is marked predominantly by residential land use, narrow and organic streets/lanes, and dilapidated structures with low light and ventilation. It has one of the highest gross population density of 641 persons per hectare within the walled city. The ‘KATRA’ or the neighbourhood consisting of several clusters of houses around a cul-de-sac forms the basic module of all the wards in the walled city as seen in map 4.3.

- **Ranjit Avenue**, Ward No. 43 near the northern bypass is selected from the new city for the study purpose. It is defined by the Grand Trunk or northern bypass on the north, Circular Road on the eastern and southern side and Ajnala Road on the western side as seen in Key Plan in map 4.2. The grid iron pattern in the ward is representative of a typical planned neighbourhood with approximately 256 persons per hectare gross density. It is characterized by straight avenues and plotted development of row houses on either side interspersed with neighbourhood parks, playground, market place and other public facilities and amenities as seen in map 4.4.

4.2.2 Detailed study of the Neighbourhoods

4.2.2.1 Katra Dullo, Amritsar – Low Rise High Density Neighbourhood (LRHD)

Katra Dullo, a low rise high density neighbourhood is divided into 12 units for study and analyses as indicated in figure 4.1. Poor housing condition; poor built to open space relationship and high intensity of development with 149DUs/hectare characterize Katra Dullo. Most of the buildings are in bad condition and require immediate maintenance as seen in plate 4.3. Most buildings are G+2 storeyed and have 100% plot coverage. There are no open spaces for the community or playgrounds for the children except for the squares which are meagre in number and unmaintained. Greenery is almost absent. Roads are narrow and congested. They are so narrow (1.2-1.5m) that vehicular traffic is restricted in the inner parts. Additionally, garbage dumps, absence of sidewalks, on-street parking of two-wheelers make walking an unpleasant experience.

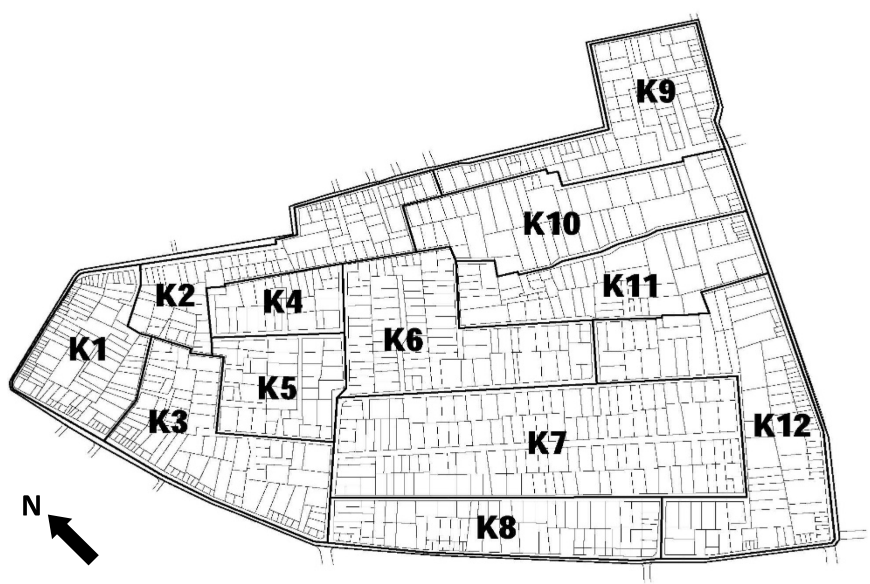


Figure 4.1: Study Units, Katra Dullo, Amritsar

Source: Author, 2013

Residential

- Katra Dullo occupies a total area of 15.5 acres out of which 64% of the area is occupied by residential land use which shows that the area is mainly residential in nature.
- The plots are of irregular sizes varying from 24 sq.yds. (20 sqm.) to 80 sq.yds (67 sqm.). All the houses are arranged in back to back manner having problem of light and ventilation.

Mixed Use

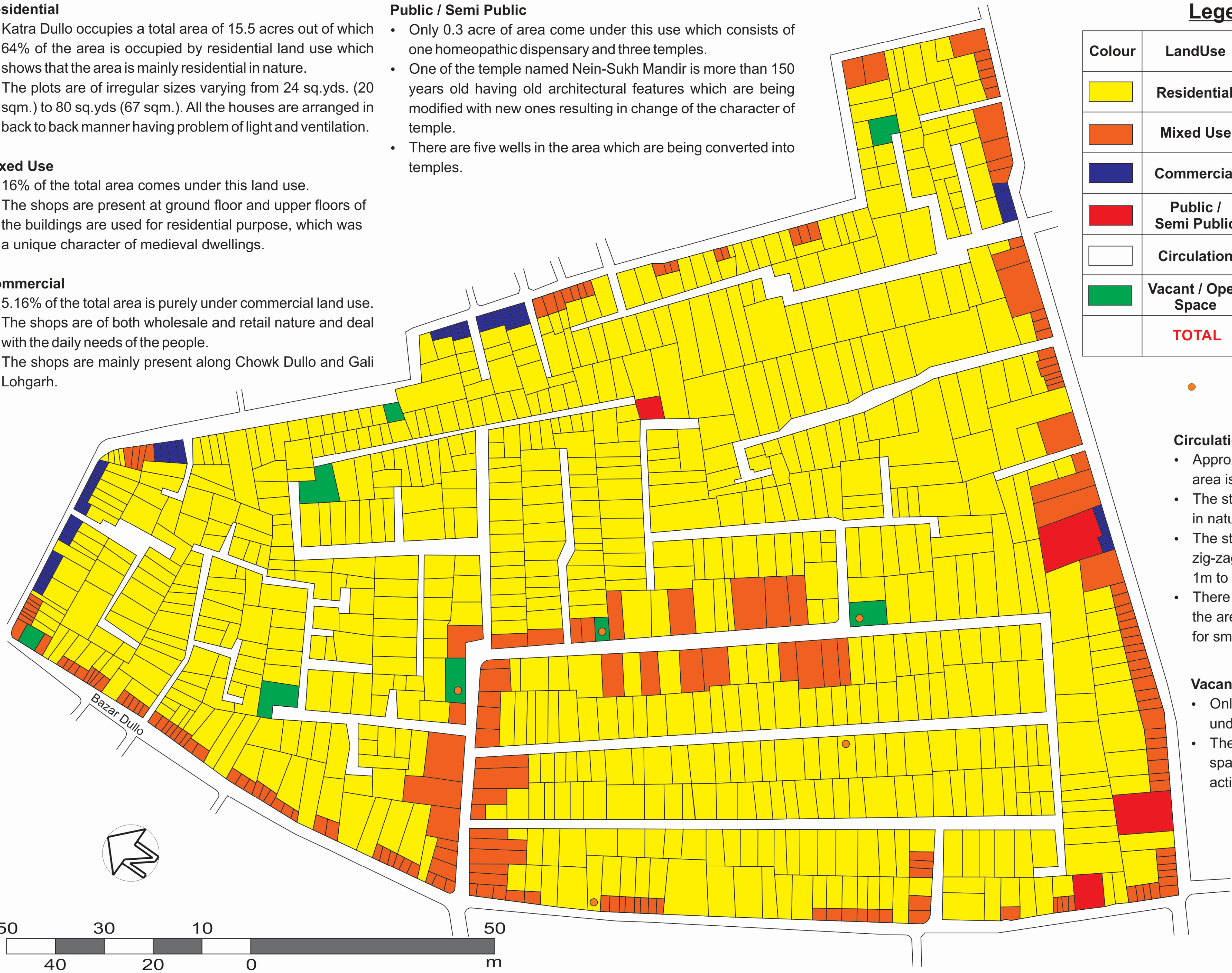
- 16% of the total area comes under this land use.
- The shops are present at ground floor and upper floors of the buildings are used for residential purpose, which was a unique character of medieval dwellings.

Commercial

- 5.16% of the total area is purely under commercial land use. The shops are of both wholesale and retail nature and deal with the daily needs of the people.
- The shops are mainly present along Chowk Dullo and Gali Lohgarh.

Public / Semi Public

- Only 0.3 acre of area come under this use which consists of one homeopathic dispensary and three temples.
- One of the temple named Nein-Sukh Mandir is more than 150 years old having old architectural features which are being modified with new ones resulting in change of the character of temple.
- There are five wells in the area which are being converted into temples.



Legend

Colour	LandUse	Area (in acres)	%
	Residential	10.4	64.00 %
	Mixed Use	2.6	16.11 %
	Commercial	0.8	5.16 %
	Public / Semi Public	0.3	1.93 %
	Circulation	1.3	8.38 %
	Vacant / Open Space	0.1	0.64 %
	TOTAL	15.5	100

Well

Circulation

- Approximately 8% of the total area is under circulation.
- The street pattern is irregular in nature.
- The streets are narrow and zig-zag in nature varying from 1m to 5m in width.
- There are 32 dead ends in the area which do not allow for smooth flow of traffic.

Vacant / Open Spaces

- Only 0.1 acre land comes under this land use.
- There is only one open space along Bazar Dullo, acting as a market square.

Map 4.3: Land-use Map of Katra Dullo, Amritsar

Residential

- Ranjit Avenue (Block A and Block B) occupies a total area of 180.74 acres approx.
- Area under District Shopping Center occupies 54.59 acres (refer key plan).
- Hence, planned neighbourhood occupies an area of 126.15 acres out of which 47% of the area is occupied by residential land use which shows that the area is mainly residential in nature.
- The plots are of regular shape and size. The different size of the plots are 4marlas (100 sqm.), 6marlas (150 sqm.), 8marlas (200 sqm.), 10marlas (250 sqm.) and 1kanal (500sqm.).
- The plots are arranged in a systematic manner (pinwheel arrangement) to give a regular pattern of development in the form of row and semi-detached houses.

Mixed Use

- Approximately only 1% of the total area comes under this land use indicating that most residents (60%) are economically well-off and have separate business establishments in the commercial areas of the city. Others are engaged in the service sector.
- Generally small outlets are present on some portion of the ground floor abutting the road of some 4marla and 6marla houses and garages of flatted development. The rest of the ground floor and upper floors of the buildings are used for residential purposes.

Commercial

- 4.08% of the total area is under commercial land use.
- The neighbourhood shopping centre consisting of double storeyed shops (DSS) and booths occupies 4.82 acres.
- The shops are mainly retail in nature and deal with the daily needs of the people. Some of the upper floors of the DSSs' are functioning as health clinics, coaching centres, etc.
- Booth markets specialize as eating outlets serving popular local cuisines.
- Some informal markets (greengrocers, cycle-scooter repair, food carts and kiosks etc.) also form part of the commercial area.
- Another convenience shopping consisting of booths is located in Block B and occupies little less than 0.5 acre area.

Public / Semi Public

- 12.6% or 15.91 acres of area comes under this use which consists of one private hospital, some area reserved for public works, two pre-primary schools, two primary schools and two high schools.
- However, there are no religious buildings or community buildings in the locality.

Circulation

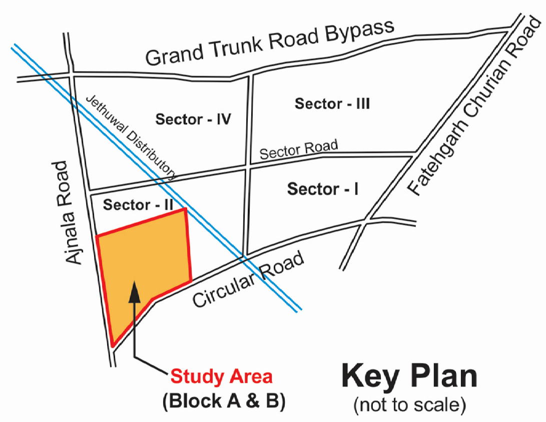
- Approximately 27% of the total area is under circulation.
- The road pattern is regular in nature. All roads are metal paved and well maintained.
- The width varies from 60'-80' (18-25m) for primary roads, 30' (10m) for secondary roads and 20' (6m) for tertiary roads.

Open Spaces / Green Belt

- 8.80 acres or approximately 7% of the area is occupied by well maintained parks and open spaces.
- The parks are furnished with furniture, lights, swings, paved pathways etc.
- The parks are used in the evening for playing and social interaction.
- Indigenous trees are abundantly planted in the parks and green belts of the neighbourhoods.

Buildings to be Retained

- About 2.04 acres area is left untouched in the locality as they consist of some old buildings (residential in nature) that are to be preserved for their architectural heritage.



Key Plan
(not to scale)

Legend

Colour	Landuse	Area (in acres)	%
Yellow	Residential	59.27	46.98
Orange	Mixed Use	0.98	0.77
Blue	Commercial	5.15	4.08
Red	Public / Semi Public	15.91	12.6
White	Circulation	34.00	26.9
Green	Open Space/ Green Belt	8.80	6.97
Brown	Buildings to be Retained	2.04	1.61
	TOTAL	126.15	100

Map 4.4: Land-use Map of Ranjit Avenue, Amritsar

Plate 4.3: Poor Condition of Buildings, Katra Dullo, Amritsar

Source: Author, 2014

The level of services is also poor. Domestic waste is disposed on the roads and inspite of door to door collection filthy conditions prevail. Only 30% dwelling units are connected to the underground sewerage system. Open storm water drains run on both sides of the streets. Most drains are choked with solid waste leading to water logging and insanitary conditions in certain areas as seen in plate 4.4. The neighbourhood however has low average noise levels of 50dB because of the absence of vehicles. Shops catering to daily requirements are in close proximity for the residents of the locality.

Plate 4.4: Garbage Dumps, Open Drains, Congested Roads and Scanty Tree Cover, Katra Dullo, Amritsar

Source: Author, 2014

4.2.2.2 Ranjit Avenue, Amritsar – Low Rise Medium Density Neighbourhood (LRMD)

Ranjit Avenue is also divided into 12 units for detailed study as indicated in figure 4.2. This is an example of a low rise medium density planned neighbourhood found in many modern Indian cities as seen in plate 4.5. The neighbourhood consists of different sizes of plots arranged in a pinwheel arrangement around a central open space as seen in map 4.4. The residential density is around 36DUs/hectare. Roads are wide, well maintained and shaded as seen in plate 4.7. Trees are also found in abundance (tree cover=49%) in the open spaces of the neighbourhood.

Plate 4.5: Plotted Development and View of Park, Ranjit Avenue, Amritsar

Source: Author, 2014

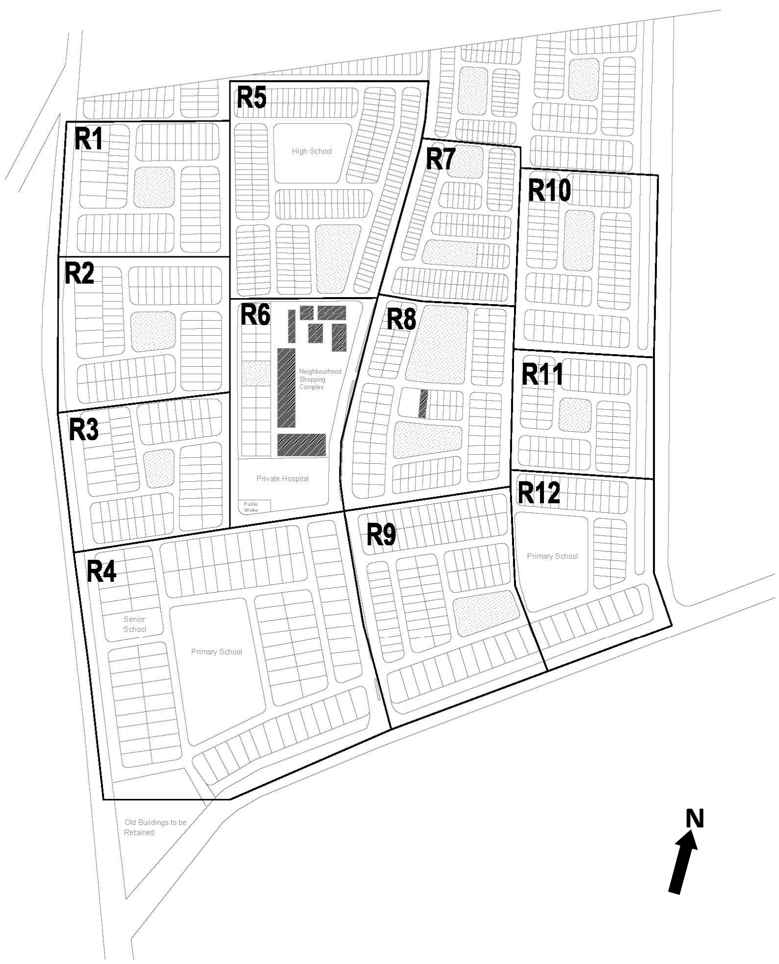


Figure 4.2: Study Units, Ranjit Avenue, Amritsar

Source: Author, 2013

Most (75%) of the buildings are G+1 storeyed on varying plot sizes (1Kanal=500sqm, 10Marla=250sqm, 8Marla=200sqm and 6Marla=150sqm approximately) except for the flatted developments restricted to two pockets that are G+2 and G+3 storeyed high (constituting 13% and 2% of the building stock) as seen in plate 4.6. The level of infrastructure and services is fairly well. Door to door collection of domestic waste and sweeping of the roads is done on a daily basis. Garbage disposal points are located at suitable distances along boundary walls of the plots for collecting street garbage as seen in plate 4.8.

Plate 4.6: Types of Plots and Residential Buildings, Ranjit Avenue, Amritsar

Source: Author, 2014

Plate 4.7: Condition of Roads and Sidewalks, Ranjit Avenue, Amritsar

Source: Author, 2014

The formal and informal markets within a radius of 0.5km serve the daily needs of the residents as seen in plate 4.9. The noise levels in the locality are somewhat high (average – 65dB). On-street parking causes some congestion in the internal streets. Overall, Ranjit Avenue has good facilities. Certain study units have higher air pollution and noise levels due to use of DG sets, air conditioning units and traffic especially coming to the commercial areas. The key features of both the neighbourhoods are summarised in table 4.1, figure 4.3 and figure 4.4.

Plate 4.8: Level of Infrastructure and Services, Ranjit Avenue, Amritsar
Source: Author, 2014

Plate 4.9: Types of Commercial Establishments, Ranjit Avenue, Amritsar

Source: Author, 2014

Table 4.1: Key Features of Case Study Neighbourhoods, Amritsar

Brief Description of the Neighbourhoods	
Katra Dullo	**Ranjit Avenue**
The neighbourhood covers an area of about 6 hectares. Organic form, poor housing condition, poor built to open space relationship and high intensity of development characterize Katra Dullo.	It covers an area of about 50 hectares. It is a planned neighbourhood located in the new part of the city outside the walled area. It is characterized by straight avenues and plotted development of row houses.
Population Density	
641pph	**256pph**
Residential Density	
149DUs/ha	**36DUs/ha**

Table 4.1 (contd.): Key Features of Case Study Neighbourhoods, Amritsar

Katra Dullo	Ranjit Avenue
Residential Pattern	
LRHD	**LRMD**
Most buildings are G+2 storeyed and have 100% plot coverage. Many of them are in a dilapidated condition.	Most of the buildings are G+1 storeyed on varying plot sizes except for the flatted developments restricted to two pockets that are G+2 and G+3 storeyed.
Plot Sizes	
The plots are irregular in shape and size varying from 20sqm to 67sqm approximately. All the houses are arranged in back to back manner having problem of light and ventilation.	It is a planned neighbourhood that consists of different sizes of plots (1Kanal=500sqm, 10Marla=250sqm, 8Marla=200sqm and 6Marla=150sqm) arranged in a pin-wheel arrangement around a central open space.
Open Spaces	
There are no open spaces for the community or playgrounds for the children except for the small and unmaintained squares. Greenery is almost absent.	Parks and playgrounds are maintained. Trees like neem, jamun, devil tree are found in the open spaces of the neighbourhood.
Roads and Sidewalks	
Roads are narrow (1.2-1.5m in the inner parts) and congested. Additionally, garbage dumps, absence of sidewalks, on-street parking of two-wheelers make walking an unpleasant experience.	Roads are wide, well maintained and shaded. However sidewalks are discontinuous or absent in some places. On-street parking causes congestion.
Level of Services	
The level of services is also poor. Domestic waste is disposed on the roads. Choked open drains create insanitary conditions. Only 30% DUs are connected to sewerage system.	The level of infrastructure and services is fairly well. Door to door collection of waste and road sweeping is done on daily basis.
Miscellaneous	
Shops catering to daily requirements are in close proximity for the residents of the locality. Overall condition of infrastructure and services is quite poor in Katra Dullo.	All daily need items are available in near proximity within a radius of 0.5km. Ranjit avenue has overall good facilities.

Source: Author, 2014

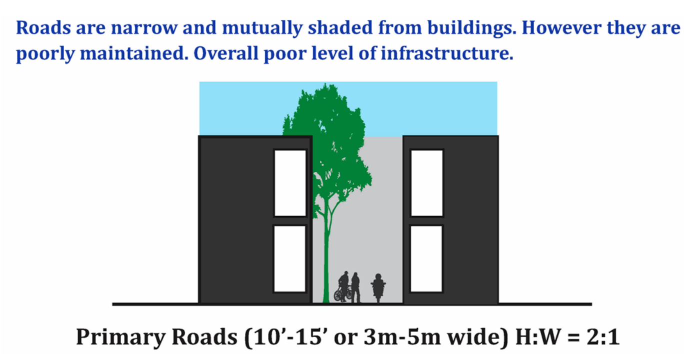
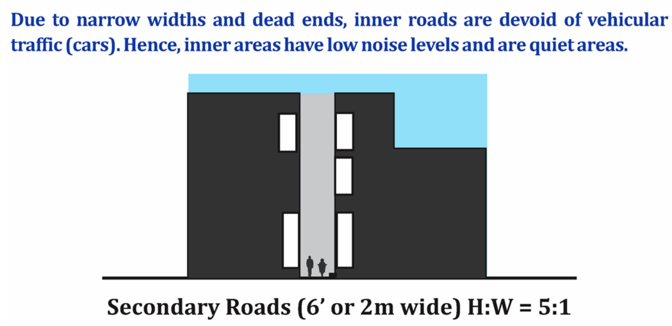


Figure 4.3: Typical Section, Katra Dullo, Amritsar

Source: Author, 2013



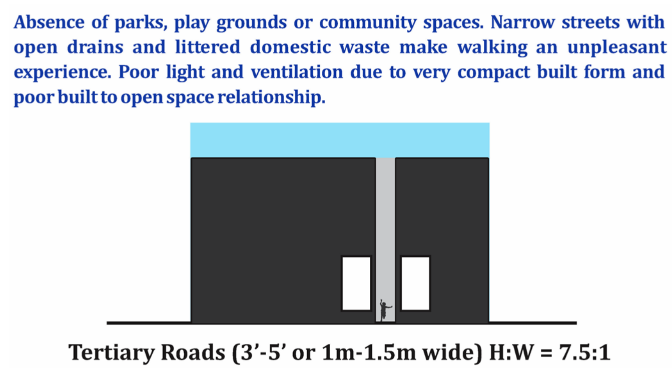
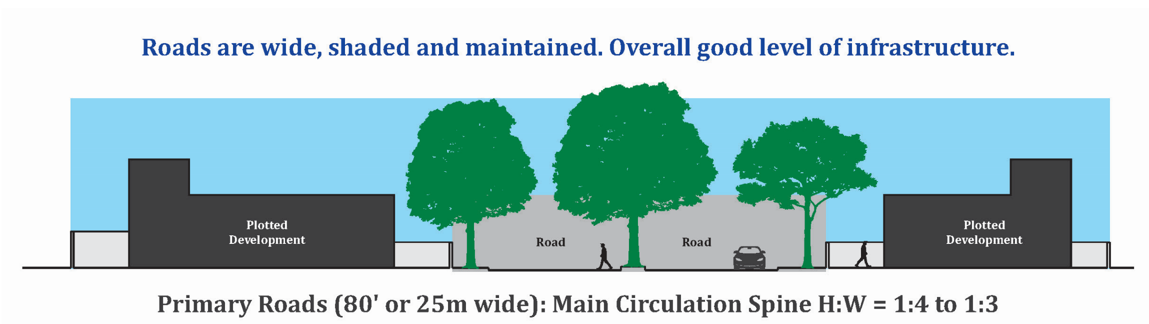


Figure 4.3 (contd.): Typical Sections, Katra Dullo, Amritsar

Source: Author, 2013



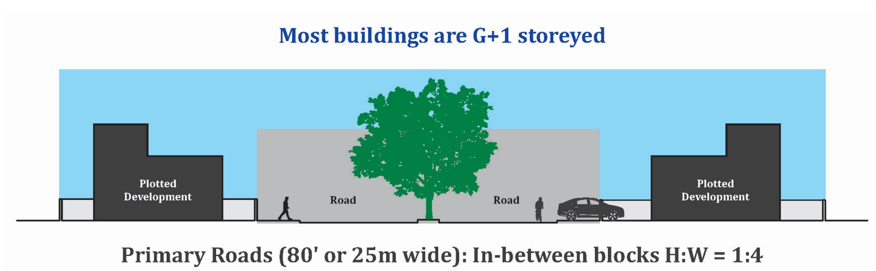
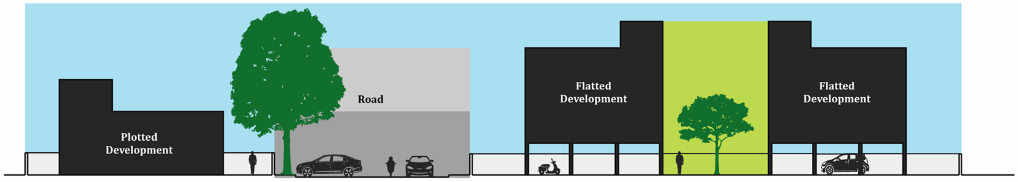


Figure 4.4: Typical Sections, Ranjit Avenue, Amritsar

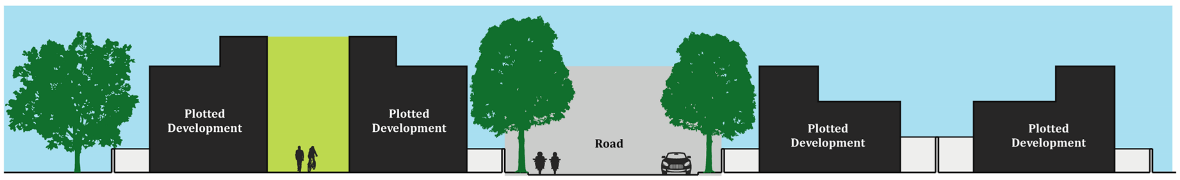
Source: Author, 2013

Flatted development in few pockets is G+2 & G+3 storeyed. On-street parking causes congestion in internal roads,



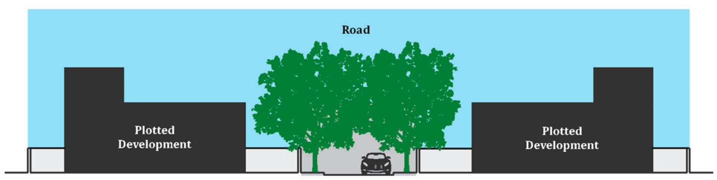
Secondary Roads (60' or 20m wide): In-between two clusters H:W = 1:3 to 1:1.5

H:W between buildings vary from 1:1 to 1:4 thus permitting natural light into the buildings.



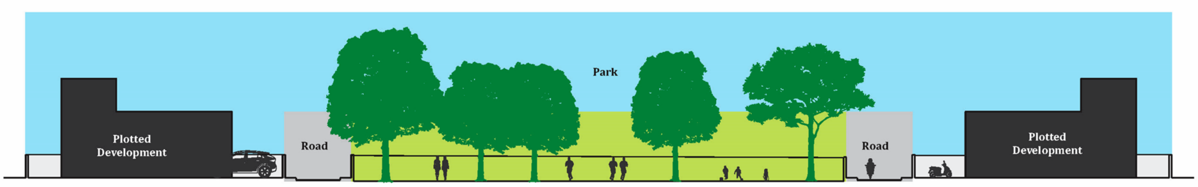
Secondary Roads (60' or 20m wide): In-between two clusters H:W = 1:2

Tertiary roads are shady thus providing comfortable environment for users.
However sidewalks are discontinuous and occupied by street hawkers and littered garbage occasionally.



Tertiary Roads (30' or 10m wide): In-between two clusters H:W = 1:1.6

Parks and playgrounds are maintained and used for playing and social interaction.
Shady trees like neem, jamun, devil tree are found in the open spaces of the neighbourhood.
They regulate the micro-climate, absorb air pollutants and reduce noise levels.



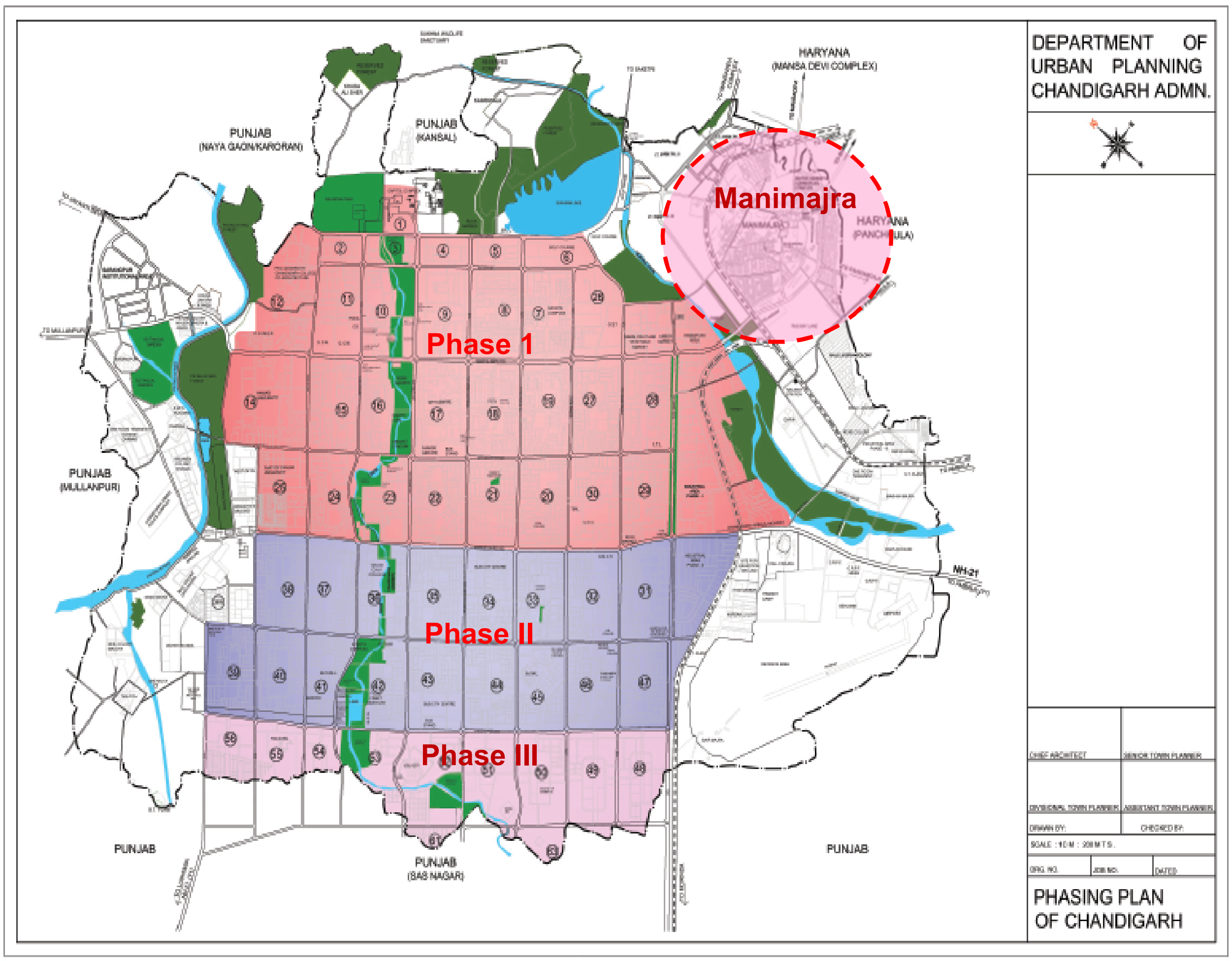
Tertiary Roads (20' or 6m wide): Within a cluster with a central open space (H:W = 1:1)

Figure 4.4 (contd.): Typical Sections, Ranjit Avenue, Amritsar

Source: Author, 2013

4.3 Brief overview of Chandigarh

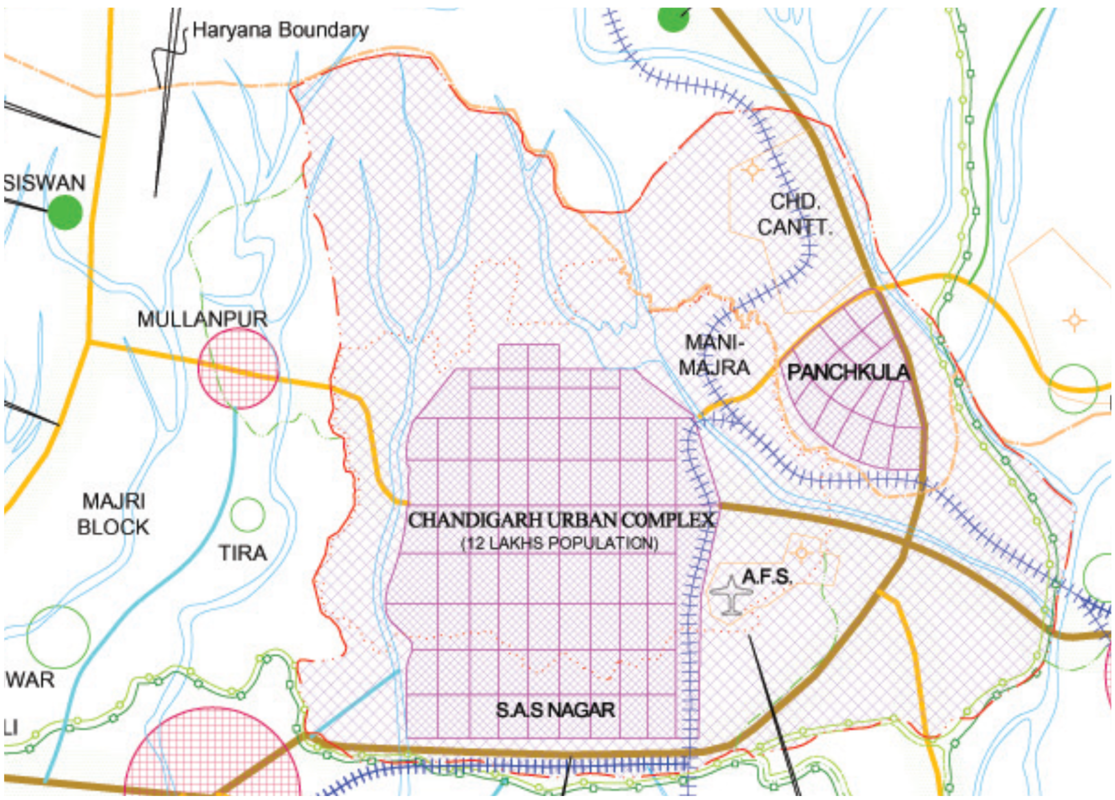
The union territory of Chandigarh was initially planned for a population of 500,000 spread out over an area of 70 sq. km. The first phase (sectors 1-30) of the city had low density low rise houses with residential plots ranging from 5 Marla (125 sqm) to 8 Kanals (4000 sqm). The second phase (sectors 31-47) had much higher density with three to four storey flats and largest plot size being 2 Kanals (1000 sqm). As the population went on increasing, to augment the housing stock additional residential sectors in the third phase and Manimajra (land falling between Chandigarh Kalka Road and the interstate boundary with Panchkula) was planned for construction of residential cum commercial areas as seen in map 4.5.



Map 4.5: Phasing Plan of Chandigarh

Source: Chandigarh Master Plan - 2031

However, Chandigarh with an area of 114 sq. km offered very limited land for future development. Due to limited scope for horizontal growth, it became obvious that to accommodate the future requirement, the development required to be vertical. However, keeping in view the overall architectural ambience of the city, it was also essential to prepare the Master Plan to not only accommodate future requirements but also strike a balance between the built and natural environment. Hence, considering the inevitable in-migration to the city and large scale developments in the peripheral areas and satellite towns, the Chandigarh Master Plan 2031 was formulated. It intrinsically linked the development of Chandigarh with the periphery and the satellite towns of Panchkula and Mohali or SAS Nagar **(TCPO, 2011)**. The entire area subsequently came to be known as the Chandigarh Urban Complex or CUC as shown in map 4.6.[24]



Map 4.6: Chandigarh Urban Complex (CUC)

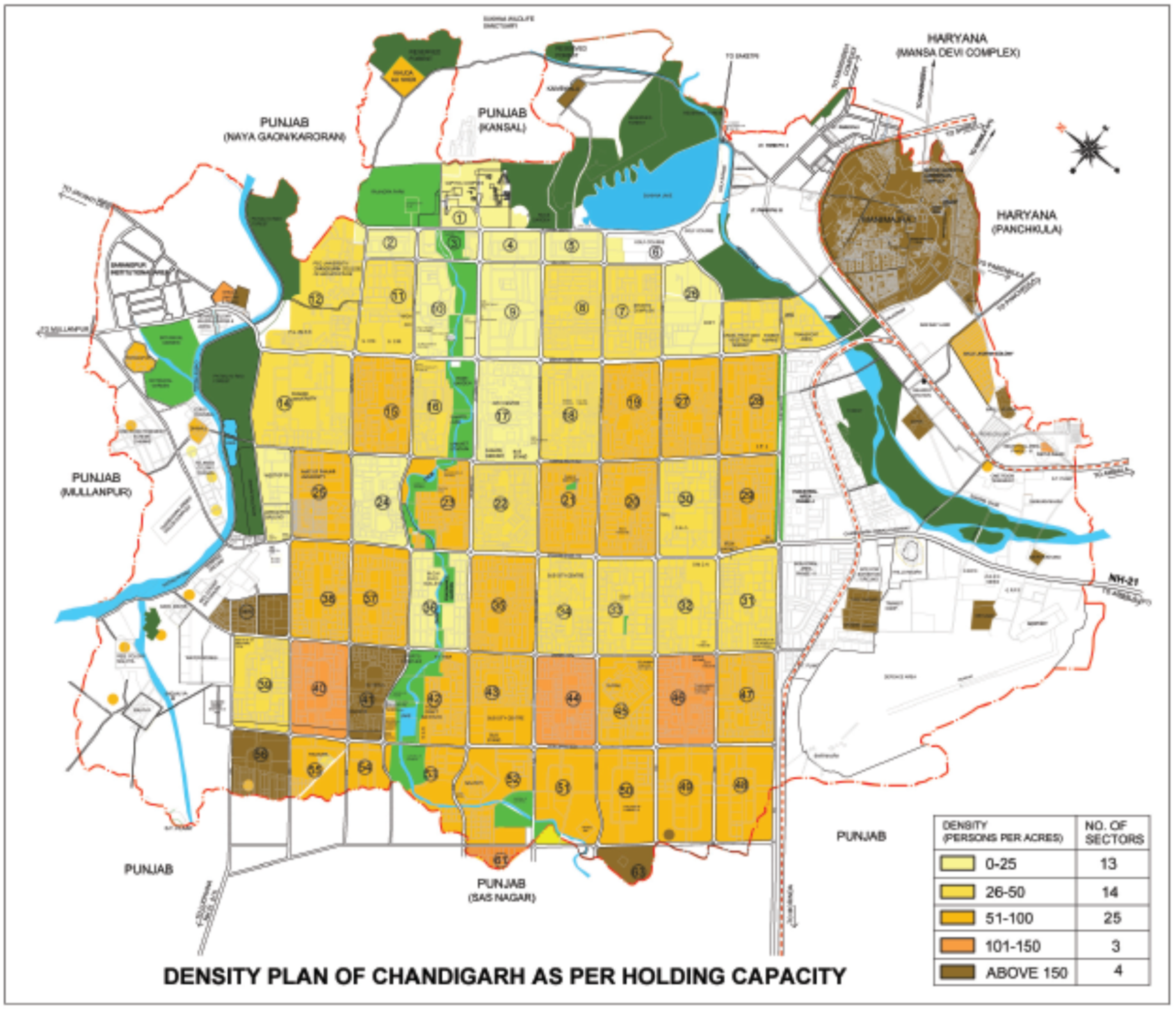
Source: Chandigarh Master Plan - 2031

24 Annexures, Chandigarh Master Plan – 2031. [online] Available at: http://chandigarh.gov.in/cmp2031/mp-area.pdf [Accessed 14 June 2012].

4.3.1 Choice of Residential Neighbourhoods

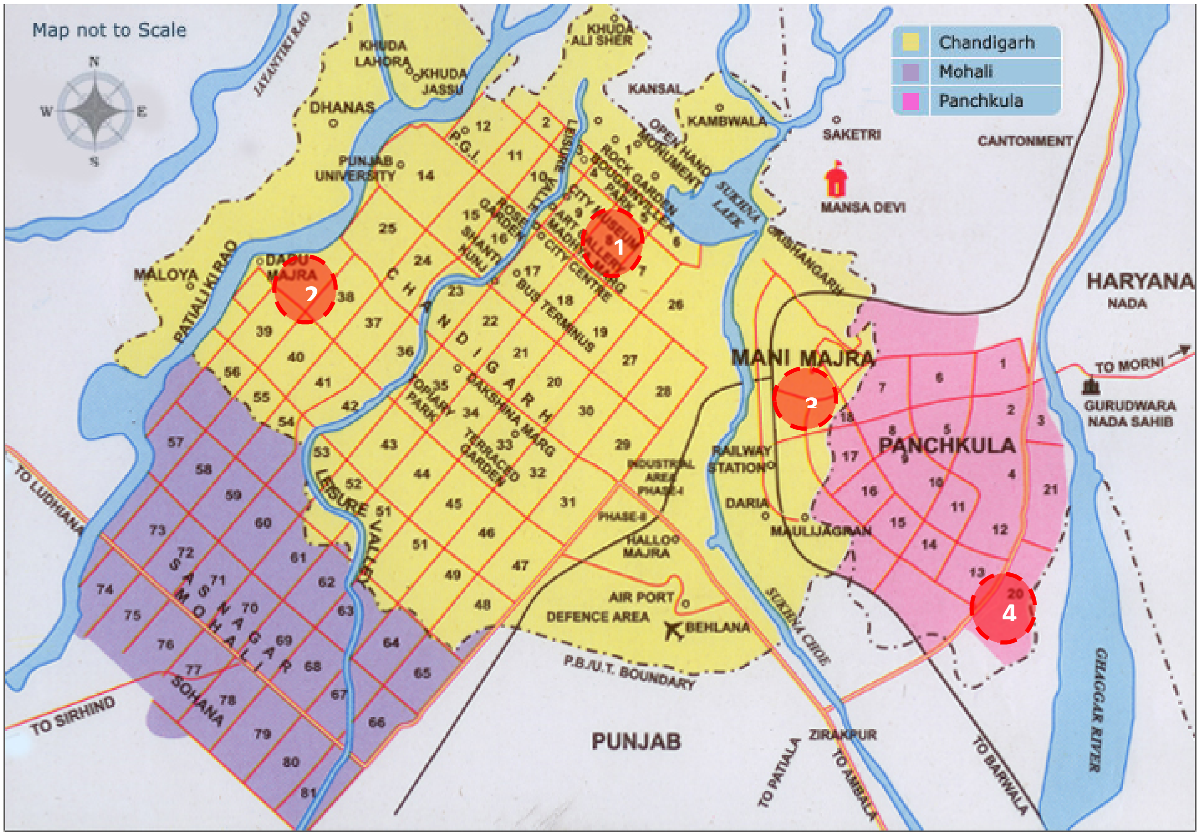
For the present study, as per the Phasing Plan (map 4.5), Density Plan (map 4.7) and Map of Tri-City, four residential localities with different density patterns as compared to Amritsar are identified for detailed study and analyses as seen in map 4.8. The neighbourhoods are as follows:

1. Low Rise Low Density (LRLD) – Sector 8, Chandigarh
2. Low Rise High Density (LRHD), Planned – Sector 38 West, Chandigarh
3. Medium Rise Medium Density (MRMD) – Marble Arch Apartments, Manimajra
4. Medium Rise High Density (MRHD) – Group Housing, Sector-20, Panchkula



Map 4.7: Gross Population Density Plan of Chandigarh City

Source: Chandigarh Master Plan - 2031



Map 4.8: Map of Tri-City with Identified Neighbourhoods

Source: http://carsonkolbergindia.blogspot.in/2011/06/about-chandigarh-and-tri-city.html

4.3.2 Detailed study of the Neighbourhoods

The reconnaissance survey shows that sectors of Chandigarh are planned according to the neighbourhood concept and as per the V7 system of roads laid down by French Architect Le Corbusier. The area of the chosen localities varies from 35 hectares to 105 hectares. They generally have low rise structures varying from single storey to G+3 buildings with metalled roads, neighbourhood parks, open spaces, greenery and overall services as seen in plate 4.10. On the other hand, the newly developing peripheral areas like Manimajra and satellite cities like Panchkula and Mohali constituting the Chandigarh Urban Complex (CUC) in addition to the low rise structures have medium and high rise structures coming up in recent years. These gated communities and group housing societies range from 2 hectares to 130 hectares – the latter forming whole sectors in some places and are characterised by apartment blocks, community open spaces, shared facilities and amenities as seen in plate 4.11. The Chandigarh/Panchkula Municipal Corporation looks after the sectors whereas inside the gated communities residents' welfare associations are responsible for upkeep and maintenance.

Plate 4.10: Low Rise Structures, Old Sectors, Chandigarh

Source: Author, 2015

Plate 4.11: Medium Rise Structures, New Areas, Chandigarh Urban Complex

Source: Author, 2015

The land-use maps 4.9, 4.10, 4.11 and 4.12 in the following pages give a snap shot of the typical features of the different neighbourhoods. The four neighbourhoods are divided into smaller units for detailed survey and analyses as indicated in figures 4.5, 4.6, 4.7 and 4.8.

Commercial

- 4.6% of the total area is under commercial land use.
- The shopping centre along Madhya Marg consists of double storeyed SCOs (Shop cum Offices) and occupies 9.15 acres.
- The shops are mainly retail in nature. Some of the upper floors of the SCOs' are functioning as diagnostic centres, smart offices, coaching centres, insurance and banking activity, etc.
- The neighbourhood shopping consists of SCFs (shop cum flats) and covers an area of about 3 acres.
- These shops cater to the daily needs of the residents of the sector.
- Some informal markets (greengrocers, cycle-scooter repair, food carts and kiosks etc.) also form part of the commercial area.

Public / Semi Public

- 11% or 28.7 acres of area comes under this use which consists of a Govt. Dispensary, some area reserved for public works, grid substation, community centre and club, one pre-primary school, two senior secondary schools and womens' hostel.
- A temple and gurudwara form important landmark buildings of the neighbourhood.

Circulation

- Approximately 17% of the total area is under circulation.
- The road pattern is in a grid form. All roads are metal paved and well maintained.
- The V2 and V3 roads define the sector while the V4, V5 and V6 form the internal roads of the sector.
- The width varies from 60'-80' (18-25m) for primary roads, 40'-45' (13m) for secondary roads and 30'-35'(10m) for tertiary roads.

Open Spaces / Green Belt

- 23.6 acres or approximately 9% of the area is occupied by parks and open spaces.
- The parks lack maintenance.
- However they are used to some extent for playing and social interaction.
- Indigenous trees are abundantly planted in the parks, along roads and green belts of the neighbourhood.

Residential

- Sector 8 occupies a total area of 260.8acres approx.
- It is planned based on Albert Mayer's plan in a grid of 1200m x 800m.
- 58.3% of the area is occupied by residential land use which shows that it is a residential neighbourhood.
- The plots are of regular shape and size. The different size of the plots are 5marlas (126 sqm.), 8marlas (200 sqm.), 10marlas (250 sqm.), 16marlas (400sqm.), 1kanal (500sqm.) to 5kanal (2500sqm.).
- The plots are arranged in a systematic manner to give a regular pattern of development in the form of row and detached houses.

Mixed Use

- Approximately only 1.5-2% of the total area comes under this land use indicating that most residents are economically well-off and have separate business establishments in the commercial areas of the city. Others are engaged in the service sector.
- Generally small outlets/offices/clinics etc. are present on the ground floor. The rest of the ground floor and upper floors of the houses are used for residential purposes.

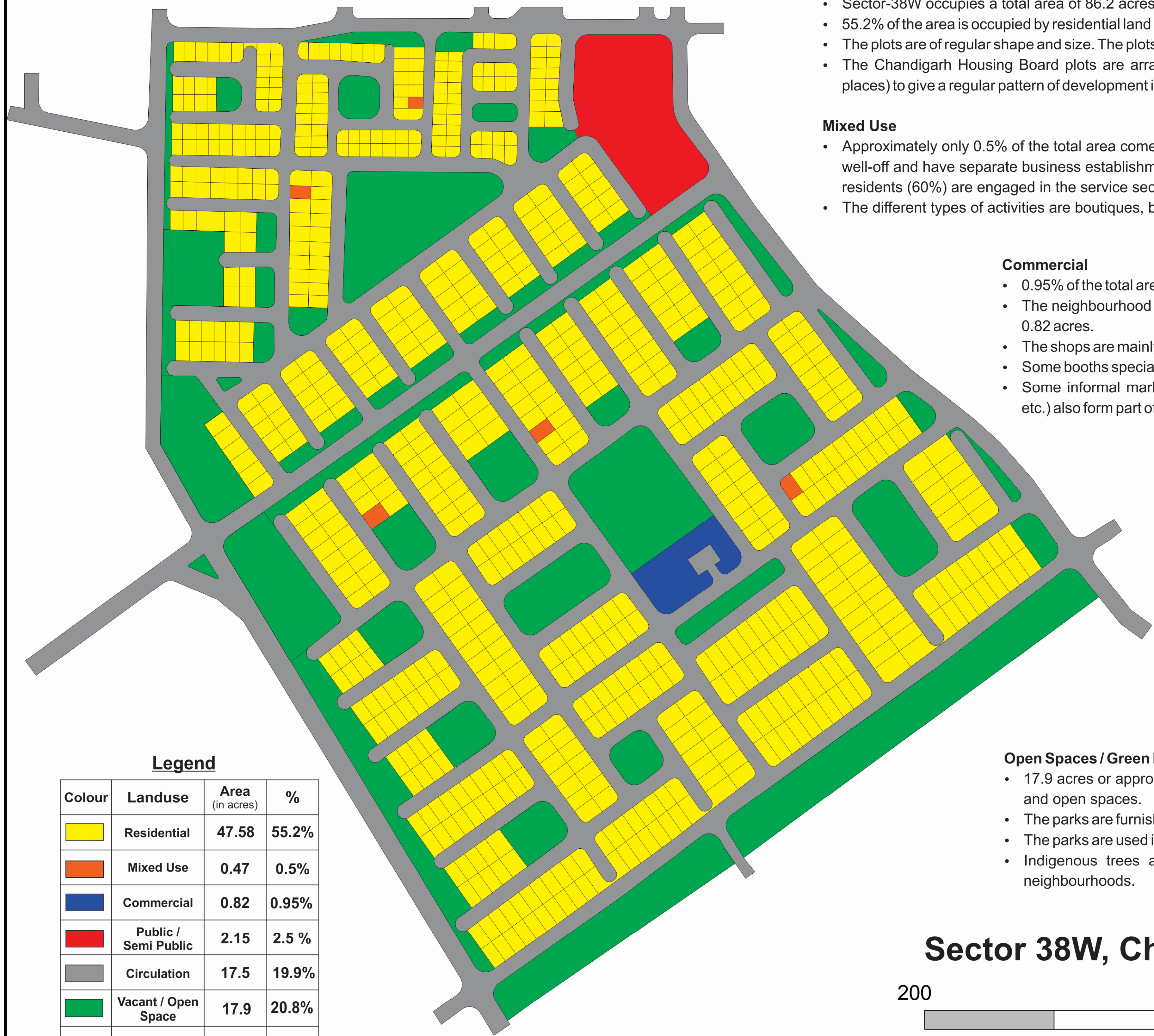
Legend

Colour	Landuse	Area (in acres)	%
Yellow	Residential	148.96	57.1 %
Orange	Mixed Use	3.04	1.2%
Blue	Commercial	12	4.6%
Red	Public / Semi Public	28.7	11%
Grey	Circulation	44.5	17.1%
Green	Vacant / Open Space	23.6	9%
	TOTAL	260.8	100

Sector 8
Chandigarh

200 0 200 m
100

Map 4.9: Land-use Map of Sector-8, Chandigarh



Residential
- Sector-38W occupies a total area of 86.2 acres approx.
- 55.2% of the area is occupied by residential land use which shows that the area is mainly residential in nature.
- The plots are of regular shape and size. The plots are 8marlas (200 sqm.) and 10marlas (250 sqm.) in size.
- The Chandigarh Housing Board plots are arranged in a systematic manner (pinwheel arrangement at some places) to give a regular pattern of development in rows of three storeyed apartments.

Mixed Use
- Approximately only 0.5% of the total area comes under this land use indicating that residents are economically well-off and have separate business establishments in the commercial areas of the city. Most of the other residents (60%) are engaged in the service sector.
- The different types of activities are boutiques, beauty parlours, coaching centers etc.

Commercial
- 0.95% of the total area is under commercial land use.
- The neighbourhood shopping (convenience shopping) consisting of booths occupies 0.82 acres.
- The shops are mainly retail in nature and deal with the daily needs of the people.
- Some booths specialize as eating outlets serving popular local cuisines.
- Some informal markets (greengrocers, cycle-scooter repair, food carts and kiosks etc.) also form part of the commercial area.

Public / Semi Public
- 2.5% or 2.15 acres of area comes under this use which consists of one high school.
- There is also an important Gurudwara - religious building of the Sikh community and oil filling station located within a distance of 1km from the neighbourhood.

Circulation
- Approximately 19.9% of the total area is under circulation.
- The road pattern is regular in nature. All roads are metal paved and well maintained.
- There is some problem of congestion due to haphazard parking at the dead ends.
- The width varies from 10m - 15m (33' - 50').

Open Spaces / Green Belt
- 17.9 acres or approximately 20.8% of the area is occupied by well maintained parks and open spaces.
- The parks are furnished with furniture, lights, swings, paved pathways etc.
- The parks are used in the evening for playing and social interaction.
- Indigenous trees are abundantly planted in the parks and green belts of the neighbourhoods.

Sector 38W, Chandigarh

N

200 0 200 m
100

Legend

Colour	Landuse	Area (in acres)	%
	Residential	47.58	55.2%
	Mixed Use	0.47	0.5%
	Commercial	0.82	0.95%
	Public / Semi Public	2.15	2.5 %
	Circulation	17.5	19.9%
	Vacant / Open Space	17.9	20.8%
	TOTAL	86.2	100

Map 4.10: Land-use Map of Sector-38W, Chandigarh

Legend

Colour	Landuse	Area (in acres)	%
Yellow	Residential	2.16	40 %
Orange	Mixed Use	-	-
Blue	Commercial	0.02	0.4%
Red	Public / Semi Public	0.29	5.4 %
Grey	Circulation	1.32	24.2%
Green	Vacant / Open Space	1.62	30%
	TOTAL	5.4	100

Residential

- Marble Arch, Chandigarh occupies a total area of 5.4 acres.
- It is situated along the periphery of the city on a triangular site.
- It is developed as a gated community and a new prototype of urban housing.
- It consists of 168 luxury apartments.
- The different size of the 3 bedroom and 4 bedroom apartments varies from 205sqm to 265sqm.
- The apartment blocks are arranged in three rows so as to achieve FAR of 1.5 with 40% ground coverage and five storeyed linear blocks with maximum height of 15.24m (50'-0").

Mixed Use

- No area comes under this land use indicating that all residents are economically well-off and have separate business establishments in the commercial areas of the city. Others are engaged in the service sector.

Commercial

- 0.4% of the total area is under commercial land use.
- The retail outlets occupy an area of 0.02 acres.
- They deal with the daily needs of the people.
- The rest of the needs are met by the sector shopping located at a distance of 1km.

Public / Semi Public

- 5.4% or 0.29 acres of area comes under this use which consists of swimming pool, gymnasium, health club, private jacuzzi, creche and service area.
- The community is flanked by two high schools and one institute on all three sides.
- However, there are no religious buildings within the boundary.

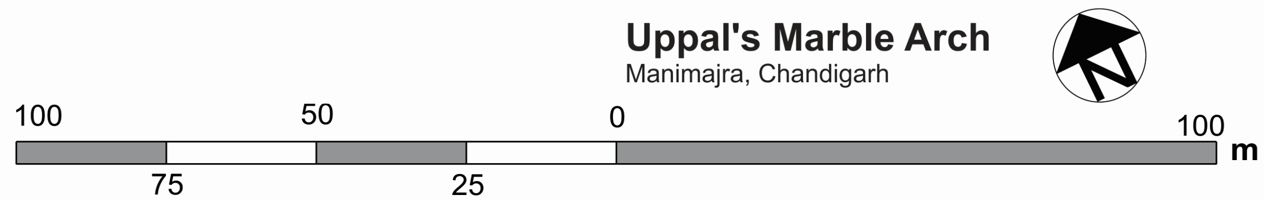
Circulation

- Approximately 24.2% of the total area is under circulation.
- The vehicular road is restricted to the periphery of the site. All roads are metal paved and well maintained.
- The width of the road is 6m (20'-0") for easy movement of cars and the fire tender in case of emergency.
- Pedestrian paths of 3.5m width in regular pattern connect the blocks through the open spaces.

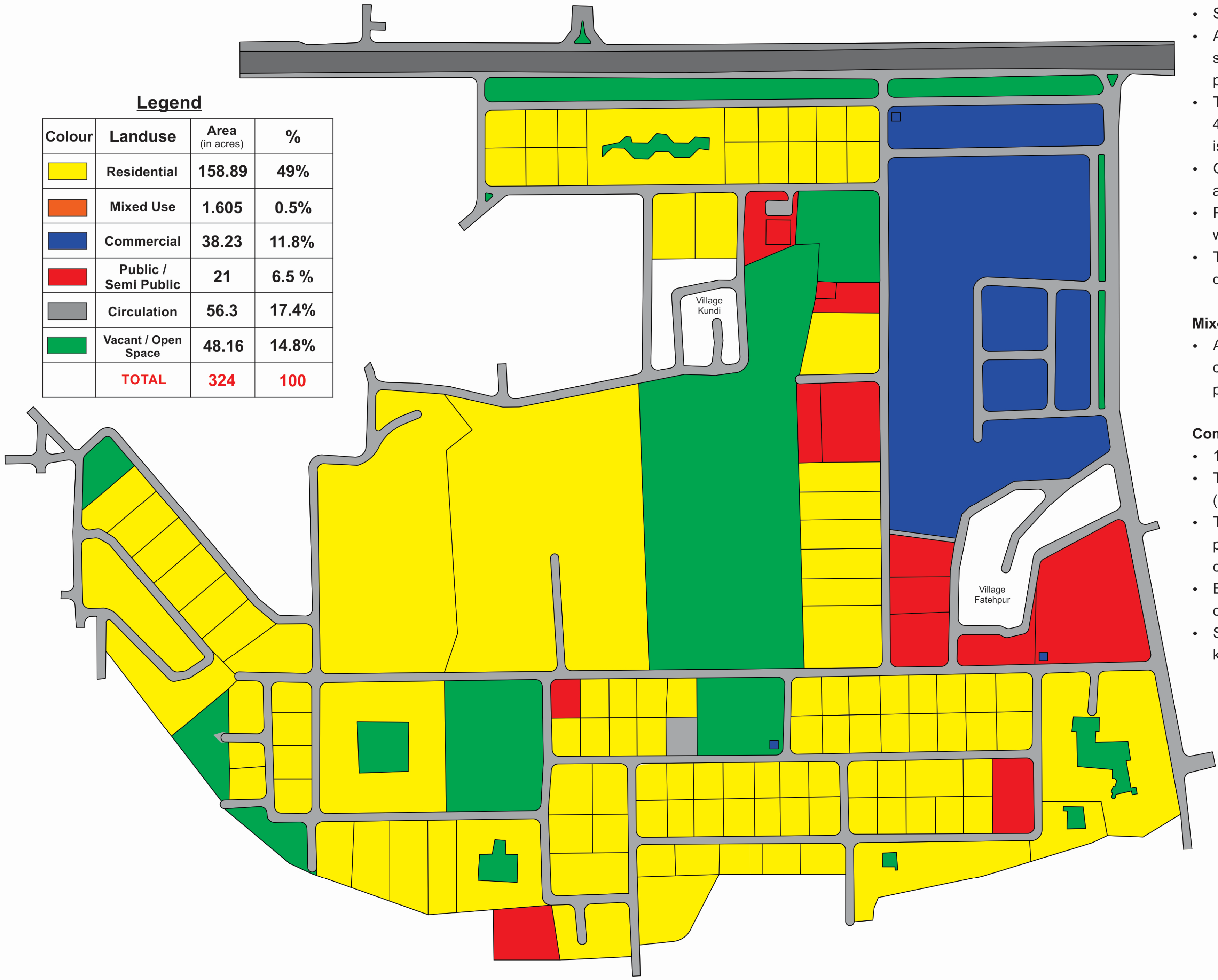
Open Spaces / Green Belt

- 1.62 acres or approximately 30% of the area is occupied by well maintained parks and open spaces.
- The parks are furnished with furniture, lights, swings, paved pathways etc.
- The parks are used in the evening for playing and social interaction.
- Indigenous trees are abundantly planted in the parks and green belts of the gated community.
- A badminton and basketball court also form part of the open spaces.

Uppal's Marble Arch
Manimajra, Chandigarh



Map 4.11: Land-use Map of Marble Arch (Manimajra), Chandigarh



Legend

Colour	Landuse	Area (in acres)	%
Yellow	Residential	158.89	49%
Orange	Mixed Use	1.605	0.5%
Blue	Commercial	38.23	11.8%
Red	Public / Semi Public	21	6.5 %
Grey	Circulation	56.3	17.4%
Green	Vacant / Open Space	48.16	14.8%
	TOTAL	324	100

Residential
- Sector-20 occupies a total area of 324 acres approx.
- Area under commercial use occupies 38.23 acres. It has grain market, cold storage units for fruits, vegetables and flowers (10 acres approx.) that are proposed to cater to the entire Panchkula District.
- The rest of the planned neighbourhood occupies an area of 286.4 acres. 49% of the area is occupied by residential land use which shows that the area is mainly residential in nature.
- Group Housing Societies developed as gated communities characterize the area.
- Plot sizes vary from 0.5 acres to as large as 26 acres. Most common are within 1 - 5 acres.
- The plots are arranged in a systematic manner to give a regular pattern of development in the form of medium rise (5-8 storeyed) gated communities.

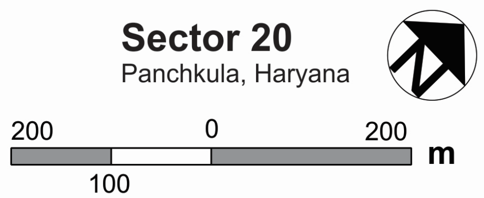
Mixed Use
- Approximately only 1% of the total area comes under this land use. The commonly found activities include offices of architects, advocates, property dealers, boutiques, beauty parlours, coaching centres, etc.

Commercial
- 11.8% of the total area is under commercial land use.
- The neighbourhood shopping centre consisting of double storeyed shops (DSS) and booths and occupies an area of 28.23 acres.
- The shops are mainly retail in nature and deal with the daily needs of the people. Some of the upper floors of the DSSs' are functioning as health clinics, coaching centres, etc.
- Booth markets consist of eating outlets, stationery stores, general store, chemists, drycleaners, car-scooter repair, etc.
- Some informal markets (greengrocers, cycle-rickshaw repair, food carts and kiosks etc.) also form part of the commercial area.

Public / Semi Public
- 6.5% or 21 acres of area comes under this use which consists of police station, telephone exchange, electric substation, Govt. Dispensary, community centre, temple, some area reserved for public works, one pre-primary school, two primary schools and two high schools.

Circulation
- Approximately 17.4% of the total area is under circulation.
- The road pattern is regular in nature. All roads are metal paved and well maintained.
- The width varies from 30'-50' (10-15m) for primary roads and 20' (6m) for secondary roads.

Open Spaces / Green Belt
- 48.16 acres or approximately 14.8% of the area is occupied by well maintained parks and open spaces.
- A 27.4acres Mango Garden acts as a lung for the entire sector.
- The neighbourhood parks are furnished with furniture, lights, swings, paved pathways etc.
- The parks are used in the evening for playing and social interaction.
- Indigenous trees are abundantly planted in the parks and green belts of the neighbourhood.
- The larger gated communities with plot sizes of 5 acres and above have developed and maintained their own open spaces with community facilities like club, gymnasium, swimming pool, children's play areas etc.



Map 4.12: Land-use Map of Sector-20 (Panchkula), Chandigarh

Figure 4.5: Study Units, Sector-8, Chandigarh

Source: Author, 2015

Figure 4.6: Study Units, Sector-38 West, Chandigarh

Source: Author, 2015

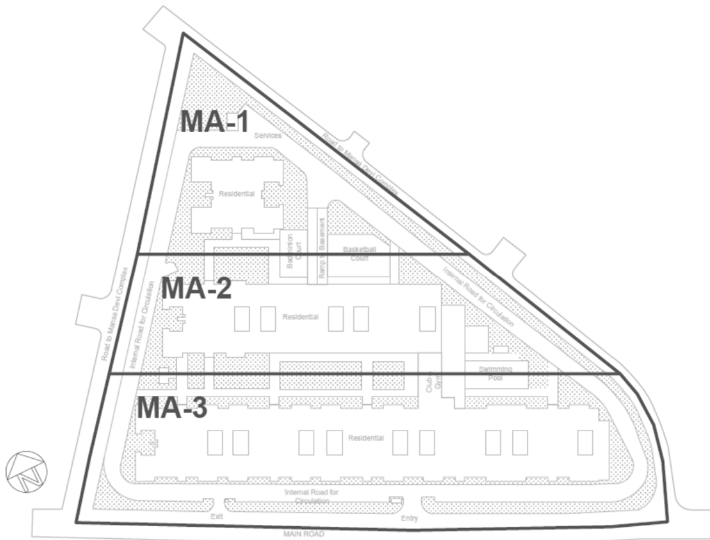


Figure 4.7: Study Units, Marble Arch (Manimajra), Chandigarh

Source: Author, 2015

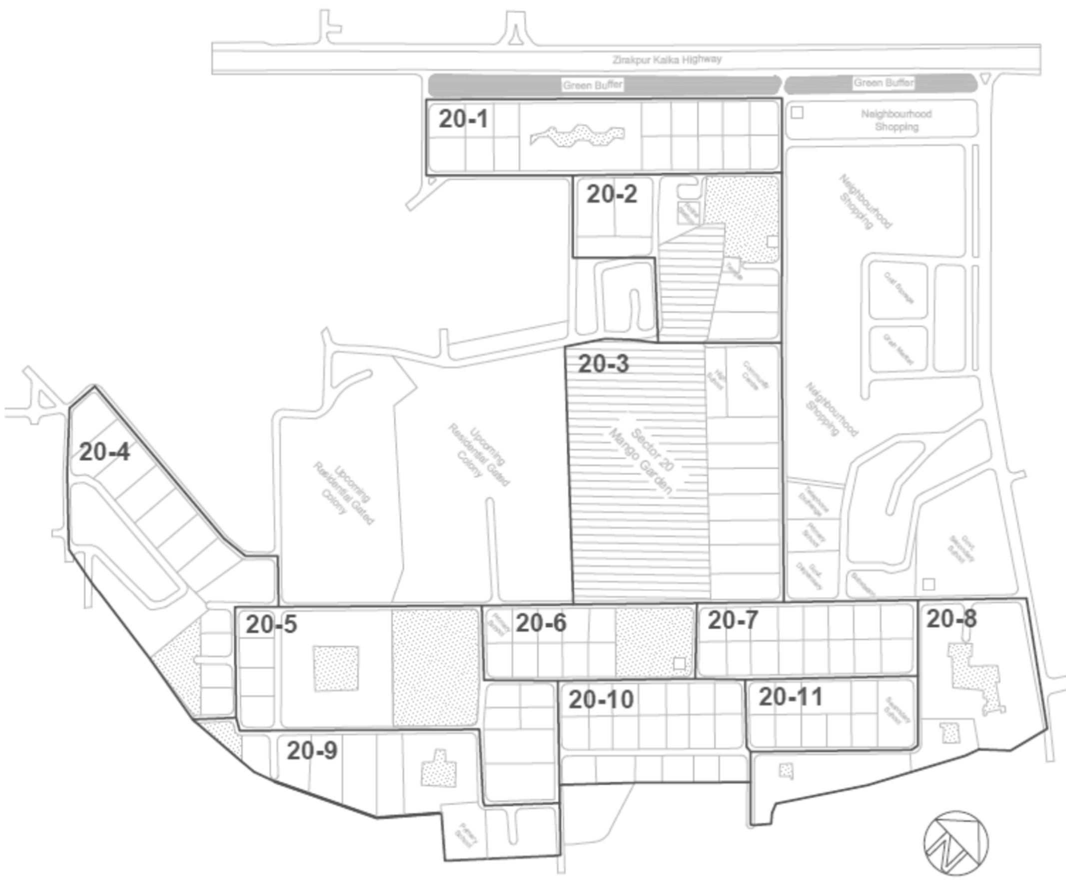


Figure 4.8: Study Units, Sector-20 (Panchkula), Chandigarh

Source: Author, 2015

4.3.2.1 Key Features of the Case Study Neighbourhoods of Chandigarh

The key features of the four neighbourhoods are presented in a tabular format in table 4.2 and the plates and typical sections as given in the following pages:

Table 4.2: Key Features of Case Study Neighbourhoods, Chandigarh

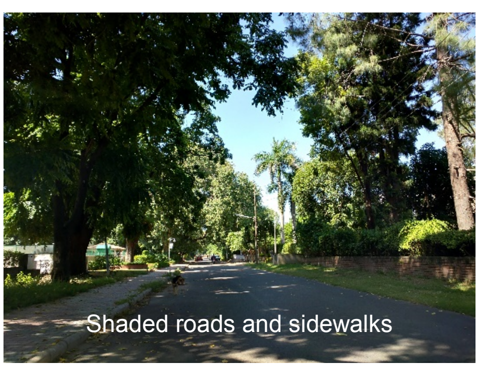
Brief Description of the Neighbourhoods			
Sector 8	**Sector 38 West**	**Marble Arch, Manimajra**	**Sector 20, Panchkula**
The neighbourhood covers an area of about 104 hectares. It is laid out in the grid iron system. V2 & V3 roads define the sector whereas V5 (neighbourhood streets) and V6 (access roads) form the road network within the locality. Two V4 (shopping streets) divide the sector into three parts.	The neighbourhood covers an area of about 32.2 hectares. It is wedge shaped in plan. It is an extension of the main 38 sector and lies to its west, hence the name Sector-38 West.	The neighbourhood is a gated community spread in an area of 2 hectares approximately. The site is triangular in shape and located in Manimajra lying 200m north of the Chandigarh-Kalka Highway. It is a pedestrian friendly neighbourhood with vehicular roads restricted to the periphery.	The neighbourhood covers an area of about 130 hectares. It is irregular in shape. It lies along the Zirakpur-Kalka Highway and is one of the densest residential neighbourhoods
Population Density			
95pph	**441pph**	**345pph**	**540pph**
Residential Density			
17DUs/ha	**76DUs/ha**	**65DUs/ha**	**98DUs/ha**
Residential Pattern			
LRLD	**LRHD**	**MRMD**	**MRHD**
G, G+1 and occasionally G+2 plotted development characterize the area. It is one of the earliest planned sectors of Chandigarh by Albert Mayer. It abounds in large plots with bungalow type houses in addition to plotted row house development.	Compactly placed G+2 flatted apartment style residential blocks in a pin-wheel and row house arrangement signify the area.	G+4 storeyed apartment blocks interspersed with community open space and shared facilities and amenities identify this locality.	Group Housing Societies developed as gated communities characterize the area. The plots are arranged in a systematic manner with medium rise (5-8 storeyed) buildings.
Plot Sizes			
The sizes of the plots are 5marlas, 8marlas, 10marlas, 16marlas, 1 Kanal–5 Kanals.[25]	The sizes of the plots are 8marlas and 10marlas.	Consists of three rows of apartment blocks. Size of DUs varies from 205-265sqm.	Plot sizes vary from 0.5-26acres. Most common sizes are between 1-5acres.

[25] 1Marla = 25.293sqm, 1Kanal = 505.857sqm and 1Kanal = 20Marlas – All these are traditional Indian units of land area especially used in northern India. Its use in India is in decline with urban land measurements standardizing the use of square meters.

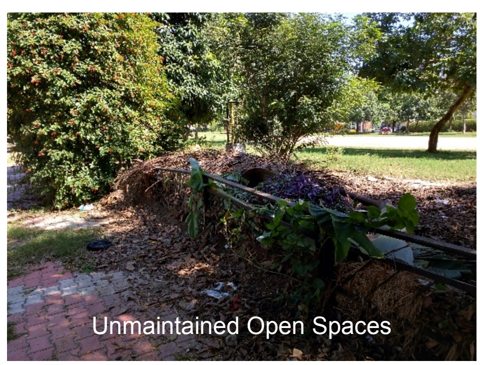
Table 4.2 (contd.): Key Features of Case Study Neighbourhoods, Chandigarh

Sector 8	Sector 38 West	Marble Arch, Manimajra	Sector 20, Panchkula
Open Spaces			
There are abundant open spaces and trees in the neighbourhood. However there is lack of maintenance. Some spaces are used for playing and social interaction. People are more inclined towards using private gardens.	Parks and open spaces are maintained and used by the children and residents. Level of infrastructure is good.	Well maintained parks and open spaces with paved pathways and good infrastructure. Used for gatherings and social interaction. A badminton and basketball court form part of the open spaces.	There are sector level parks as well as parks/open spaces in all of the gated communities. A large mangrove acts as lungs for the high density neighbourhood.
Roads and Sidewalks			
The road pattern is in a grid form. All roads are metaled. However sidewalks are discontinuous or absent in some places.	The road pattern is regular with dead end roads. On-street parking causes congestion in the neighbourhood.	The vehicular road is restricted to the periphery. Sidewalks and pedestrian pathways through the open spaces connect the blocks.	There are ample roads in the neighbourhood. However, due to heavy traffic because of high density, there is congestion on the roads.
Level of Services			
Overall level of services is good in all neighbourhoods in Chandigarh with 100% houses connected to the sewerage and drainage system and regular door-to-door collection of domestic waste. The problem observed in some neighbourhoods is the provision of adequate nos. of community bins or littered garbage near the bins causing filthy conditions, growth of insects and pathogens (flies and mosquitos), clogging of storm-water drains and foul smell thus affecting the environmental quality.			
Miscellaneous			
The sector shopping, temple, gurudwara, etc. serve the daily needs of the people. However discontinuity of sidewalks discourages people to walk.	The on-street parking and congestion renders roads unsafe for children and elderly.	People walk freely inside the gated community. However they have to use vehicles for daily needs.	Some people come to the neighbourhood parks, shopping etc. on their vehicles while some walk on the sidewalks.

Source: Author, 2015



Shaded roads and sidewalks



Unmaintained Open Spaces

Plate 4.12: Roads and sidewalks, trees and open spaces in Sector-8, Chandigarh

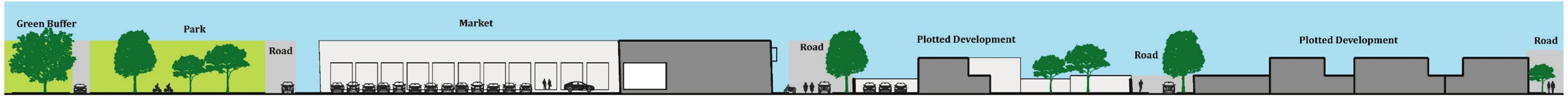
Plate 4.13: Key Features of Sector-8, Chandigarh

Plate 4.14: Maintained parks, roads and greenery, Sector-38W, Chandigarh

Plate 4.15: Key Features of Sector-38W, Chandigarh

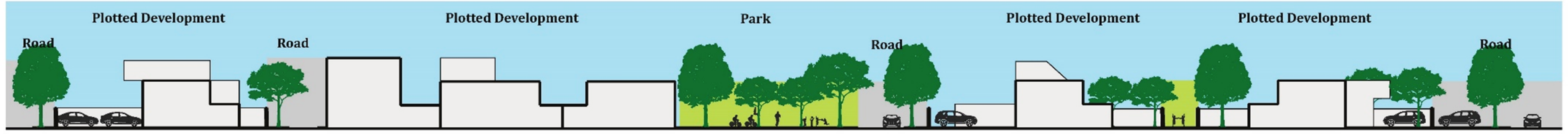
Plate 4.16: Aerial view, open spaces and facilities of Marble Arch (Manimajra), Chandigarh

Study units near the commercial belt have higher noise levels and poor air quality due to vehicular traffic, air-conditioning units and DG Sets. They also lack open spaces and thus less PGA/Capita.



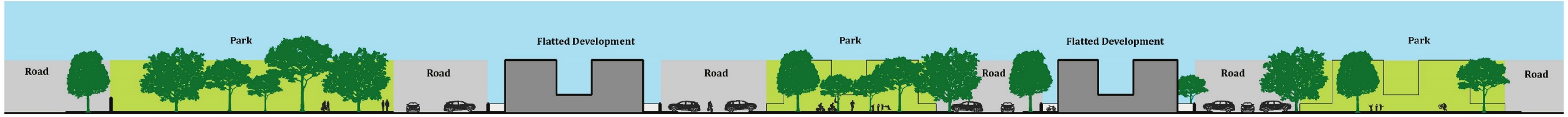
Sector-8 Study Units near the Commercial Stretch with relatively higher residential density
(Primary Roads - 60'- 80' or 18-25 m, Secondary Roads = 40'- 45' or 13 m, Tertiary Roads = 30'- 35' or 10 m)
H:W = 1:2, 1:3

Inner study units have better open spaces, larger plot sizes, comparatively lesser population density with higher BUA/Capita and PGA/Capita. More trees and shaded sidewalks are seen here that add to the overall environmental quality.



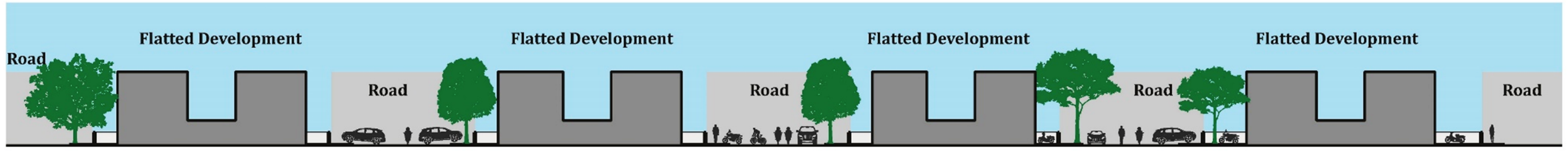
Sector-8 Inner Study Units with low rise low residential density
(Primary Roads = 60'- 80' or 18-25 m, Secondary Roads = 40'- 45' or 13 m, Tertiary Roads = 30'- 35' or 10 m)
H:W = 1:1, 1:3

Certain blocks fare well because of comparatively lower population and residential density and better open spaces for promoting different types of activities with higher intensity of activities.



Sector-38 West Study Units with low rise high residential density interspersed with Parks (30'- 50' or 10-15 m wide roads)
H:W = 1:1.2

Some pockets (38W-1, 38W-4, and 38W-5) have low PGA/Capita, low PRL/Capita and high M.F. as a result of congestion due to on-street parking and lots of dead ends in the road network. The tree cover is also less.



Sector-38West Study Units with low rise high residential density devoid of Parks (30'- 50' or 10-15 m wide roads)
H:W = 1:1.2

Figure 4.9: Typical Sections, Sector 8 and Sector 38 West, Chandigarh

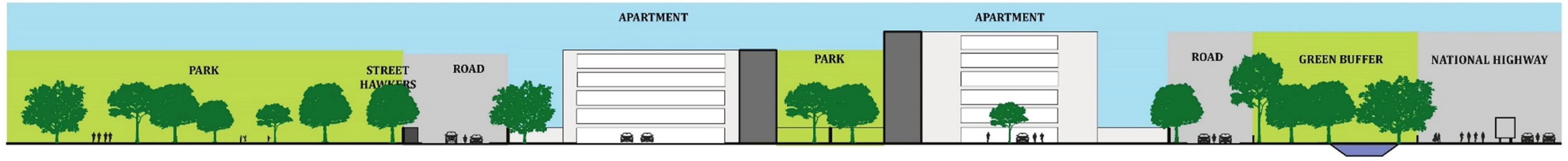
Source: Author, 2015

Inner areas of the gated community have better open spaces, more PGA/Capita and hence better intensity of activities.

Outer areas towards the road have higher noise levels and less open spaces.

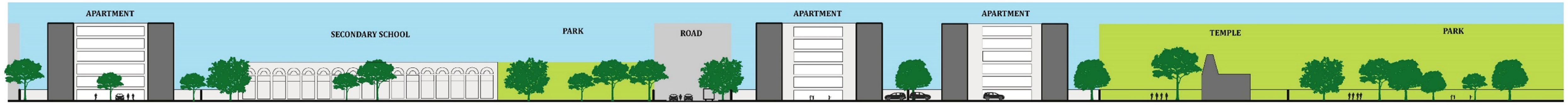
Marble Arch, Manimajra (20' or 6 m wide internal roads)
H:W = 1:1.5

Gated communities towards the road have higher noise levels and more air pollution due to heavy vehicular traffic.



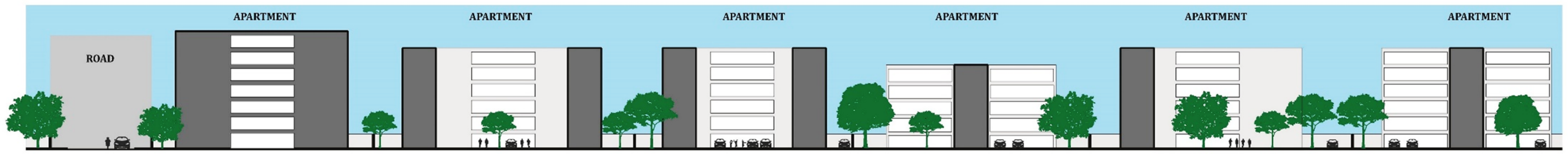
Sector 20 (Panchkula) Study Unit near Zirakpur Kalka National Highway (Primary Roads - 30'-50' or 10-15 m, Secondary Roads - 20' or 6 m)
H:W = 1:1, 1.2:1,1.4:1, 3:1

Gated communities with comparatively better open spaces and proximity to amenities and facilities.



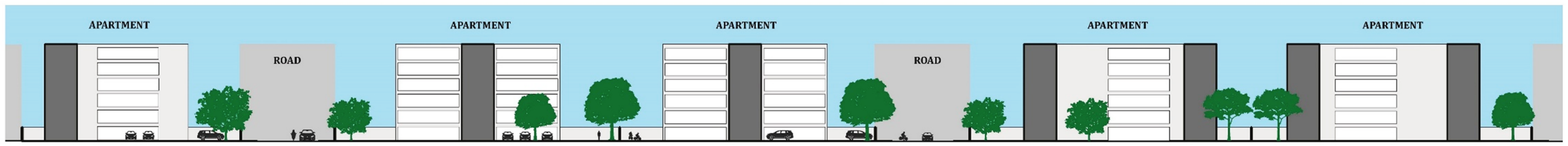
Sector 20 (Panchkula) Inner Study Unit near Park, School and Temple (Primary Roads - 30'-50' or 10-15 m, Secondary Roads - 20' or 6 m)
H:W = 1:1, 1.2:1,1.4:1

Gated communities with very high residential and population density and low PGA/capita and BUA/Capita. Heavy congestion on main sector spine leading to noise and air pollution.



Sector 20 (Panchkula) Central Study Unit opposite Main Neighbourhood Shopping (Primary Roads - 30'-50' or 10-15 m, Secondary Roads - 20' or 6 m)
H:W = 1:1, 1.2:1,1.4:1

Gated communities away from daily needs shops and other facilities (>1km) and lacking public open spaces like parks, playgrounds etc. in near vicinity.



Sector 20 (Panchkula) Study Units away from Main Neighbourhood Shopping and Central Facilities (Primary Roads - 30'-50' or 10-15 m, Secondary Roads - 20' or 6 m)z
H:W = 1:1, 1.4:1

Figure 4.10: Typical Sections, Marble Arch (Manimajra) and Sector 20 (Panchkula), Chandigarh

Source: Author, 2015

Plate 4.17: Built Form & Hierarchy of Parks and Open Spaces, Sector-20 (Panchkula), Chandigarh

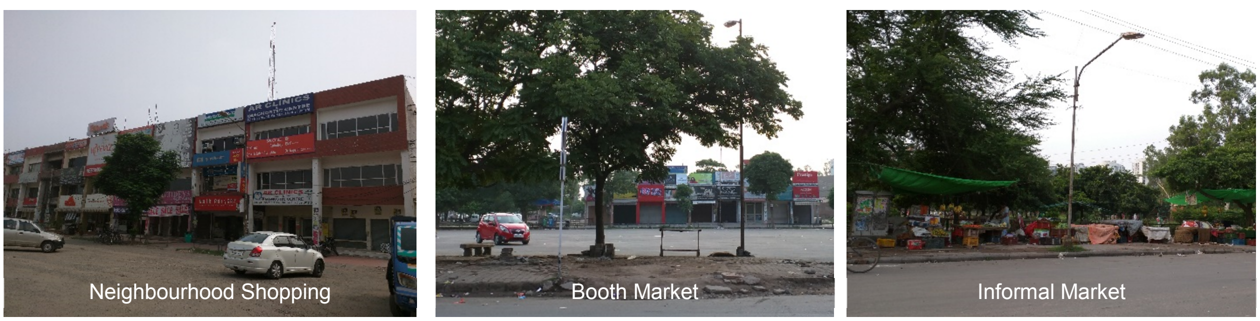
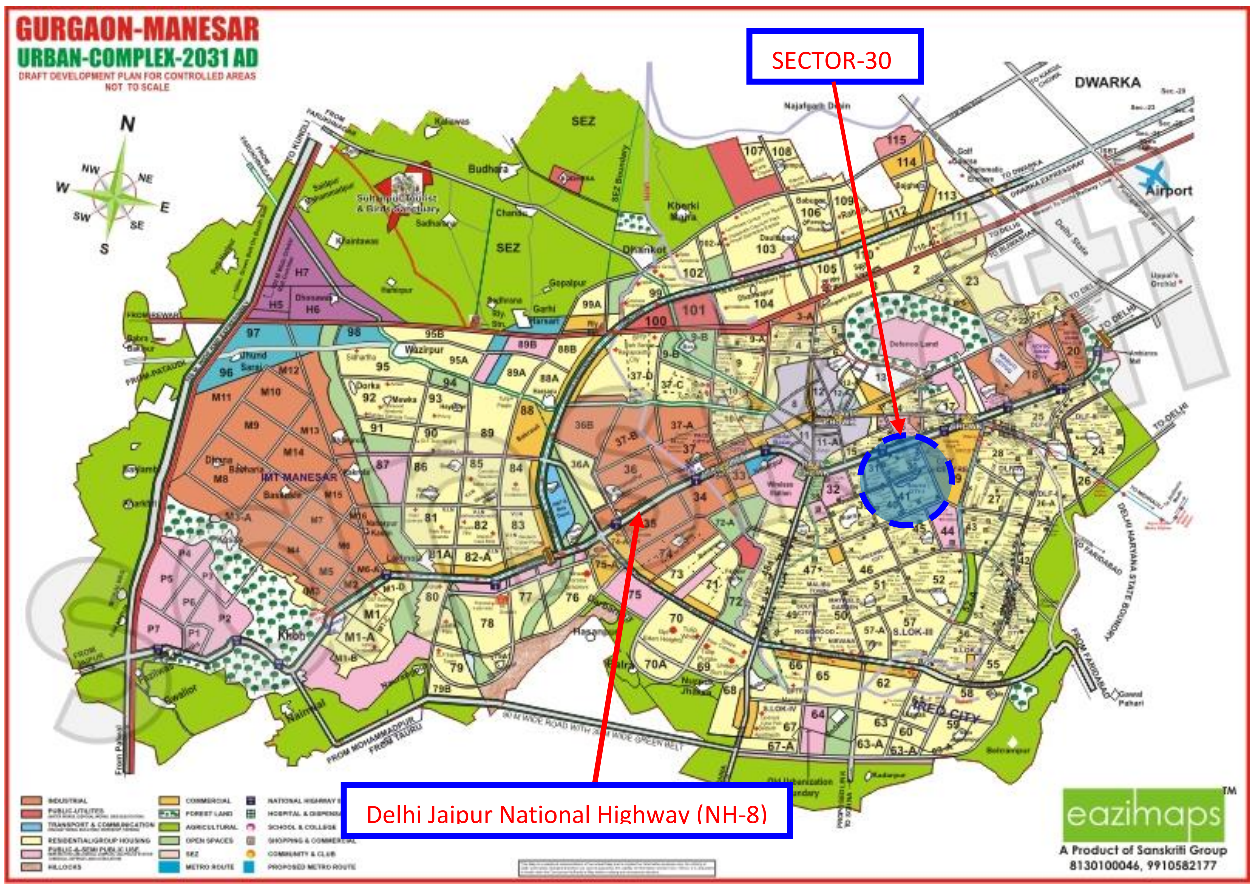


Plate 4.18: Types of Commercial Establishments, Sector-20 (Panchkula), Chandigarh

Plate 4.19: Roads and Sidewalks, Sector-20 (Panchkula), Chandigarh

4.4 Brief overview of Gurugram

As mentioned earlier in Chapter 3, Gurugram – more popularly known as 'Gurgaon' was a village that transformed into a financial and industrial city after leading Indian automobile manufacturer Maruti Suzuki India Limited established a manufacturing plant in Gurgaon in the 1970s. It emerged as a flashy boom-town with shopping-malls, condominiums and swanky office towers at the turn of the millennium. The urban form generally consists of glass and concrete high-rise structures scattered here and there. The overall urban form of Gurugram was envisioned as a road-based suburbia with the national highway (NH-8) bisecting the city into two parts as seen in map 4.13.



Map 4.13: Master Plan of Gurgaon (now called Gurugram) – Manesar Urban Complex, 2031AD

Source: http://stayinGurugram.com/Gurugram-maps#prettyPhoto[6761]/1/

The city consists of office blocks, shopping malls and gated communities. There are very few public spaces of any kind. At the city level, the few green areas are in form of private golf courses – hardly conducive for creating a vibrant urban community. There are very few places for generalized social interaction such as public parks, sports complexes, temples, art hubs etc. Very recently, there has been a belated effort to remedy the situation. The Delhi Metro has been extended to Gurugram. A new municipal governance structure has also been developed.

4.4.1 Choice of Residential Neighbourhoods

For the present study, two residential neighbourhoods – gated communities located in Sector-30 as seen in map 4.13 and plate 4.20 along the National Highway NH-8 with different density patterns as compared to Amritsar and Chandigarh are identified for detailed study and analyses. The neighbourhoods are as follows:

1. High Rise Low Density (HRLD) – World Spa, Sector-30, Gurugram
2. High Rise High Density (HRHD) – Uniworld City, Sector-30, Gurugram

Plate 4.20: High Rise Structures, World Spa and Uniworld City, Gurugram

Source: Author, 2016

Both the neighbourhoods are built and managed by private developers and are examples of the very common type of residential pattern being adopted in all the cities so as to accommodate relatively more people on a piece of land and provide them with all amenities and facilities like parks, open spaces to interact and socialise, play areas, gym, pool, retail outlets catering to daily requirements, etc. within the boundary of the locality or the gated community. However, even though these communities have high quality physical infrastructure, there is a need to integrate the neighbourhoods by providing ‘urban software’ at the city level – a main thrust area of **AMRUT (2015)** that can have a positive impact on the urban environmental quality.

4.4.2 Detailed Study of the Neighbourhoods

4.4.2.1 World Spa, Gurugram – High Rise Low Density Neighbourhood (HRLD)

World Spa, a high rise low density neighbourhood is divided into two parts World Spa – East (WS-E) and World Spa – West (WS-W) for detailed study and analyses as shown in figure 4.11. It covers an area of about 7.5 hectares. Two distinct but compatible architectural vocabularies differentiate the designs of both the parts. The project comprises of townhouses (208sqm), 4/5 bedroom apartments (381-462sqm) and penthouses (618-731sqm) spread over 11 towers (6 towers in WS-W and 5 towers in WS-E). Most of the towers are 17 storeyed except for two towers in WS-E that are 13 storeyed. The town houses are G+2 storeyed and constitute just 7.5% of the total dwelling units. The gross population density is 178pph and the residential density is 44DUs/ha.

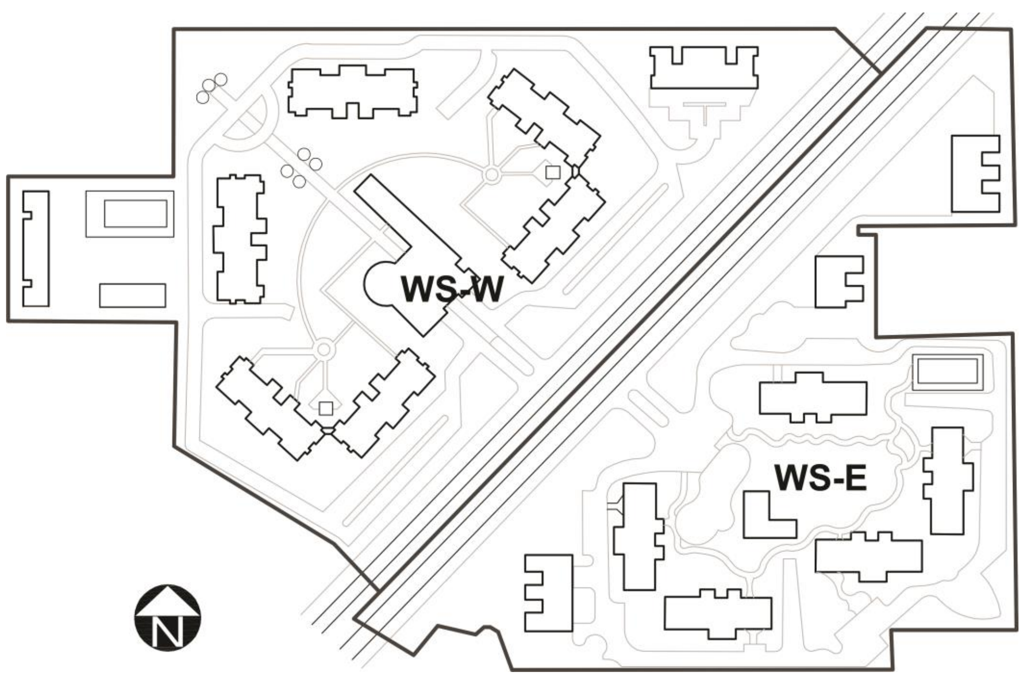


Figure 4.11: Study Units, World Spa, Gurugram

Source: Author, 2016

The high rise towers are of regular shape and are arranged in a systematic manner around central facilities to give a characteristic pattern of development with low building footprint and comparatively large open spaces and landscaped areas as seen in map 4.14. 60% of the area is occupied by open spaces with well-maintained parks and abundant greenery. The vehicular roads are restricted to the periphery with provision of open parking lots along them. Rest of the parking is in the basement. Pedestrian pathways are well laid out in the open spaces and along roads for easy movement of people.

Commercial

- 0.13% of the total area is under commercial land use.
- The neighbourhood shopping consists of 2-3 retail outlets and covers an area of about 0.025 acres.
- These shops cater to the daily needs of the residents of the neighbourood.

Public / Semi Public

- 2.13% or 0.4 acres comes under this use which consists of a community centre, club, gymnasium, etc.

Circulation

- Approximately 25.4% of the total area is under circulation.
- The vehicular roads (10-12m wide) are laid along the periphery. All roads are metal paved and well maintained.
- Pedestrian pathways are well laid out in the open spaces and along roads for easy movement of people .

Open Spaces / Green Belt

- 11.32 acres or approximately 60% of the area is occupied by parks and open spaces.
- The parks are well maintained.
- They are used for playing and social interaction.
- Indigenous trees are abundantly planted in the parks, along roads and green belts of the neighbourhood.

World Spa
Sector 30, Gurugram

Residential

- World Spa is a high rise low density gated community that occupies a total area of 19acres approx.
- 12% of the area is occupied by residential land use.
- 13 and 17 storeyed high rise towers of regular shape and size are arranged in a systematic manner around central facilities to give a characteristic pattern of development with low building footprint and comparatively large open spaces and landscaped areas.

Mixed Use

- Approximately only 0.2% of the total area comes under this land use indicating that most residents are economically well-off and have separate business establishments in the commercial areas of the city. Others are engaged in the service sector.

Legend

Colour	Landuse	Area (in acres)	%
	Residential	2.3	12.10
	Mixed Use	.05	0.2%
	Commercial	.025	0.13%
	Public / Semi Public	0.4	2.13%
	Circulation	4.8	25.4%
	Vacant / Open Space	11.32	60.04%
	TOTAL	18.89	100

Map 4.14: Land-use map of World Spa, Sector – 30, Gurugram

Source: Author, 2016

Plate 4.21: Open Spaces and Community Facilities, World Spa, Sector – 30, Gurugram

4.4.2.2 Uniworld City, Gurugram – High Rise High Density Neighbourhood (HRHD)

Uniworld City, a high rise high density neighbourhood is divided into two parts Uniworld – East (UW-E) and Uniworld – West (UW-W) for detailed study and analyses as shown in figure 4.12. It covers an area of about 4 hectares. Here also two distinct but compatible architectural vocabularies differentiate the designs of both the parts. The project comprises of 3/4 bedroom apartments and penthouses ranging from 236-375sqm spread over 11 towers (8 towers in UW-W and 3 towers in UW-E). All the towers are 13-14 storeyed with 2 flats per floor in UW-E and 4 flats in UW-W. The town houses are G+2 storeyed and constitute just 3.7% of the total dwelling units. The gross population density is 735pph and the residential density is 147DUs/ha.

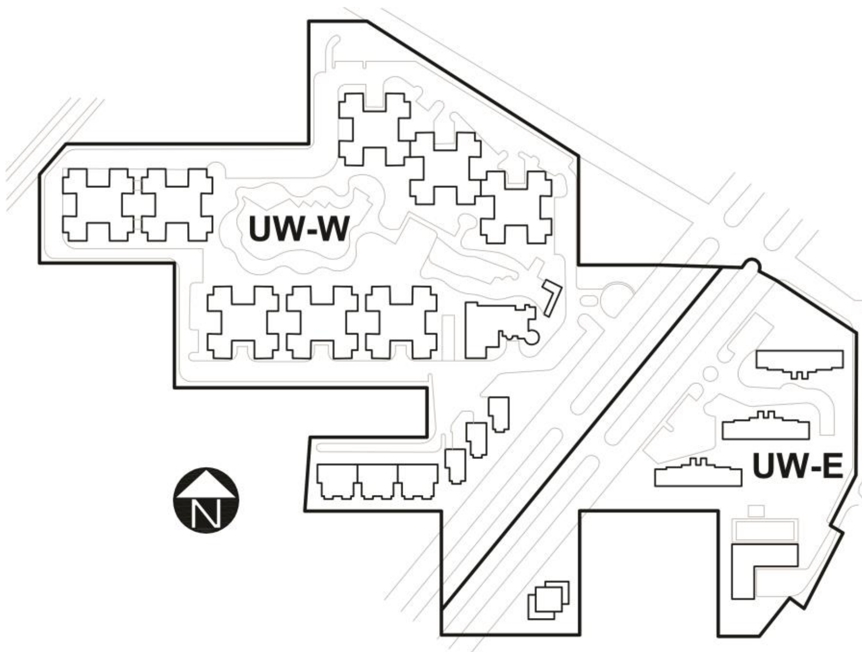
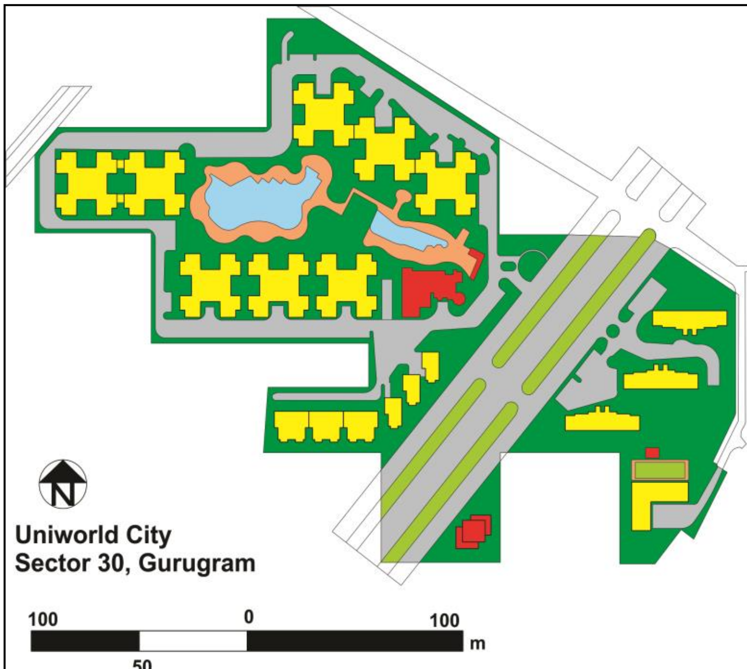


Figure 4.12: Study Units, Uniworld City, Gurugram

Source: Author, 2016

The same principles are seen here as far as the planning of the gated community is concerned with central amenities and facilities laid out amongst lush green lawns and abundantly planted landscaped areas as seen in map 4.15 and plate 4.22. However, as the land area is less and the number of dwelling units are more leading to higher gross residential and population density, the eastern part UW-E seems bit congested. However, in terms of intensity of use of spaces, more people are seen to engage in different types of activities in the different spaces provided.



Commercial

- 0.25% of the total area is under commercial land use.
- The neighbourhood shopping consists of some retail outlets and covers an area of about 0.025 acres.
- These shops cater to the daily needs of the residents of the neighbourhood.

Public / Semi Public

- 1.6% or 0.15 acres comes under this use which consists of community centre, club, gymnasium, swimming pool, etc.

Circulation

- Approximately 30% of the total area is under circulation.
- The vehicular roads (10-12m wide) are laid along the periphery. All roads are metal paved and well maintained.
- Pedestrian pathways are well laid out in the open spaces and along roads for easy movement of people .

Open Spaces / Green Belt

- 5.1 acres or approximately 51% of the area is occupied by parks and open spaces.
- The parks are well maintained.
- They are used for playing and social interaction.
- Indigenous trees are abundantly planted in the parks, along roads and green belts of the neighbourhood.

Residential

- Uniworld City is a high rise high density gated community that occupies a total area of 10acres approx.
- 16% of the area is occupied by residential land use.
- 13-14 storeyed high rise towers of regular shape and size are arranged in a systematic manner around central facilities to give a characteristic pattern of development with low building footprint and comparatively large open spaces and landscaped areas.

Mixed Use

- Approximately only 0.8% of the total area comes under this land use indicating that most residents are economically well-off. Others are engaged in the service sector.

Legend

Colour	Landuse	Area (in acres)	%
	Residential	1.62	16.15 %
	Mixed Use	0.08	0.8%
	Commercial	0.025	0.25%
	Public / Semi Public	0.15	1.6%
	Circulation	3.03	30.22%
	Vacant / Open Space	5.1	51%
	TOTAL	10.005	100

Map 4.15: Land-use map of Uniworld City, Sector – 30, Gurugram

Source: Author, 2016

Plate 4.22: Open Spaces and Community Facilities, Uniworld City, Sector – 30, Gurugram

The key features of both the gated communities are summarised in table 4.3 and figure 4.13.

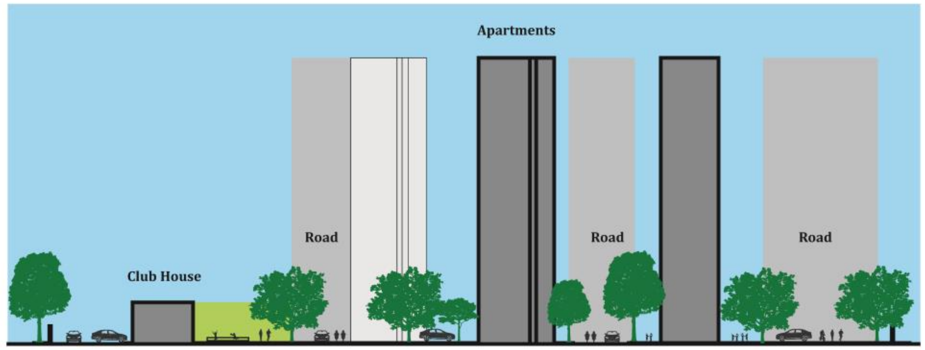
Table 4.3 Key features of Case Study Neighbourhoods, Gurugram

Brief Description of the Locality	
World Spa	**Uniworld City**
A high rise low density gated community located in Sector-30 along the National Highway NH-8.	A high rise high density gated community located in Sector-30 along the National Highway NH-8.
Population Density	
178pph	**735pph**
Residential Density	
44DUs/ha	**147DUs/ha**
Residential Pattern	
HRLD	**HRHD**
The project comprises of apartments primarily spread over 11 towers (6 towers in World Spa West and 5 towers in World Spa East). Most of the towers are 17 storeyed except for two towers in World Spa East that are 13 storeyed. The town houses are G+2 storeyed and constitute just 7.5% of the total dwelling units.	The project comprises of 11 towers (8 towers in Uniworld City West and 3 towers in Uniworld City East). The eastern part is more congested than the western part. All the towers are 13-14 storeyed while the town houses are G+2 storeyed and constitute just 3.7% of the total dwelling units.
Apartment Sizes	
The project comprises of townhouses (208sqm), 4/5 bedroom apartments (381-462sqm) and penthouses (618-731sqm).	The community consists of apartment blocks with 3/4 bedroom apartments and penthouses. Size of DUs varies from 236-375sqm.
Open Spaces	
Lush green lawns and abundantly planted landscaped areas with shared amenities and facilities covering 60% of the area are used for playing and social interaction.	Lush green lawns and abundantly planted landscaped areas covering 51% of the area are used as community interaction spaces.
Roads and Sidewalks	
Well maintained roads and sidewalks covering almost 25% area with provision of open parking lots are laid out along the periphery of the gated community.	Well maintained roads and sidewalks covering almost 30% area are laid out along the periphery of the gated community.
Level of Services	
The level of services is very good with chutes for domestic waste collection, 100% stormwater and sewerage system in operation.	
Miscellaneous	
Both the neighbourhoods are examples of the very common type of residential pattern being adopted in all the cities so as to accommodate relatively more people on a piece of land and provide them with all amenities and facilities.	

Source: Author, 2016

Both World Spa (WS) and Uniworld City (UW), Gurugram have favourable environmental quality with similar built environment. UW scores less because of comparatively low BUA/Capita, PGA/Capita and PRL/Capita due to high population and residential density.

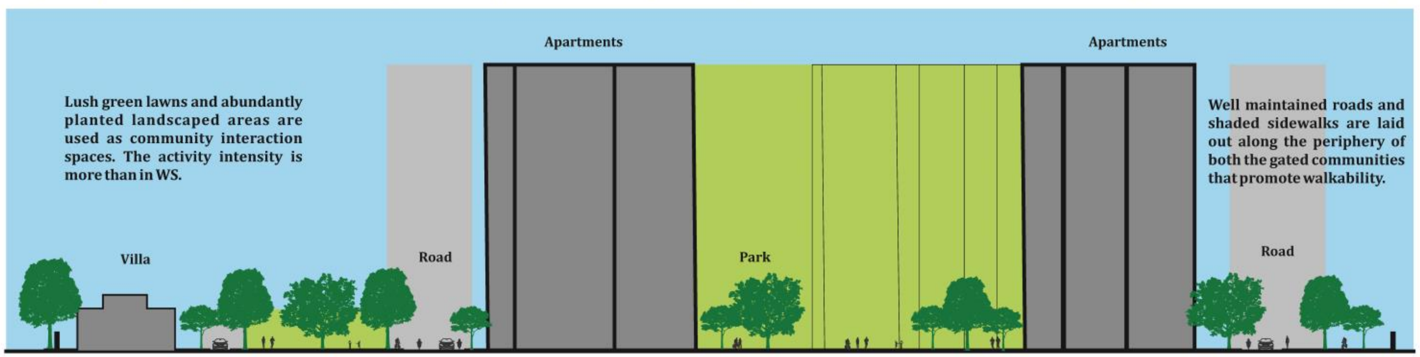
Less land area with more residential density makes the eastern part of UW bit more congested.



UW-E has congestion also due to lower road density, presence of dead ends and more number of vehicles.

Uniworld City East (30'-36' or 10-12 m wide roads)
H:W = 1:1 (villas), 4:1 and 5:1 (high rise apartment blocks)

In both the high rise gated communities, towers range from 13-17 storeys while the town houses are G+2 storeyed. Town houses or villas constitute very less percentage of the total dwelling units. Air pollution due to proximity to NH-8 is one of the reasons for lowering the environmental quality.



Uniworld City West (30'-36' or 10-12 m wide roads)
H:W = 1:1 (villas) and 5:1 (high rise apartment blocks)

Figure 4.13: Typical Sections, Uniworld City, Gurugram

Source: Author, 2016

4.5 Data Organisation

This stage consists of organising the primary and secondary data in excel sheets using MS Excel 2013 and comparing the same with threshold values from different Standards/Guidelines, Government or Semi Government Documents and Reports like URDPFI 2014; Handbook of Service Level Benchmarking, MoUD, Govt. of India and suggested norms by Government Bodies like Central Pollution Control Board (CPCB), etc. All the data is suitably arranged in four categories of excel sheets namely (i) Crowding and Congestion, (ii) Nature and Use of Open Spaces (iii) Shade-Ventilation, Temperature Variations and Noise Levels; and (iv) Walkability and Level of Cleanliness as indicated in Annexure 2.

4.6 Comparative Analysis and Preliminary Findings

The comparative analyses of the data of the eight neighbourhoods reveal some important associations and trends that are presented in the following pages.

4.6.1 Crowding and Congestion

As stated in Chapter 3, population density is considered as one of the first attributes influencing environmental quality. The probability of crowding and congestion both internal and external increases with higher population densities. Population density along with residential density, built-form characteristics like FAR, plot coverage, etc. and distribution of open spaces, roads etc. help in determining built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita), paved road length per capita (PRL/Capita) and mobilization factor (M.F.) that are instrumental in ascertaining the level of crowding and congestion in the neighbourhood. The present study tries to understand the relationship between the various density variables (people, building and spatial density) and indicators of neighbourhood crowding and congestion by a comparative and correlation analysis of the varying parameters with changing residential patterns found in the rapidly urbanising case study cities.

The indicators of crowding and congestion are tabulated with population and residential density (people density), FAR and plot coverage (building density) and distribution of open spaces and roads (spatial density) as indicated in table 4.4. The primary values are compared against the threshold values from published sources (as indicated in table 4.4) to ascertain the level of crowding and congestion in the case study neighbourhoods.

Table 4.4: People Density, Building Density and Spatial Density; and Indicators of Crowding and Congestion*

Neighbourhood	Population Density (persons/ha)	Residential Density (DUs/ha)	FAR	Plot Coverage (%)	Dist. of Open Spaces (%)	Dist. of Roads (m/ha)	Average BUA/Capita (sqm/person)	Average PGA/Capita (sqm/person)	Average PRL/Capita (m/person)	Average Mobilization Factor (M.F.)
Sector 8, Chandigarh	95	17	1.00	49%	37%	189	94.84	48.99	1.78	1.26
Ranjit Avenue, Amritsar	256	36	1.00	30%	55%	354.38	23.14	20.30	0.99	0.41
World Spa, Gurugram	178	44	2.00	11%	89%	422	88.53	50.56	2.01	0.50
Marble Arch, Manimajra	345	65	1.57	31%	68%	232.79	44.93	23.65	0.67	1.00
Sector 38W, Chandigarh	441	76	2.00	70%	30%	403	28.45	10.36	0.68	1.36
Sector 20, Panchkula	540	98	2.00	35%	65%	179	22.23	19.36	0.33	0.85
Uniworld City, Gurugram	735	147	2.03	15%	85%	192	27.97	7.56	0.57	0.75
Katra Dullo, Amritsar	641	149	3.00	85%	15%	737	47.62	2.43	0.56	1.96
						Threshold Values	**20-30**	**12**	**0.91**	**≤1**
						Source of Information	*Analyzing Urban Layouts - SB Patel 2011*	*URDPFI 2014*	*Amritsar Master Plan 2010-2031*	*Environment Quality Indicators- WIT Press 2000*

Legend:

(red)	Less than threshold value	(green)	Within range or equal to threshold value	(grey)	More than threshold value

* Refer Annexure 2, Data Sheet 1 - Data Sheet 7

The data indicates that generally the built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita) and paved road length per capita (PRL/Capita) decrease with increasing people density (population density and residential density) as seen in figure 4.14, 4.15 and 4.16. The association is strongest and statistically significant between residential density and public ground area per capita (PGA/Capita) with $p<0.05$. **Since the study finds similar relationships of residential densities and population densities, therefore findings mainly describe residential densities in dwelling units per hectare (DUs/ha).**

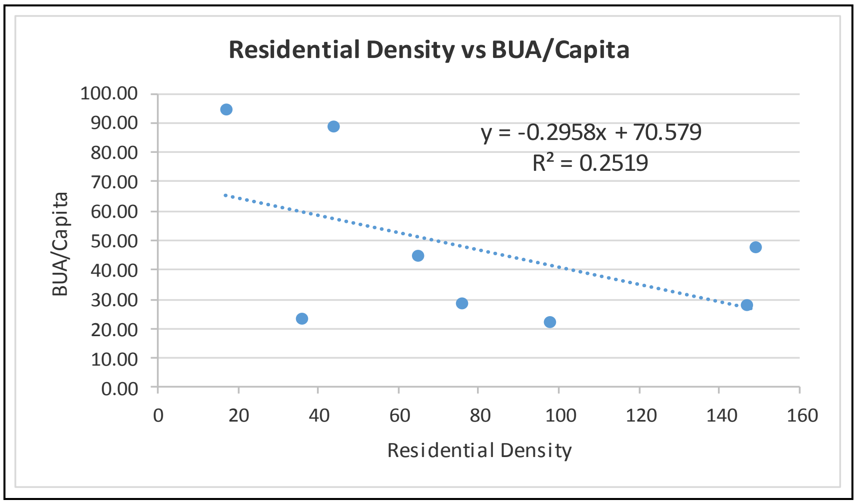


Figure 4.14: Residential Density versus BUA/Capita

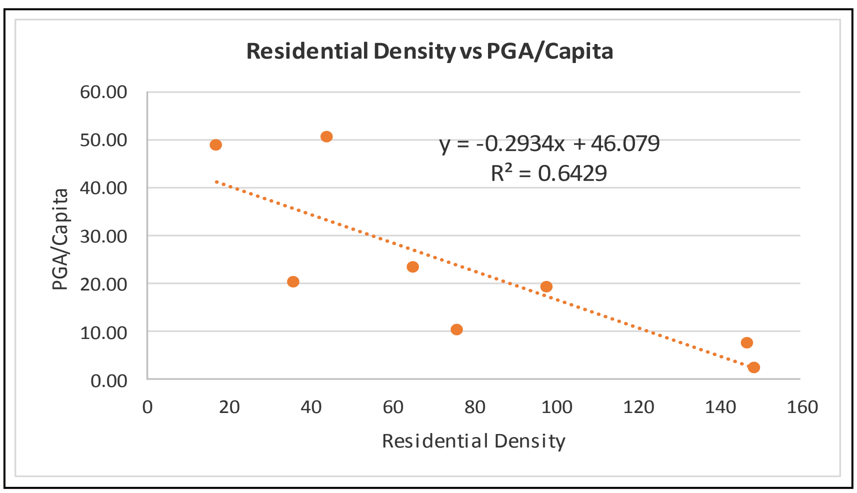


Figure 4.15: Residential Density versus PGA/Capita

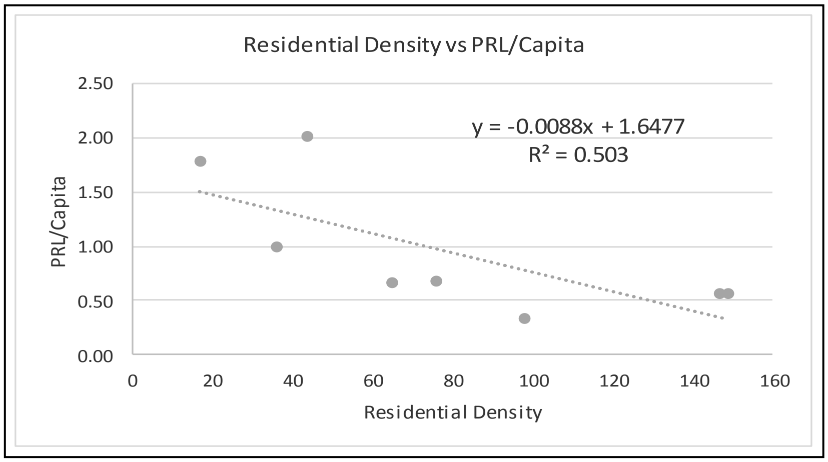


Figure 4.16: Residential Density versus PRL/Capita

The study also indicates that there is generally no internal crowding as the average built-up area per capita (BUA/Capita) values either are within the range (20-30sqm/person) or are well above the required norms. However, there is external crowding particularly in Katra Dullo, Amritsar – LRHD neighbourhood because of very low public ground area per capita (PGA/Capita) of 2.43sqm/person and low paved road per length per capita (PRL/Capita) of 0.56m/person. Congestion on roads is also observed in Uniworld City, Gurugram – HRHD and Sector-20, Panchkula – MRHD neighbourhood with paved road length per capita (PRL/Capita) of 0.57m/person and 0.33m/person respectively. Even though there is significantly less association between residential density and mobilization factor as indicated in figure 4.17, increasing on-street parking causes congestion in the internal streets as denoted by the higher mobilization factor in Sector-8 (1.26) and Sector-38W (1.36), Chandigarh and Katra Dullo (1.96), Amritsar.

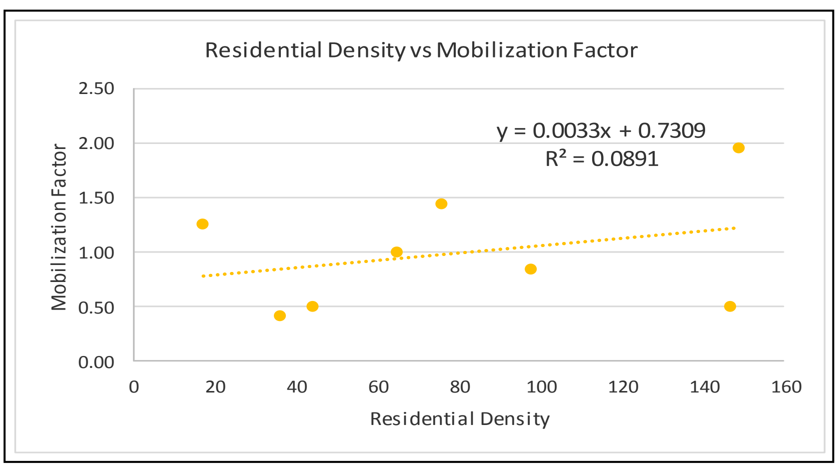


Figure 4.17: Residential Density versus Mobilization Factor

Table 4.5: Correlation between Density and Crowding and Congestion

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

			Environmental Quality Indicators			
			BUA per Capita	PGA per Capita	PRL per Capita	Mobilization Factor
People Density	Population Density	Pearson Correlation	-.480**	-.752**	-.718**	.179
		Sig. (2-tailed)	.000	.000	.000	.156
	Residential Density	Pearson Correlation	-.312*	-.695**	-.633**	.280*
		Sig. (2-tailed)	.012	.000	.000	.025
Building Density	FAR	Pearson Correlation	-.060	-.585**	-.487**	.455**
		Sig. (2-tailed)	.640	.000	.000	.000
	Plot Coverage	Pearson Correlation	.015	-.464**	-.265*	.448**
		Sig. (2-tailed)	.904	.000	.034	.000
Spatial Density	Dist. of Open Spaces	Pearson Correlation	-.287*	.336**	-.047	-.472**
		Sig. (2-tailed)	.022	.007	.713	.000
	Dist. of Roads	Pearson Correlation	-.109	-.474**	-.151	.181
		Sig. (2-tailed)	.392	.000	.234	.153
	Domestic Waste	Pearson Correlation	-.068	.410**	.235	-.387**
		Sig. (2-tailed)	.594	.001	.062	.002
	Stormwater Drainage	Pearson Correlation	-.064	.413**	.238	-.390**
		Sig. (2-tailed)	.616	.001	.059	.001
	Sewerage	Pearson Correlation	-.071	.417**	.243	-.401**
		Sig. (2-tailed)	.578	.001	.053	.001

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The building density in terms of FAR and plot coverage show significant negative correlation with public ground area per capita (PGA/Capita) and paved road length per capita (PRL/Capita) whereas positive correlation with mobilization factor as indicated in table 4.5. This implies that as FAR and plot coverage increase the PGA/Capita and PRL/Capita tend to decrease while the congestion on the roads tends to increase with higher mobilization factor.

The spatial density variables indicate that as the distribution of open spaces and roads increases, the public ground area per capita (PGA/Capita) varies accordingly. The increase in open spaces also reduces congestion as more people walk within the neighbourhood using the sidewalks and pedestrian pathways. This is particularly noticed in the gated communities. Good level of services ensures neat and clean roads and open spaces thus reducing congestion as shown by the negative correlation with mobilization factor and more PGA/Capita indicated by the positive correlation.

4.6.2 Nature and Use of Open Space

The nature and use of open space is measured using a score that signifies the type (park, playground, square, etc.) and condition of the space in terms of maintained, unattended or encroached; percentage tree cover, activity intensity and activity diversity as explained in the literature review and as indicated in table 4.6. It is seen that generally the gated communities have better condition of open spaces and tree cover as compared to other neighbourhoods. The activity intensity is highest in Katra Dullo, Amritsar and Uniworld City, Gurugram both having high population and high residential density thus indicating a positive correlation between people density and activity intensity as seen in figure 4.18. The similar results are also observed for values of activity diversity thus suggesting that more people engage in different activities and greater social interaction happens in high density neighbourhoods.

Table 4.6: People Density and Indicators of Nature and Use of Open Space*

Neighbourhood	Population Density (persons/ha)	Residential Density (DUs/hectare)	Type & Condition of Open Space (score)	Tree Cover (%)	Activity Intensity (persons/ha)	Activity Diversity (score)
Sector 8, Chandigarh	95	17	0.24	28%	11	0.04
Ranjit Avenue, Amritsar	256	36	0.30	49%	28	0.05
World Spa, Gurugram	178	44	0.52	41%	20	0.10
Marble Arch, Manimajra	345	65	0.44	35%	48	0.14
Sector 38W, Chandigarh	441	76	0.36	23%	45	0.03
Sector 20, Panchkula	540	98	0.31	25%	19	0.03
Uniworld City, Gurugram	735	147	0.52	41%	201	0.15
Katra Dullo, Amritsar	641	149	0.20	3%	552	0.12

* Refer Annexure 2, Data Sheet 8 - Data Sheet 14

The correlation analysis between density variables and indicators of nature and use of open space as indicated in table 4.7 shows the above mentioned associations and hence indicates that nature and use of open spaces varies with residential patterns. Activity intensity increases with increase in population density, residential density, FAR and plot coverage as expected. Activity diversity also shows an increasing trend with increasing residential density. However, both show negative correlation with better distribution of services as a result of higher PGA/Capita in the cleaner and maintained neighbourhoods. The condition of open spaces is best in the gated communities with higher distribution of open spaces and tends to decrease with increasing plot coverage. The tree cover decreases with increasing population density, residential density, FAR and plot coverage but increases with the amount/distribution of open spaces, shaded sidewalks and maintained open spaces as a result of good services.

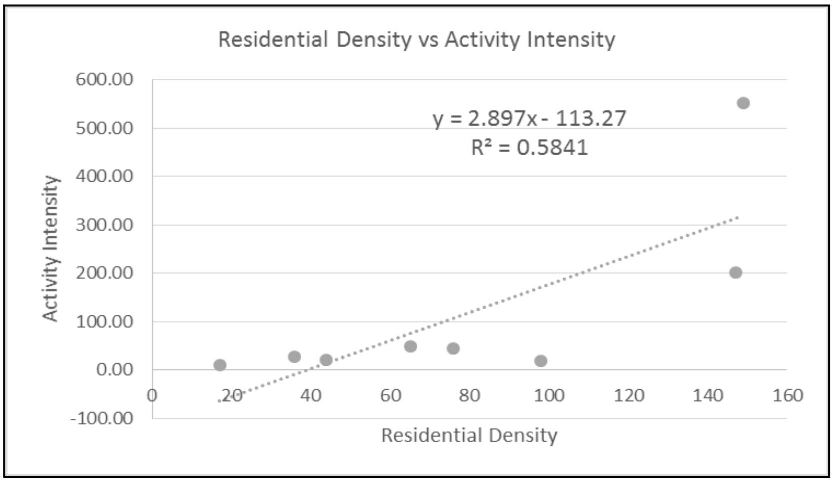


Figure 4.18: Residential Density versus Activity Intensity

Table 4.7: Correlation between Density and Nature and Use of Open Spaces

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

			Environmental Quality Indicators			
			Type & Cond. of Open Space	Tree Cover	Activity Intensity	Activity Diversity
People Density	Population Density	Pearson Correlation	-.078	-.532**	.445**	.145
		Sig. (2-tailed)	.540	.000	.000	.253
	Residential Density	Pearson Correlation	-.112	-.626**	.577**	.277*
		Sig. (2-tailed)	.378	.000	.000	.027
Building Density	FAR	Pearson Correlation	-.160	-.581**	.515**	.213
		Sig. (2-tailed)	.207	.000	.000	.092
	Plot Coverage	Pearson Correlation	-.295*	-.635**	.549**	.118
		Sig. (2-tailed)	.018	.000	.000	.352
Spatial Density	Dist. Of Open Spaces	Pearson Correlation	.484**	.520**	-.506**	-.154
		Sig. (2-tailed)	.000	.000	.000	.225
	Sidewalks	Pearson Correlation	-.007	.434**	-.325**	-.004
		Sig. (2-tailed)	.953	.000	.009	.972
	Domestic Waste	Pearson Correlation	.302*	.550**	-.738**	-.474**
		Sig. (2-tailed)	.015	.000	.000	.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.6.3 Shade and Ventilation

The study also endeavours to take note of the variables like building height to road width ratio and street orientation in the representative neighbourhoods to assess shade, ventilation and temperature variations. The amount of direct radiation received by a building and the street in an urban area is determined by the street width and its orientation. The buildings on one side of the street tend to cast a shadow on the street and on the opposite building, by blocking the sun's radiation. Thus the width of the street can be relatively narrow or wide depending upon whether the solar radiation is desirable or not. For instance in walled city Amritsar where Katra Dullo (a traditional neighbourhood) is located most of the streets are narrow with buildings shading each other as seen in map 4.3 that reduce the solar radiation, street temperature and heat gain of the buildings. This is however not the case in Ranjit Avenue as seen in map 4.4 and many of the other neighbourhoods that are laid out in a regular/grid form or in the gated communities where each block is considerable distance away from the other block and mutual shading of buildings or shading of neighbourhood streets is minimal. For the present study, onsite observations are undertaken and the shade is objectively measured in terms of shade rating and ventilation is measured as a score as given below:

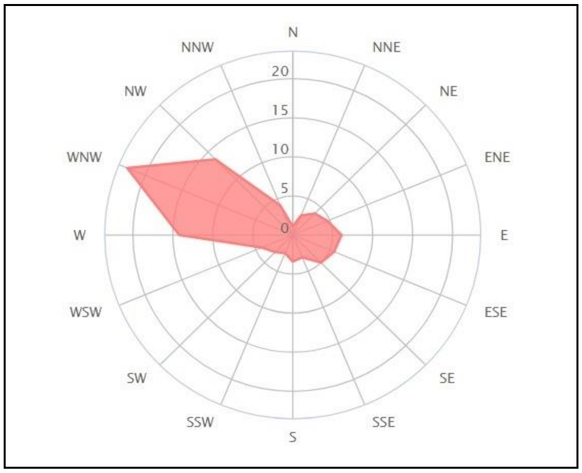
- **Shade Rating** is based on number of hours of shade provided by trees and buildings in a study unit. Average of all the units gives shade rating for the locality.
  (Source: https://www.student.cs.uwaterloo.ca/~cs132/Project/200501/Shade.html)

No. of hours of shade		Shade Rating
< 2	Sunny	1
2-5	Partially Shady	3
≥6	Shady	5

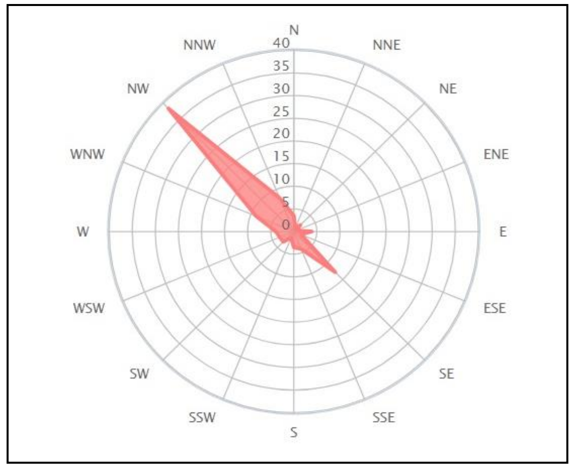
- **Ventilation Score** is based on orientation of street network. It is crucial because the potential for a comfortable outdoor life and passive climatic response in the built form follows from it. (Source: **Koenigsberger et.al. 1973**)

Street Type	Score	Criteria
⊥ or // Grid	1	Maximum radiation and minimum shade that negates the effect of wind.
Winding	3	Minimum radiation, reduces effect of stormy winds, establishes shadow space throughout the day that provides a cool and comfortable micro-climate.
Diagonal Grid	5	Less radiation and better shade enhancing the micro climate. Supports dynamic movement of air and hence outdoor ventilation.

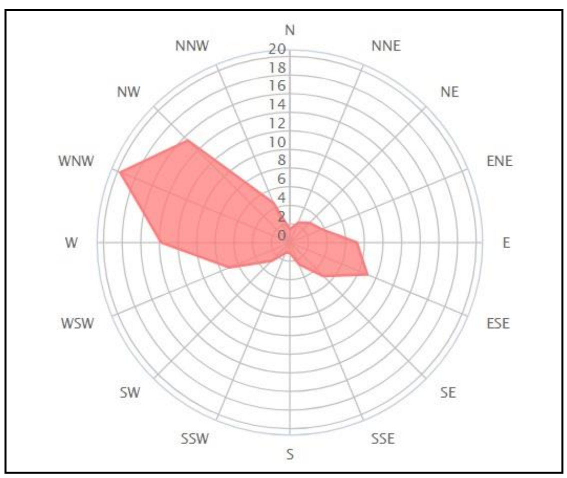
The wind rose diagrams of Amritsar[26], Chandigarh[27] and Gurugram[28] as shown in figure 4.19 are taken into consideration to ascertain the predominant wind direction especially in the hot and humid weather (June-September) and relate it with the orientation of the roads/streets of the study neighbourhoods to aid in the calculation of the ventilation score.



Predominant Wind Direction, Amritsar



Predominant Wind Direction, Chandigarh



Predominant Wind Direction, Gurugram

Figure 4.19: Wind Rose Diagrams

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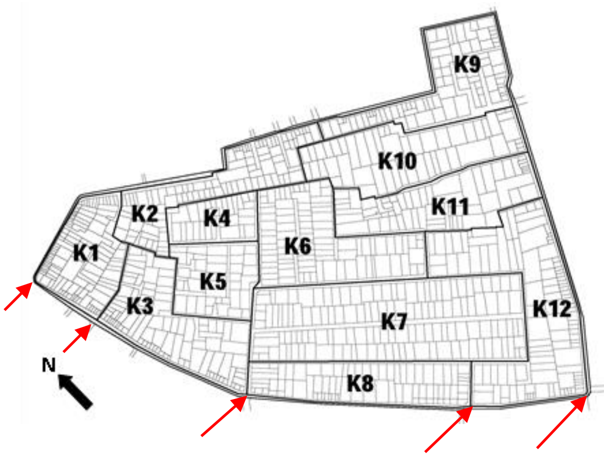
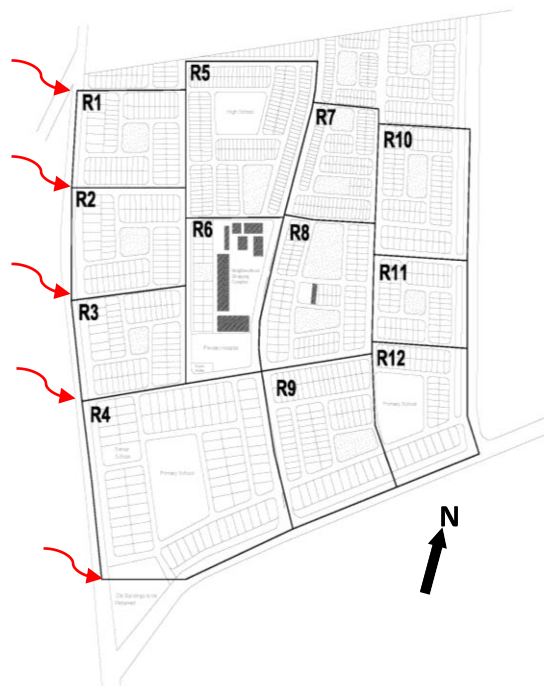
[26] Retrieved from https://www.windfinder.com/windstatistics/amritsar_airport on 21 June 2017

[27] Retrieved from https://www.windfinder.com/windstatistics/chandigarh on 21 June 2017

[28] Retrieved from https://www.windfinder.com/windstatistics/delhi_indira_gandhi_airport on 21 June 2017

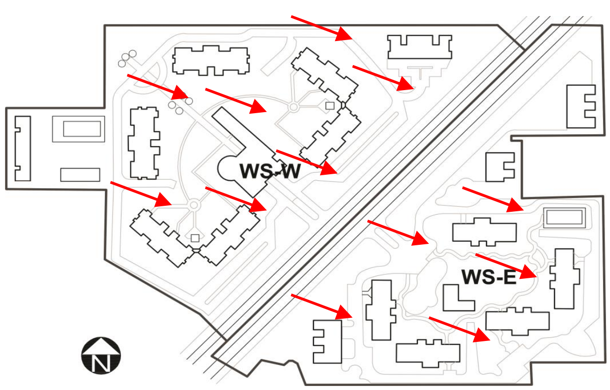
It is observed from the wind rose diagrams that in Amritsar and Gurugram, the predominant wing direction is from West North West to East South East. In case of Chandigarh, the predominant direction is from North West to South East. Now superimposing the predominant wind direction on the neighbourhood map and considering no major obstructions around, the following conclusions can be drawn as indicated in figure 4.20 and 4.21:

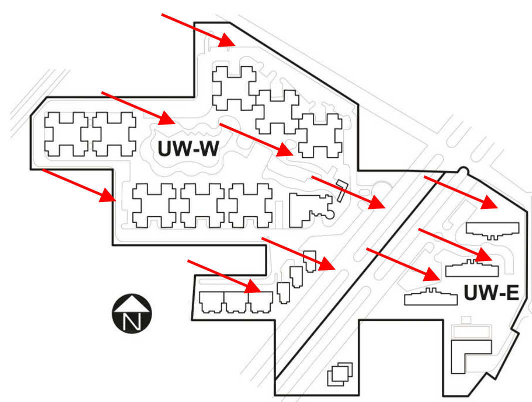




AMRITSAR

- **Katra Dullo** – WNW wind enters into the winding streets and creates cool and comfortable micro-climate.
- **Ranjit Avenue** – WNW wind flows through the regular grid with not much effect.





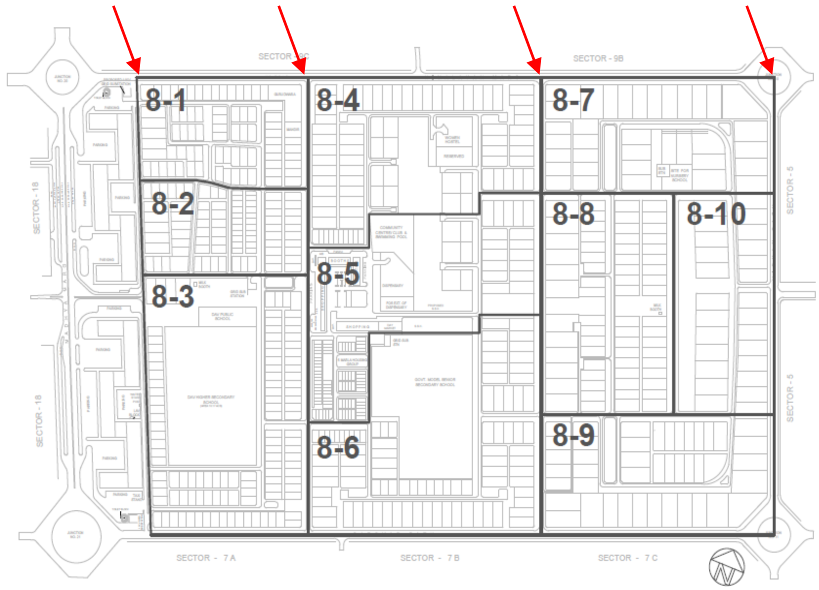
Gurugram

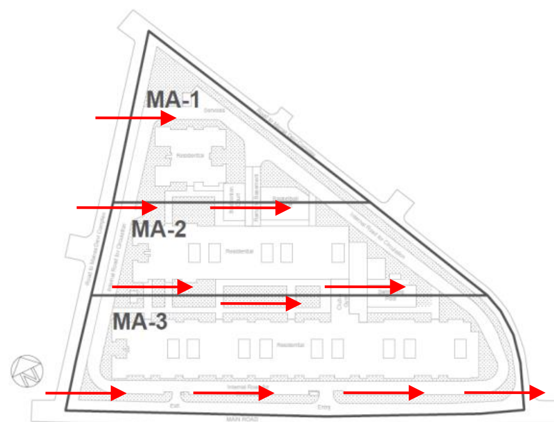
- **World Spa** – Dynamic air movement created in the western part because of obstruction to the flow of wind as a result of the tall towers. The effect is less in the eastern part.
- **Uniworld City –** Wind flows past the tall towers in the western part. The height and placement enhances the wind especially in the eastern part.

Figure 4.20: Wind Movement in neighbourhoods of Amritsar and Gurugram

Chandigarh

- **Sec-8** – NW winds flow // to the grid plan with minimal effect.
- **Sec-38W** – Part of the neighbourhood has the grid diagonal to the wind direction thus supporting dynamic movement of air and better ventilation. The other part has grid // to the wind flow thus having minimal effect on outdoor ventilation.





Marble Arch – Grid // to wind flow, thus minimal effect on ventilation.
Sec-20 – Most of the neighbourhood has wind flowing // to the grid. In certain gated communities internal open spaces cause dynamic air movement and better ventilation score.

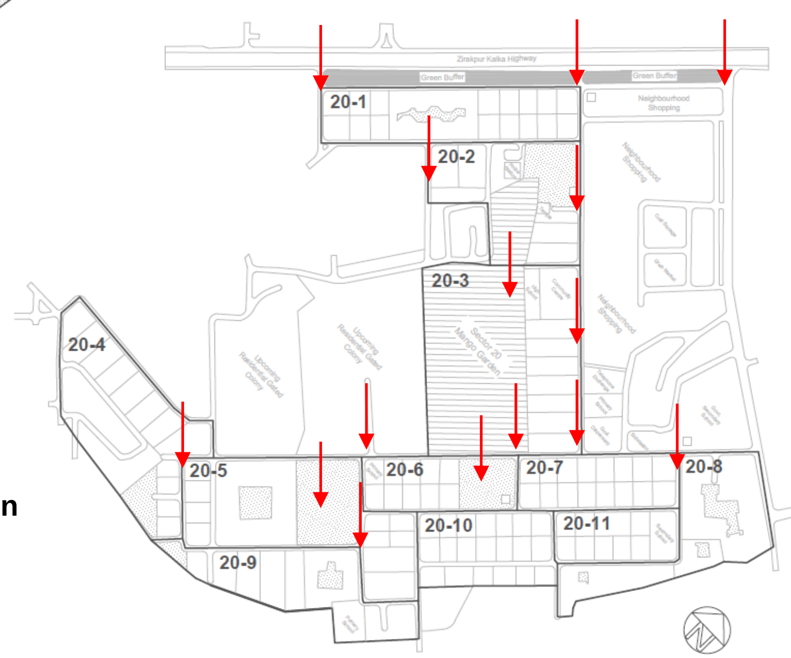


Figure 4.21: Wind Movement in neighbourhoods of Chandigarh

Two tables (table 4.8 and table 4.9) are shown below to illustrate the calculation of Shade Rating and Ventilation Score of Katra Dullo and Ranjit Avenue, Amritsar. Similar tables are also generated for the other neighbourhoods as indicated in Annexure 2.

Table 4.8: Shade Rating and Ventilation Score of Katra Dullo, Amritsar

UNIT OF STUDY	KATRA DULLO, AMRITSAR			
	Shade			Ventilation
	Building Ht. to Street Width Ratio (H/W)	No. of hours of Shade	SHADE RATING	SCORE
1	2:1, 5:1, 7.5:1	5	3	3
2	2:1, 5:1, 7.5:1	5	3	3
3	2:1, 5:1, 7.5:1	5	3	3
4	5:1, 7.5:1	6	5	3
5	5:1, 7.5:1	6	5	3
6	5:1, 7.5:1	6	5	3
7	5:1, 7.5:1	6	5	3
8	2:1, 5:1, 7.5:1	5	3	3
9	2:1, 5:1, 7.5:1	5	3	3
10	2:1, 5:1, 7.5:1	5	3	3
11	2:1, 5:1, 7.5:1	5	3	3
12	2:1, 5:1, 7.5:1	5	3	3
		MEAN	**4**	**3**

Table 4.9: Shade Rating and Ventilation Score of Ranjit Avenue, Amritsar

UNIT OF STUDY	TYPE OF PLOTS	RANJIT AVENUE, AMRITSAR			
		Shade			Ventilation
		Building Ht. to Road Width Ratio (H/W)	No. of hours of Shade	SHADE RATING	SCORE
R4	1K	1:1.5	2-5hrs	3	1
R1	1K/10M	1:1	2-5hrs	3	1
R2	1K/10M	1:1	2-5hrs	3	1
R3	1K/10M	1:1	2-5hrs	3	1
R9	1K/10M	1:1.5, 1:1	2-5hrs	3	1
R8	10M	1:1	2-5hrs	3	1
R12	1K/8M	1:1	2-5hrs	3	1
R10	8M	1:1	2-5hrs	3	1
R11	8M	1:1	2-5hrs	3	1
R5	6M	1:1	2-5hrs	3	1
R6	Flatted	1:1.5	2-5hrs	3	1
R7	10/4M	1:1	2-5hrs	3	1
			MEAN	**3**	**1**

4.6.4 Temperature variations within and outside the neighbourhood

The arrangement of buildings and open spaces in a neighbourhood affect the radiation falling on the building surfaces, streets, roads etc. These in turn heat or cool the air temperature and have considerable effect on the micro-climate. The same principle works in case of the study neighbourhoods. For example, in Katra Dullo, Amritsar it is observed that as a result of higher shade rating, ambient temperatures measured with the RH Temperature Data Logger at street level in July 2014 within the neighbourhood are almost 2 degrees lower than surrounding areas. Similarly, the presence of trees filter the sunlight, reduce air temperature by evaporation, protect smaller plants on the ground and reduce glare from bright overcast skies. In most of the other neighbourhoods, because of the presence of parks, playgrounds and trees, the temperatures are about 1 degree lower than the surrounding areas as seen in table 4.10. Overall it is noted that the ambient temperatures in Ranjit Avenue, Sector-8, Sector-38W, Marble Arch, World Spa and Uniworld City are lesser because of presence of trees in these neighbourhoods. Thus, both shade and naturalness increase the outdoor comfort conditions for the residents especially during the summer months. The table 4.10 shows the temperature values for Katra Dullo and Ranjit Avenue, Amritsar.

Table 4.10: Mean temperature difference within and outside the neighbourhood, Amritsar

Katra Dullo			Ranjit Avenue			
UNIT OF STUDY	Within Neighbourhood	Outside Neighbourhood	UNIT OF STUDY	TYPE OF PLOTS	Within Neighbourhood	Outside Neighbourhood
	Observations	Observations at 4-5 random locations			Observations	Observations at 6-7 random locations
1			R4	1K	27.2°C	
2	28.1°C	30.1°C	R1	1K/10M	31.3°C	31.6°C
3	28.1°C	30.0°C	R2	1K/10M	31.3°C	
4			R3	1K/10M	29.9°C	31.6°C
5	28.0°C		R9	1K/10M	32.6°C	33.1°C
6			R8	10M	32.6°C	33.1°C
7	27.8°C	30.0°C	R12	1K/8M	32.1°C	
8			R10	8M	31.6°C	
9	27.8°C	29.7°C	R11	8M	32.1°C	32.1°C
10			R5	6M	31.3°C	
11	28.1°C	29.9°C	R6	Flatted	31.6°C	31.6°C
12			R7	10/4M	31.2°C	33.1°C
Average Temp. =	**27.98°C**	**29.94°C**		**Average Temp. =**	**31.2°C**	**32.3°C**
Mean Temperature Difference		**1.96°C**		**Mean Temperature Difference**		**1.1°C**

The average shade rating and ventilation scores w.r.t. the density variables is tabulated for all the neighbourhoods as shown in table 4.11 below:

Table 4.11: Density variables and Indicators of Shade, Ventilation and Temperature Variation*

Neighbourhood	Residential Density (DUs/ha)	FAR	Plot Coverage (%)	Building Height to Road Width (Ratio)	Dist. Of Open Spaces (%)	Tree Cover (%)	Shade Rating	Ventilation Score	Temp. Variation (°C)
Sector 8, Chandigarh	17	1.00	49%	0.40	37%	28%	3.00	1.00	0.9
Ranjit Avenue, Amritsar	36	1.00	30%	0.93	55%	49%	3.00	1.00	1.1
World Spa, Gurugram	44	2.00	11%	3.17	89%	41%	3.00	4.00	1.2
Marble Arch, Manimajra	65	1.57	31%	0.50	68%	35%	3.00	1.00	1.1
Sector 38W, Chandigarh	76	2.00	70%	0.83	30%	23%	3.00	2.00	0.8
Sector 20, Panchkula	98	2.00	35%	1.40	65%	25%	1.00	1.00	0.3
Uniworld City, Gurugram	147	2.03	15%	3.17	85%	41%	3.00	3.00	1.2
Katra Dullo, Amritsar	149	3.00	85%	5.30	15%	3%	4.00	3.00	2.0

* Refer Annexure 2, Data Sheet 8 - Data Sheet 21

This is followed by a correlation analysis to ascertain the association between the density variables and indicators of environmental quality. The correlation analysis (as indicated in table 4.12) shows that there is significant association between building height to road width ratio and shade rating. This means that as the height to width ratio increases, the shade also increases in the neighbourhood as seen in figure 4.22. This is particularly observed in case of Katra Dullo, Amritsar, World Spa and Uniworld City, Gurugram.

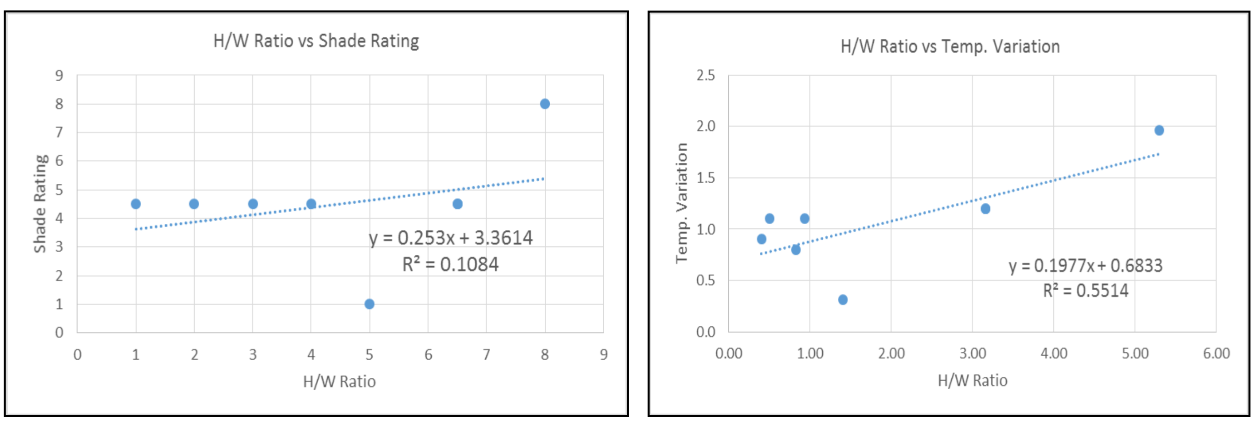


Figure 4.22: H/W ratio versus Shade Rating and Temperature Variations

Table 4.12: Correlation between Density and Shade, Ventilation and Temperature Variation

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

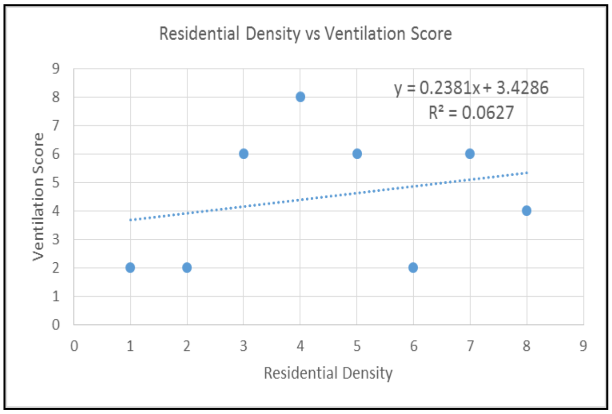
			Environmental Quality Indicators		
			Shade Rating (Spearman's rho)	Ventilation Score (Spearman's rho)	Temperature Variation (Pearson Correlation)
People Density	Residential Density	Correlation Coeff.	.050	.446**	.410**
		Sig. (2-tailed)	.410	.000	.001
Building Density	FAR	Correlation Coeff.	.105	.351**	.569**
		Sig. (2-tailed)	.079	.000	.000
	Plot Coverage	Correlation Coeff.	.055	.199**	.516**
		Sig. (2-tailed)	.359	.001	.000
Spatial Density	Height to Width Ratio	Correlation Coeff.	.477**	.735**	.781**
		Sig. (2-tailed)	.000	.000	.000
	Dist. of Open Spaces	Correlation Coeff.	-.229**	.226**	-.617**
		Sig. (2-tailed)	.000	.000	.000
Quality Indicator	Tree Cover	Correlation Coeff.	.061	.036	-.320**
		Sig. (2-tailed)	.307	.547	.010

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The correlation matrix also substantiates the above findings by showing significant positive correlation between residential density, FAR, height to width ratio and ventilation and temperature variations as seen in figure 4.23 and figure 4.24. This happens because as the built-form becomes more compact with narrow street widths, the wind speeds increase as a result of the tunnel effect. Also because of the considerably higher shade hours, the temperature variations within and outside the neighbourhood are enhanced.

The negative correlation between the distribution of open spaces, tree cover and temperature variations seen in figure 4.25 validate the point that presence of naturalness and greenery regulates the temperatures, reduces fluctuations and helps in creating a comfortable microclimate.



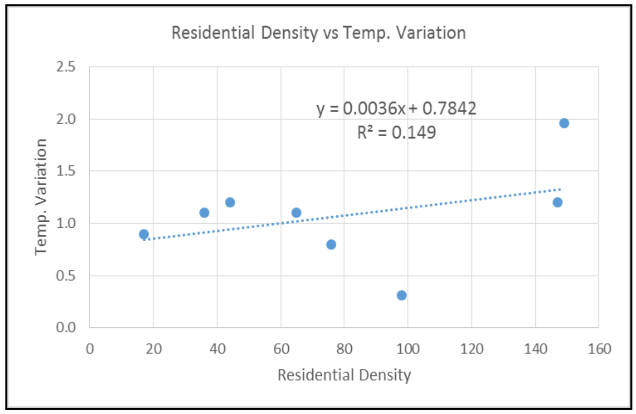
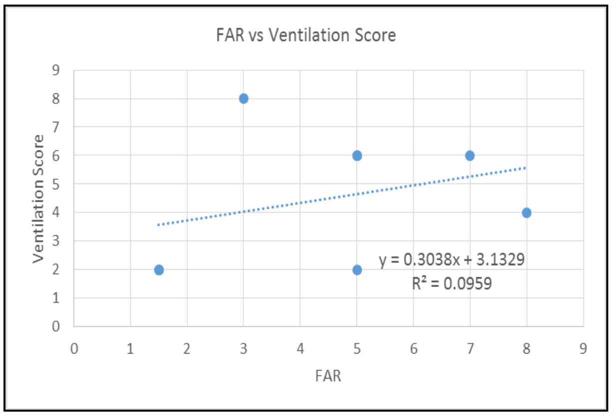


Figure 4.23: Residential Density versus Ventilation Score and Temperature Variation



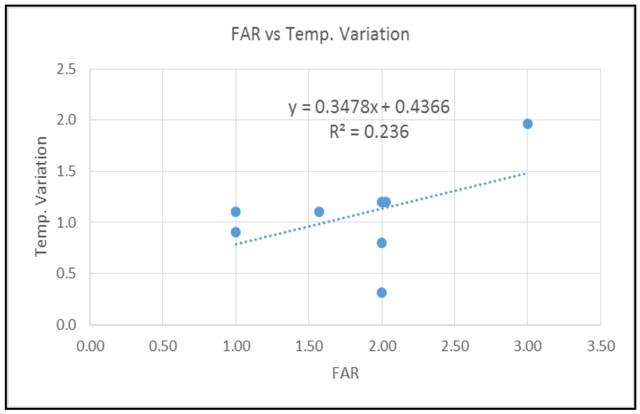


Figure 4.24: FAR versus Ventilation Score and Temperature Variation

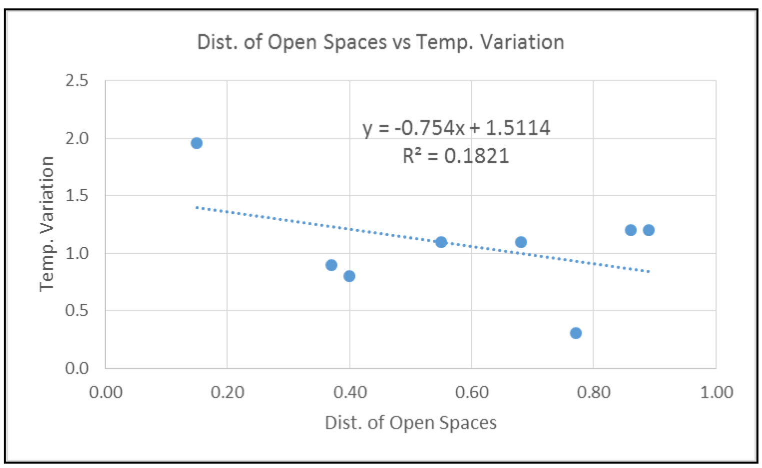


Figure 4.25: Distribution of Open Spaces versus Temperature Variation

4.6.5 Noise Levels

To control the generation of noise by various sources in the environment, the Central Pollution Control Board (CPCB), under the Ministry of Environment and Forests, Government of India, has set sound standards for different categories of areas (residential, commercial, industrial and silence zones), separately for day-time and at night as indicated in table 4.13.

Table 4.13: Sound Standards for different categories of areas for day time and night time

Area code	Category of area/zone	Limits in dB(A) leq*	
		Day time	Night time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence zones	50	40

*dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing. Source: Central Pollution Control Board, India

Source: Central Pollution Control Board, Govt. of India.

The present study uses the Smartphone DeciBel Android Application to record the noise at entry / exit points, inner areas and peripheral roads of all the neighbourhoods. From the recorded values, the average noise level of each of the neighbourhoods is calculated and tabulated as in table 4.14:

Table 4.14: Density variables and Average Noise Level in Case Study Neighbourhoods*

Neighbourhood	Population Density (persons/ha)	Residential Density (DUs/hectare)	FAR	Plot Coverage (%)	Dist. of Open Spaces (%)	Dist. of Roads (m/ha)	Average Noise Level (dB)
Sector 8, Chandigarh	95	17	1.00	49%	37%	189	54
Ranjit Avenue, Amritsar	256	36	1.00	30%	55%	354.38	65
World Spa, Gurugram	178	44	2.00	11%	89%	422	67
Marble Arch, Manimajra	345	65	1.57	31%	68%	232.79	53
Sector 38W, Chandigarh	441	76	2.00	70%	30%	403	56
Sector 20, Panchkula	540	98	2.00	35%	65%	179	61
Uniworld City, Gurugram	735	147	2.03	15%	85%	192	68
Katra Dullo, Amritsar	641	149	3.00	85%	15%	737	50

* Refer Annexure 2, Data Sheet 15 - Data Sheet 21

As per the conceptual framework (table 3.9, Chapter 3), sound is expected to vary mainly with distribution of roads and open spaces. It is also expected to have an association with people and building density based on the assumption that more people or dwelling units will imply more traffic in the neighbourhood and hence more noise. Higher FAR and plot coverage is also expected will have the same impact.

Table 4.15: Correlation between Density and Noise Levels

Note: Significant correlations (p<0.01) are highlighted, positive in green and negative in red

			Environmental Quality Indicator
			Noise Level
People Density	Population Density	Pearson Correlation	-.048
		Sig. (2-tailed)	.706
	Residential Density	Pearson Correlation	-.129
		Sig. (2-tailed)	.311
Building Density	FAR	Pearson Correlation	-.233
		Sig. (2-tailed)	.063
	Plot Coverage	Pearson Correlation	-.526**
		Sig. (2-tailed)	.000
Spatial Density	Dist. of Open Spaces	Pearson Correlation	.642**
		Sig. (2-tailed)	.000
	Dist. of Roads	Pearson Correlation	-.458**
		Sig. (2-tailed)	.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

However, the correlation matrix as indicated in table 4.15 shows some unexpected associations. While there is no significant association between people density, FAR and noise levels; there is significant association of plot coverage, distribution of open spaces and roads with noise level as indicated in figure 4.26. It is found that noise level tends to decrease with increase in plot coverage and distribution of roads and increase with distribution of open spaces, both situations contrary to the assumptions. This may be because in compact neighbourhoods with high plot coverage, people tend to generally walk for their daily needs and short trips. Even the presence of more road length per hectare, does not prompt them to use their motorized vehicles thus lowering the noise levels. This is particularly observed in Katra Dullo, Amritsar and Sec-38W, Chandigarh. On the other hand, noise levels show positive correlation with distribution of open spaces because the following neighbourhoods: Sec-20, Panchkula; World Spa and Uniworld

City, Gurugram even though have considerable parks and open spaces are situated along major roads where noise levels are high (>60dB). Thus, location of the neighbourhood in the city becomes an important factor for average noise levels irrespective of the distribution of open spaces. It is also observed that many of the neighbourhoods have lower noise levels (46-55dB) inside the locality. The lower level may be due to the presence of trees and vegetation that also contribute to the decrease **(Naturvardsverket, 1996)**. Soft ground and vegetation also decrease the noise levels. Because of the presence of parks and playgrounds, this is particularly experienced in the inner areas of Ranjit Avenue, Amritsar and Sec-8 and Marble Arch, Chandigarh with average day time noise levels of 48dB inspite of vehicular traffic. Vegetation also contributes by shielding the visual intrusion of traffic and thus making it less disturbing **(Bolund and Hunhammar, 1999)**. Evergreen trees like Indian Devil Tree, Mango, Jamun, Ashok, Peepal, etc. found abundantly in these neighbourhoods help in this regard.

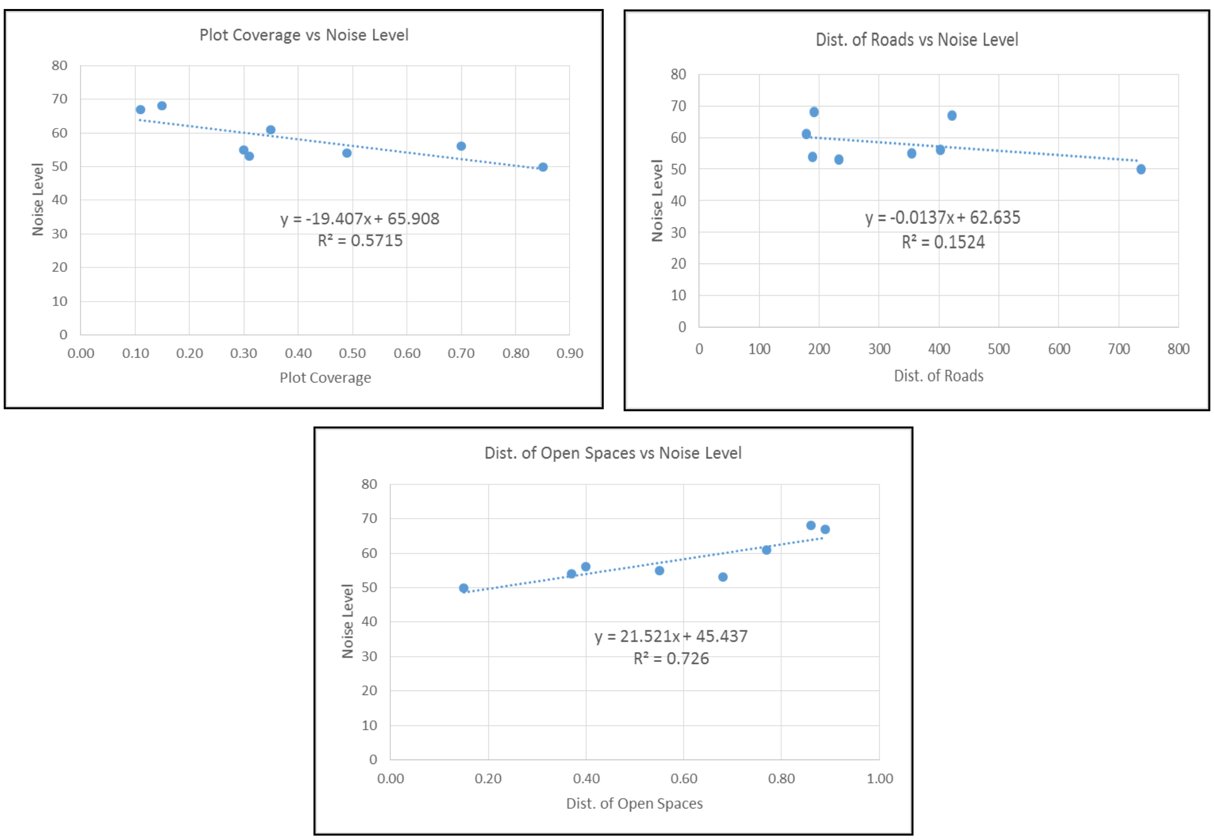


Figure 4.26: Plot Coverage, Distribution of Roads & Open Spaces versus Noise Levels

4.6.6 Level of Cleanliness

The level of cleanliness is assessed on the basis of three factors namely domestic waste management, provision of storm water drainage and sewage network. As per the Handbook of Service Level Benchmarking of the Ministry of Urban Development, Govt. of India; 100% of the road length should be attended by primary/secondary solid waste collection service and covered by storm water drainage; and all properties should be connected to the sewage network to achieve and maintain cleanliness in the locality. The study showed that the situation in Katra Dullo, Amritsar is especially bad with the average values of the cleanliness indicator, drainage indicator and sewage indicator being 59%, 53% and 35% respectively as indicated in table 4.16. Open drains are a common sight in Katra Dullo. Only 30-35% houses are connected to the underground sewage system laid by the municipal corporation. Storm water drains are choked with solid waste that lead to water-logging in central areas of Katra Dullo. Inspite of door to door collection of solid waste, foul and filthy conditions prevail in most parts as people dispose the waste near door fronts, junctions and community spaces which are further littered by stray dogs and cattle.

Table 4.16: Level of Services in Katra Dullo, Amritsar

Study Unit	**Domestic Waste Mgmt.**		**Storm-water Drainage**		**Sewage Network**		
	Road length attended	**Cleanliness Indicator**	Road length covered	**Drainage Indicator**	Total no. of properties	No. of properties connected	**Sewage Indicator**
K1	140	0.70	120	0.60	97	39	0.40
K2	98	0.70	56	0.40	78	31	0.40
K3	154	0.70	88	0.40	77	31	0.40
K4	82.5	0.50	66	0.40	30	8	0.25
K5	75	0.50	75	0.50	33	8	0.25
K6	115	0.50	138	0.60	79	20	0.25
K7	321	0.50	321	0.50	90	27	0.30
K8	205.8	0.60	172	0.50	71	28	0.40
K9	258	0.60	258	0.60	65	26	0.40
K10	166.2	0.60	166	0.60	45	18	0.40
K11	181.2	0.60	181	0.60	50	20	0.40
K12	261.6	0.60	262	0.60	60	24	0.40
	Avg. Value =	**59%**	**Avg. Value =**	**53%**	**775**	**Avg. Value =**	**35%**
	Threshold Value	**100%**		**100%**			**100%**
		Handbook of Service Level Benchmarking, MoUD, GOI		*Handbook of Service Level Benchmarking, MoUD, GOI*			*Handbook of Service Level Benchmarking, MoUD, GOI*

The rest of the neighbourhoods have good quality services with average values of the cleanliness indicator, drainage indicator and sewage indicator all being 100% as shown in Annexure 2. The services cater to the existing population and generally provide a neat and clean environment for the people to stay. Occasionally, solid waste and garden waste is seen littered near the community bins and along sidewalks that create filthy conditions and have a negative impact on the neighbourhood environmental quality. This situation is observed in certain parts of Ranjit Avenue, Amritsar; Sec-8 and Sec-38W, Chandigarh; and Sec-20, Panchkula, Chandigarh.

Table 4.17: Correlation between Density and Level of Cleanliness

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

			Environmental Quality Indicator
			Level of Cleanliness
People Density	Population Density	Pearson Correlation	-.278*
		Sig. (2-tailed)	.026
	Residential Density	Pearson Correlation	-.385**
		Sig. (2-tailed)	.002
Spatial Density	Domestic Waste	Pearson Correlation	.675**
		Sig. (2-tailed)	.000
	Stormwater Drainage	Pearson Correlation	.655**
		Sig. (2-tailed)	.000
	Sewerage	Pearson Correlation	.677**
		Sig. (2-tailed)	.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The correlation matrix clearly indicates that with rise in population and residential density and poor distribution of services or inadequate services as in Katra Dullo, Amritsar; the level of cleanliness is low as indicated by the negative correlation. On the other hand good distribution of services and regular maintenance and upkeep of the neighbourhood ensure higher level of cleanliness as indicated by the positive correlation. Therefore, there is significant correlation between density and neighbourhood environmental quality based on level and adequacy of services as seen in table 4.17.

4.6.7 Walkability

Physical environment is associated with physical activity in the form of walking/cycling for transport. Approaches to urban design termed Smart Growth and New Urbanism have emerged in response to the need to improve air quality, solve traffic congestion and promote better overall quality of life **(Frank, 2000; Jackson et al., 2002 and Chen, 2000)**. Various studies have demonstrated associations between physical variables of the built environment such as density, connectivity, proximity, land use mix and walkability. Other potential environmental correlates of non-motorized transport that have shown a significant effect on neighbourhood walkability are presence and quality of sidewalks/bicycle lanes/trails; park characteristics, tree canopy and topography; cost, location and availability of parking (lots); weather and crime.

Based on the above understanding, the walkability of all the neighbourhoods is assessed in terms of proximity to daily needs, condition of sidewalks, adequacy of streetlights and type and condition of open spaces. Average scores for each of the variables is calculated as Very Good =5, Good =4, Average =3, Bad =2 and Poor =1. The observations are tabulated in table 4.18 and are plotted as a bar chart as shown in figure 4.27.

Table 4.18: Average Scores of Indicators of Walkability*

Indicators of Walkability					
Neighbourhood	Average Score				
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights	Type & Condition of Open Space	Aggregate Walkability Score
Sector-8, Chandigarh	4	2	5	2	3
Ranjit Avenue, Amritsar	5	3	4	3	4
World Spa, Gurugram	5	5	5	5	5
Marble Arch, Manimajra	1	3	5	4	3
Sector-38W, Chandigarh	5	2	5	4	4
Sector-20, Panchkula	3	2	5	3	3
Uniworld City, Gurugram	5	5	5	5	5
Katra Dullo, Amritsar	5	1	4	2	3

* Refer Annexure 2, Data Sheet 22 – Data Sheet 28

The bar chart clearly indicates that average walkability score or neighbourhoods that are more walkable are those that have better proximity to daily needs, good condition of sidewalks and open spaces.

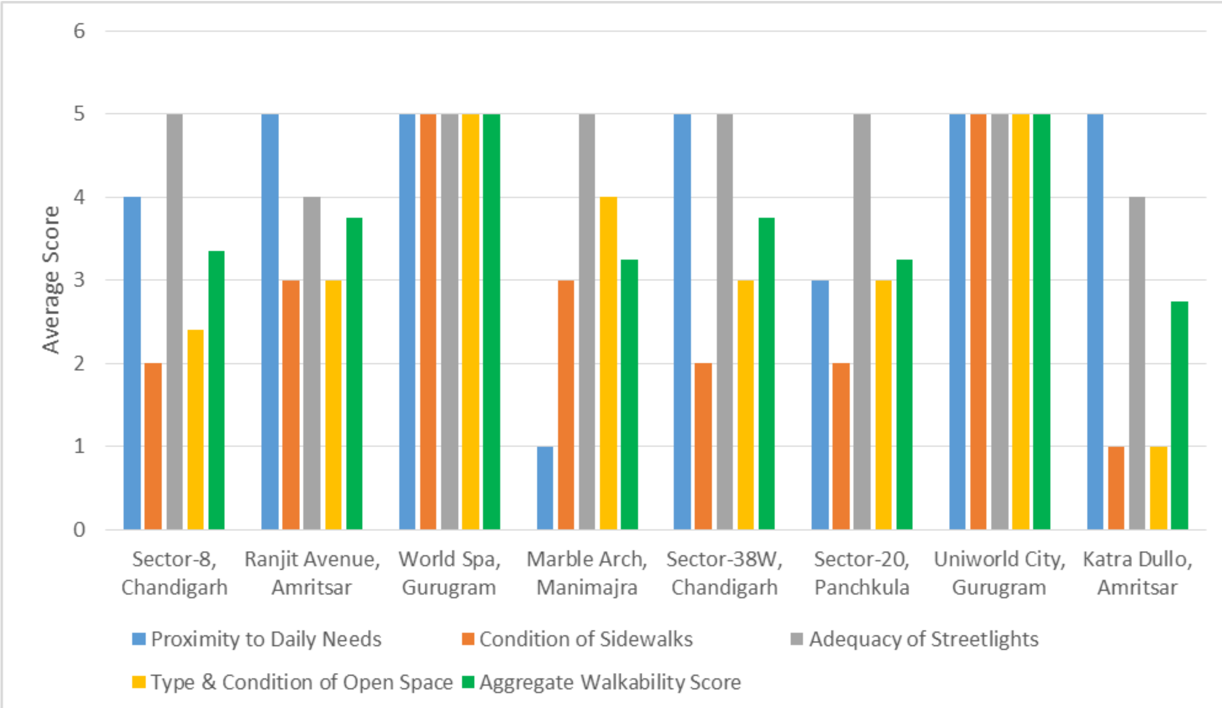


Figure 4.27: Walkability indicators in different case study neighbourhoods

It also shows that neighbourhoods where daily needs are within 1/2km distance encourage people to walk. However, Katra Dullo, Amritsar fares badly as there are no sidewalks along the wider roads on the periphery and inner streets are narrow and congested because of rickshaws, cycles and scooters; on-street parking; and garbage dumps creating filthy conditions for people to walk. Most of the street lights are not in working condition thus rendering it unsafe to walk after sunset. The poor quality/nature of spaces and absence of parks etc. is also a major hindrance to the creation of a walkable neighbourhood. On the other hand, though Ranjit Avenue, Amritsar and Sec-8, Chandigarh have tree lined shaded avenues that inspire people to walk, the absence of continuous sidewalks hampers the experience and curbs peoples' wish to walk. Also wider roads promote fast traffic jeopardizing the safety of the pedestrians. Marble Arch (Manimajra), Chandigarh scores less because of the distance to daily needs and Sec-20 (Panchkula), Chandigarh has average score because of the bad and discontinuous sidewalks. In Sec-38W, Chandigarh; World Spa and Uniworld City, Gurugram; proximity to daily needs and parks and open spaces encourage people to walk, jog, relax and interact within these spaces thus adding to the overall environmental quality. The comparatively high height to width ratio (3.17) in World Spa and Uniworld City, Gurugram also adds to the aggregate walkability score.

The correlation matrix as indicated in table 4.19 shows that there are significant positive associations between height to width ratio, distribution of open spaces and sidewalks, streetlight density, distribution of services and neighbourhood walkability. However, there is significant negative correlation between distribution of roads and neighbourhood walkability. Therefore, as the shade due to higher H/W ratio, naturalness due to open spaces, amount of sidewalks, safety due to streetlights and cleanliness increases in the neighbourhood as a result of better services like efficient solid waste management, good storm water drains and proper sewerage system, people are encouraged to walk and generally adopt walking for their daily needs and short trips within and in the immediate surroundings of their neighbourhood.

Table 4.19: Correlation between Density and Neighbourhood Walkability

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

			Environmental Quality Indicator
			Aggregate Walkability Score
Spatial Density	Height to Width Ratio	Pearson Correlation	.145*
		Sig. (2-tailed)	.015
	Dist. of Open Spaces	Pearson Correlation	.447**
		Sig. (2-tailed)	.000
	Dist. of Roads	Pearson Correlation	-.139*
		Sig. (2-tailed)	.020
	Sidewalks	Pearson Correlation	.751**
		Sig. (2-tailed)	.000
	Streetlight Density	Pearson Correlation	.197**
		Sig. (2-tailed)	.001
	Domestic Waste	Pearson Correlation	.353**
		Sig. (2-tailed)	.000
	Stormwater Drainage	Pearson Correlation	.340**
		Sig. (2-tailed)	.000
	Sewerage	Pearson Correlation	.347**
		Sig. (2-tailed)	.000

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.6.8 Air Quality

Central Pollution Control Board (CPCB), New Delhi has been monitoring ambient air quality in 224 cities/towns in 26 states and 5 union territories under National Ambient Air Quality Monitoring Programme (NAAQMP) through 544 ambient air quality monitoring stations. These stations have been set up for primarily monitoring Respirable Suspended Particulate Matter (RSPM), Sulphur dioxide (SO_2) and oxides of Nitrogen (NO_x).

One of the major areas of environmental concern in cities is that of rising air pollution levels as a result of increasing personalized modes of transport and intermediate modes of transport such as auto rickshaws in the absence of efficient public transportation system. For example, in Amritsar 60% of goods vehicles are auto rickshaws (2.43% of total registered vehicles). Most of these vehicles use kerosene as the fuel thus creating air pollution. The personalized vehicles are also responsible for creating congestion and pollution on roads. Apart from automobile pollution, the other major source of air pollution in the city is industrial emission of gases. The various industrial units like rice shellers, and other scattered industries in the cities release intensive air pollutants into the atmosphere, which even affect the environment of the surrounding residential areas. In addition another major source of air pollution in the city consists of pollution from developmental activities, handling and burning of municipal and domestic waste and from agriculture waste burning etc. With a view to clearly assess and monitor the status and quality of ambient air in Indian cities, several monitoring stations in different parts of the city i.e. industrial, residential and commercial zones are established and managed by Central Pollution Control Board and its zonal offices (CPCB), State Pollution Control Board (SPCB) and Pollution Control Committees (PPC). The data collected from these monitoring stations with respect to $RSPM_{10}$, SO_2 and NO_x reflects much higher $RSPM_{10}$ levels in the air in both residential and commercial areas against the permissible limit of 60μg/m^3 indicating poor quality of air in these areas. With regard to the level of SO_2 and NO_x, it has been found that the observed values are generally below the prescribed standards in all the areas as indicated in table 4.20.

Table 4.20: Density variables and Indicators of Ambient Air Quality

Neighbourhood	Population Density (persons/ha)	Residential Density (DUs/ha)	Dist. of Open Spaces (%)	Dist. of Roads (m/ha)	Level of Services (Score)	SO_2 (μg/m^3)	NO_x (μg/m^3)	$RSPM_{10}$ (μg/m^3)	Source
Sector 8, Chandigarh	95	17	37%	189	2.7	2	20	101	NAAQM Report 2012
Ranjit Avenue, Amritsar	256	36	55%	354.38	2.33	15	40	210	NAAQM Report 2012
World Spa, Gurugram	178	44	89%	422	3	6.73	15.67	112.71	HSPCB 2015-17
Marble Arch, Manimajra	345	65	68%	232.79	3	2	19	110	NAAQM Report 2012
Sector 38W, Chandigarh	441	76	30%	403	2.67	2	18	103	NAAQM Report 2012
Sector 20, Panchkula	540	98	65%	179	2.55	6.42	23.68	53.93	HSPCB 2015-17
Uniworld City, Gurugram	735	147	85%	192	3	6.73	15.67	112.71	HSPCB 2015-17
Katra Dullo, Amritsar	641	149	15%	737	1.42	8.24	32.59	81.22	CPCB 2017
				Threshold Value		50	40	60	

The present study considers monitoring stations lying in the airshed[29] at a distance of 1-3kms from the study neighbourhoods. In case of absence of a nearby monitoring station, the annual average values of SO_2, NO_x and $RSPM_{10}$ for the city are considered. For Amritsar, Vinod Milk Chilling Station is considered as the monitoring station for Katra Dullo lying in the airshed at a distance of approximately 1.5km. For Ranjit Avenue, observations at A-One Platers about 1km away are considered. Similarly, in case of Chandigarh, Institute of Microbial Technology (IMTECH), Sector-39 is considered for Sector-38W and Sector-17 lying across Madhya Marg is considered for Sector-8. For Marble Arch, Manimajra, annual average values of Chandigarh are taken for the study and Sector-20, Panchkula is assigned values obtained from Haryana State Pollution Control Board's (HSPCB) monitoring station in Sector-6, Panchkula. For the neighbourhoods of Gurugram – World Spa and Uniworld City, Sector-30, HSPCB's IIFCO Chowk (junction) monitoring station at a distance of 2.44km is considered.

It is observed that SO_2 levels are well within permissible limits in all the neighbourhoods due to various measures taken such as reduction of sulphur in diesel etc. and use of LPG as domestic fuel. Also, conversion of diesel vehicles to CNG may have contributed to reduction in ambient SO_2 levels. However, Ranjit Avenue has higher SO_2 levels because of use of diesel generators by commercial establishments and more number of vehicular traffic in the neighbourhood.

The NO_x levels though on the higher side are within permissible limits in all the neighbourhoods. There is no significant difference between the neighbourhoods due to various measures taken for vehicular pollution control such as stricter vehicular emission norms etc.

$RSPM_{10}$ levels are much higher than the permissible limits in almost all the neighbourhoods. The reasons for high particulate matter levels in most of the neighbourhoods are increasing private vehicles, re-suspension of traffic dust and dust from road sweeping, construction activities, use of generators in commercial establishments and residences, etc.

The correlation matrix as indicated in table 4.21 restates that with increase in population density and residential density or compact neighbourhoods with less dependence on vehicular traffic; air quality improves as shown by the negative correlation or decreasing values of $RSPM_{10}$. The

[29] An airshed is a part of the atmosphere that behaves in a coherent way with respect to the dispersion of emissions. It typically forms an analytical or management unit. Also: A geographic boundary for air quality standards.
Source: https://en.wikipedia.org/wiki/Airshed

increase in road distribution (m/ha) suggests more vehicles on the roads per unit area which in turn increases NO_x values as shown by the positive correlation. Increase in NO_x deteriorates the air quality and subsequently the overall environmental quality of the place.

The level of services also show significant association with indicators of air quality. As the level of services increases with better solid waste collection, the values of the indicators decrease as shown by the negative correlation. This further implies better air quality. In this context, poor level of services causing foul smell from littered garbage, smoke from 'bhattis'[30] of sweet shops, household and street dust, etc. especially trapped within the narrow streets of Katra Dullo, Amritsar affect the quality of air and deteriorate the environmental quality.

Table 4.21: Correlation between Density and Indicators of Air Quality

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in red and negative in green

			Environmental Quality Indicators		
			SO_2	NO_x	$RSPM_{10}$
People Density	Population Density	Pearson Correlation	.069	.066	-.399**
		Sig. (2-tailed)	.585	.603	.001
	Residential Density	Pearson Correlation	.015	.052	-.490**
		Sig. (2-tailed)	.906	.685	.000
Spatial Density	Dist. of Open Spaces	Pearson Correlation	.081	-.207	.040
		Sig. (2-tailed)	.527	.101	.753
	Dist. of Roads	Pearson Correlation	.209	.355**	-.020
		Sig. (2-tailed)	.098	.004	.877
	Domestic Waste	Pearson Correlation	-.158	-.362**	.277*
		Sig. (2-tailed)	.212	.003	.027

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

30 Tandoor and Bhatti are not used for indoor cooking at homes. Tandoor is a community clay oven used for fee in the neighborhoods. Bhatti is a large stove made with bricks and clay to cook foods in bulk. Bhatti is used by professional cook (Halwai - confectioners and sweet makers) for large gatherings such as wedding. Most of the cooking over Bhatti is done in very large Karahi (A bowl-shaped frying pan with two handles used in Indian cookery). Wood and charcoal are used for fuel. Most of the restaurants use a combination of Tandoor and Bhatti.

4.7 Concluding Remarks

The present chapter identifies eight neighbourhoods based on height of buildings and population density from the three case study cities of Amritsar, Chandigarh and Gurugram and presents a detailed study of the same along with the study of the relationship between the different density variables and indicators of neighbourhood environmental quality. The size of the neighbourhoods vary from 4 to 105 hectares approximately.

Traditionally formed Katra Dullo from walled city Amritsar is chosen as an example of low-rise high density neighbourhood whereas planned area Ranjit Avenue located outside the walled city is selected as an example of low rise medium density neighbourhood. Four neighbourhoods are selected from Chandigarh, namely, Sec-8, Sec-38W, Marble Arch, Manimajra and Sec-20, Panchkula. They are examples of low rise low density, low rise high density, medium rise medium density and medium rise high density neighbourhoods respectively. Finally, two gated communities are selected from Gurugram – World Spa and Uniworld City, both located in Sec-30 as examples of high rise low density and high rise high density neighbourhood.

A detailed visual survey followed by organisation of primary and secondary data and study and analyses based on the conceptual framework as indicated in table 3.9, Chapter 3 and correlation coefficient analyses yield the following results:

a) The correlation coefficient analyses show that significant relationships (both positive and negative) exist between the density variables and indicators of neighbourhood environmental quality.
b) Crowding and congestion increase with increase in people density. Higher FARs and plot coverage reduce the public ground area per capita (PGA/Capita) and paved road length per capita (PRL/Capita) and aggravate congestion on roads as indicated by the increase in mobilization factor. In the present study, it is seen that as the residential density increases from 20DUs/hectare to 150 DUs/hectare approximately, FAR from 1 to 3 and plot coverage from 15% to 80-85%, the PGA/Capita falls from 35sqm/person to less than 10sqm/person. Similarly, the PRL/Capita reduces from over 2m/person to less than 0.55m/person thus indicating increasing crowding and congestion and deteriorating environmental quality.
c) People engage in community activities and group interaction because of the type and condition of the open spaces. Activity intensity increases from 11persons/hectare to

more than 500persons/hectare with increase in people density and building density. Activity diversity also shows an increasing trend (0.03 to 0.15) with increasing residential density from 50DUs/hectare to 150DUs/hectare with a few exceptions thus suggesting that more people engage in different activities and greater social interaction happens in high density neighbourhoods.

d) Other aspects like presence and condition of sidewalks, streetlights, outdoor furniture, level of cleanliness, etc. determine peoples' desire to reside, walk and utilize spaces.

e) The arrangement of buildings and open spaces in a neighbourhood affect the radiation falling on the building surfaces, streets, roads etc. These in turn heat or cool the air temperature and have considerable effect on the micro-climate. The compact and organically woven urban form of the old city in Amritsar especially as compared to the grid iron or regular plan of the new areas is more comfortable for the residents during the summer months because of the higher shade rating (average value=4 on a scale of 1-5) and lower temperatures (almost 2°C) within the neighbourhood as compared to the surroundings. The study also shows that there is significant association between building height to road width ratio and shade rating. This means that as the height to width ratio increases, the shade also increases in the neighbourhood. This is particularly observed in case of Katra Dullo, Amritsar, World Spa and Uniworld City, Gurugram with building height to road width ratio≥3 and shade rating=3 and in some cases≈4.

f) Similarly, the presence of trees filter the sunlight, reduce air temperature by evaporation, protect smaller plants on the ground and reduce glare from bright overcast skies. In most of the neighbourhoods, because of the presence of parks and playgrounds (55%-90%); and trees (varying from 30%-50%), the temperatures are about 1 degree lower than the surrounding areas. The negative correlation between the distribution of open spaces, tree cover and temperature variations validate the point that presence of naturalness and greenery regulates the temperatures, reduces fluctuations and helps in creating a comfortable microclimate. Thus, both shade and naturalness increase the outdoor comfort conditions for the residents especially during the summer months.

g) It is observed that noise levels tend to be in the prescribed range (50-55dB) for residential areas with increase in plot coverage (30%-85%) and distribution of roads (180-750m/hectare), both situations contrary to the assumptions. This may be because in compact neighbourhoods with high plot coverage, people tend to generally walk for their daily needs and short trips. Even the presence of more road length per hectare, does not prompt them to use their motorized vehicles thus lowering the noise levels.The presence of vegetated open spaces also helps in ameliorating noise pollution in the neighbourhood.

h) Good level of services and regular maintenance and upkeep of the neighbourhood ensure higher level of cleanliness as seen in most the case study neighbourhoods.

i) Proximity to daily needs, good condition of sidewalks and open spaces helps in creating walkable neighbourhoods. It is seen that there is significant positive correlation between level of services and neighbourhood walkability. Neighbourhoods with score≥3 for the level of services and other indicators on a 5 point scale are more walkable and hence sustainable. Therefore, as the cleanliness increases in the neighbourhood as a result of better services like efficient solid waste management, good storm water drains and proper sewerage system, people are encouraged to walk for their daily needs and short trips within and in the immediate surroundings of the neighbourhood.

j) Air quality is affected by the amount of roads, vehicles and congestion on roads, types of activities and appliances used, etc. More number of vehicles and smoke generating appliances imply more pollution and deterioration of air quality. The increase in people density or in compact neighbourhoods with less dependence on vehicular traffic; air quality improves as shown by the decreasing values of $RSPM_{10}$ in Katra Dullo, Amritsar. The increase in road distribution (m/ha) suggests more vehicles on the roads per unit area which in turn increases NO_x values as found in Ranjit Avenue, Amritsar. Increase in NO_x deteriorates the air quality and subsequently the overall environmental quality of the place. In this context, efforts are required to further develop a tool and monitoring methods/equipment for residential neighbourhoods, mixed-use localities, etc. similar to the Comprehensive Environmental Pollution Index (CEPI) for industrial clusters **(CPCB, 2009)** to gauge the impact on people and the neighbourhood environment in addition to assessing the environmental pollution levels (air, surface water and land).

k) Level of services also have an impact on air quality. As the level of services increases with better solid waste collection, the values of NO_x and SO_2 decrease. This further implies better air quality. Certain smells like foul smell from littered garbage, household and street dust, dust from development activities, etc. also affect the quality of air and deteriorate the environmental quality.

Thus, it can be concluded that most of the neighbourhood environmental quality indicators have significant correlations with the density variables as indicated in table 4.22 below. This validates the conceptual framework (table 3.9, Chapter 3) between the two types of variables and points assertively towards the research hypothesis that density impacts environmental quality in residential neighbourhoods.

Table 4.22: Summary of Correlation Analysis

Density Variables	Environmental Quality Indicators							
	Crowding & Congestion	Nature and use of Open Spaces	Shade & Ventilation	Temp. Variations	Noise Levels	Level of Cleanliness	Neighbourhood Walkability	Air Quality
Population Density	Negative (65%)	Positive (44.5%)				Negative (27.8%)		Positive (39.9%)
Residential Density	Negative (54.66%)	Positive (57.7%)	Positive (44.6%)	Positive (41%)		Negative (38.5%)		Positive (49%)
FAR, Plot Coverage	Negative (20.56%)	Positive (53.2%)	Positive (27.5%)	Positive (54.25%)	Negative (52.6%)			
Height to Width Ratio			Positive (60.6%)	Positive (78.1%)			Positive (14.5%)	
Distribution of Open Spaces	Positive (33.6%)	Negative (50.6%)		Negative (61.7%)	Positive (64.2%)		Positive (44.7%)	
Distribution of Roads and Sidewalks	Negative (47.4%)				Negative (45.8%)		Negative (13.9%) Positive (75.1%)	Negative (35.5%)
Distribution of Services	Positive (41.33%)	Negative (60.6%)				Positive (66.9%)	Positive (30.92%)	Positive (36.2%)

Strong Correlation (>40%) Weak Correlation (≤40%) Empty Cells – No Apparent Correlation

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ASSESSING NEIGHBOURHOOD ENVIRONMENTAL QUALITY

5.1 Introduction

This chapter details out the process of objectively assessing the (aggregated) neighbourhood environmental quality of each of the case study neighbourhoods using the multi-criteria approach and henceforth formulating the environmental quality index (EQI) for classifying the neighbourhoods based on the level of environmental quality. The environmental quality index is further used to generate illustrative maps for each of the neighbourhoods showing sections with extremely favourable, very favourable, quite favourable, favourable, average, unfavourable, quite unfavourable, very unfavourable and extremely unfavourable environmental quality. Any number of neighbourhoods can be analysed to generate the environmental quality scores and the process can be applied to entire cities thus enabling the identification of areas with good, average and poor environmental quality at the city level. It can further help in conducting cross-case comparisons and help rank cities based on the environmental quality in the residential neighbourhoods.

The chapter also consists of generating environmental quality profiles of the case study neighbourhoods. Environmental Quality Profile (EQP) is an effective way of graphically representing the different attributes of the concept (neighbourhood environmental quality, in this case) and communicating them easily using a polar/radar chart **(Khattab, 1993)**.

The final section of the chapter consists of correlating the people density, building density and spatial density **(Cheng, 2010)** with (aggregated) neighbourhood environmental quality so as to identify the associations between the two and understand the variation in environmental quality with change in residential pattern.

5.2 The Multi-criteria Approach for assessing Environmental Quality and Formulation of the Environmental Quality Index (EQI)

All the variables identified in table 2.11, Chapter 2 and as given below in table 5.1, are converted into Standardized Z-scores using IBM SPSS Statistics 22 (Statistical Package for Social Sciences). They are then merged together (averaged) to get the ZAEQ (Standardized Aggregated Environmental Quality) values for each of the study units of a neighbourhood as indicated in table 5.2). The average of the ZAEQ values of the different study units of a neighbourhood gives the Aggregated Neighbourhood Environmental Quality (ANEQ) value. The aggregated neighbourhood environmental quality (ANEQ) values derived from standardized z-scores lie between -1 and +1 as seen in table 5.4. The range from -1 to +1 is suitably divided into nine equal intervals starting from extremely favourable to extremely unfavourable with ±0.00 as the mid-point. This helps in generating the Environmental Quality Index (EQI) as indicated in table 5.3. Based on the EQI, the study units as well as the overall neighbourhood can be classified as having extremely favourable, very favourable, quite favourable, favourable, average, unfavourable, quite unfavourable, very unfavourable or extremely unfavourable environmental quality. Thus, the Aggregated Neighbourhood Environmental Quality (ANEQ) values consider all the parameters/variables/criteria to give objective values of environmental quality. Hence, the approach is referred to as the multi-criteria approach for assessing environmental quality.

Table 5.1: EQ Indicators and List of parameters/variables/criteria to assess ZAEQ

1.	**Crowding and Congestion**	1	Built-up Area per Capita (BUA/Capita)
		2	Public Ground Area per Capita (PGA/Capita)
		3	Paved Road Length per Capita (PRL/Capita)
		4	Mobilization Factor (M.F.)
2.	**Nature and Use of Open Spaces**	5	Type & Condition of Open Space
		6	Tree Cover
		7	Activity Intensity
		8	Activity Diversity
3.	**Shade and Ventilation**	9	Shade Rating
		10	Ventilation Score
4.	**Temperature Variations**	11	Mean Temperature Difference
5.	**Noise Level**	12	Average Noise Levels
6.	**Cleanliness**	13	Level of Cleanliness
7.	**Walkability**	14	Proximity to Daily Needs
		15	Condition of Sidewalks
		16	Adequacy of Streetlights
		17	Type & Condition of Open Space
8.	**Air Quality**	18	NO_x
		19	SO_2
		20	$RSPM_{10}$
Therefore, ZAEQ =		Sum of Standardized Z-scores of Criteria 1-20	

Table 5.2: Standardized Z Scores of Environmental Quality Parameters and Standardized Aggregated Environmental Quality Values (ZAEQ)

ZBUA/Capita	ZPGA/Capita	ZPRL/Capita	ZMob. Factor	ZCond.of Open Space	ZTree Cover	ZActivity Intensity	ZActivity Diversity	ZShade Rating	ZVentilation Score	ZTemp. Variation	ZNoise Levels	ZLevel of Cleanliness	ZProximity to Daily Needs	ZAdeq. of Streetlights	ZCond. of Sidewalks	ZSO_2	ZNO_x	ZRSPM	ZAEQ
.39480	-.87666	-.66989	1.95959	-.29675	-1.37204	3.25476	2.65228	.30082	1.04583	1.75978	.02699	-.55477	.49455	.85191	-.94439	.33360	.76248	-.58365	.16
.07392	-.91295	-.66989	1.95959	-.25248	-1.37204	2.26572	.78010	.30082	1.04583	1.75978	-.54888	-.55477	.49455	.85191	-.94439	.33360	.76248	-.58365	.03
.19324	-.90511	-.73593	-.13570	-.25248	-1.37204	2.98037	1.46089	.30082	1.04583	1.75978	.02699	-1.97499	.49455	-.93570	-.94439	.33360	.76248	-.58365	.02
-.61133	-.89726	.03998	-.13570	-.42956	-1.37204	4.80420	2.82247	2.32738	1.04583	1.75978	-2.08454	-1.97499	.49455	-2.72332	-.94439	.33360	.76248	-.58365	.28
.47401	-.80553	-.55433	-.13570	-.03113	.70063	1.05321	1.29069	2.32738	1.04583	1.75978	-2.08454	-1.97499	.49455	-.93570	-.94439	.33360	.76248	-.58365	.28
.13964	-.87813	-.78546	.38812	-.69517	-1.37204	1.33139	1.12049	2.32738	1.04583	1.75978	-2.08454	-1.97499	.49455	-.93570	-.94439	.33360	.76248	-.58365	.06
.17874	-.86930	-.65339	1.95959	-1.53630	-1.37204	.15107	-.41129	2.32738	1.04583	1.75978	-1.70063	-.55477	.49455	.85191	-.94439	.33360	.76248	-.58365	-.09
.20200	-.85556	-.19114	-.13570	-1.53630	-1.37204	1.53030	1.12049	.30082	1.04583	1.75978	.60287	-.55477	.49455	-.93570	-.94439	.33360	.76248	-.58365	-.12
.10054	-.87420	-.00954	.38812	-.47383	-1.37204	.32533	.43970	.30082	1.04583	1.75978	-1.12475	-.55477	.49455	-.93570	-.94439	.33360	.76248	-.58365	-.05
.21144	-.84870	-.66989	1.95959	-.20821	-1.37204	.00420	-.58149	.30082	1.04583	1.75978	-1.50867	-1.97499	.49455	-.93570	-.94439	.33360	.76248	-.58365	-.24
.33278	-.80946	-.45528	1.95959	-.65090	-1.37204	.67134	1.12049	.30082	1.04583	1.75978	-1.50867	-1.97499	.49455	-2.72332	-.94439	.33360	.76248	-.58365	-.24
.18245	-.87224	-.73593	.38812	-.96079	-1.37204	.97531	.43970	.30082	1.04583	1.75978	-.93280	-1.97499	.49455	.85191	-.94439	.33360	.76248	-.58365	-.09
-.82907	.08672	-.07558	-.83762	-.27461	1.66114	-.43235	-.41129	.30082	-.62750	.10719	-.16496	.86544	.49455	-.93570	.68915	1.76345	1.62647	1.92618	-.20
-.77480	.20052	.13903	-.83762	-.27461	1.00395	-.43799	-.41129	.30082	-.62750	.10719	-.16496	-.55477	.49455	-2.72332	.68915	1.76345	1.62647	1.92618	-.37
-.79739	.40801	.30412	-.83762	-.27461	1.66114	-.45634	-.58149	.30082	-.62750	.10719	.02699	.86544	.49455	-2.72332	.68915	1.76345	1.62647	1.92618	-.27
-.25505	.45265	1.16258	-.92144	-.58450	.95340	-.42469	-.07089	.30082	-.62750	.10719	.02699	.86544	.49455	.85191	.68915	1.76345	1.62647	1.92618	-.05
-.50617	-.32384	.53524	-1.00525	.67719	.59953	-.39101	-.41129	.30082	-.62750	.10719	-.35692	-.55477	.49455	.85191	.68915	1.76345	1.62647	1.92618	-.09
-.50515	-.43764	-.40575	.91194	-.27461	1.15561	-.28215	-.07089	.30082	-.62750	.10719	.21895	-.55477	.49455	.85191	-.94439	1.76345	1.62647	1.92618	-.40
-.56414	-.35033	.73335	-.97382	-.27461	.90284	-.35832	-.24109	.30082	-.62750	.10719	-.35692	-.55477	.49455	.85191	.68915	1.76345	1.62647	1.92618	-.16
-.69391	-.07613	-.19114	-.97382	-.27461	.70063	-.42553	-.41129	.30082	-.62750	.10719	-.16496	-.55477	.49455	.85191	.68915	1.76345	1.62647	1.92618	-.23
-.80210	.57675	-.02605	-.92144	-.27461	1.15561	-.47523	-.75169	.30082	-.62750	.10719	-.16496	.86544	.49455	-.93570	.68915	1.76345	1.62647	1.92618	-.21
-.75087	-.28313	-.20765	-.97382	-.27461	1.56003	-.40568	-.41129	.30082	-.62750	.10719	-.16496	.86544	.49455	-2.72332	-.94439	1.76345	1.62647	1.92618	-.39
-.79064	.01854	.23809	-.83762	-.27461	1.66114	-.45358	-.58149	.30082	-.62750	.10719	-.16496	-.55477	.49455	.85191	.68915	1.76345	1.62647	1.92618	-.18
-.75930	-.16001	.38667	-.83762	-.58450	.34676	-.22046	.95029	.30082	-.62750	.10719	.02699	-1.97499	.49455	.85191	-.94439	1.76345	1.62647	1.92618	-.35
.99544	.39526	.46921	-.73286	.67719	-.71485	-.46167	-.58149	.30082	-.62750	-.27713	.21895	-.55477	.49455	-.04190	-.94439	-.98626	-.70549	-.19815	.11
.66478	-.27087	.22158	.56622	-1.53630	-.05766	-.39526	-.39427	.30082	-.62750	-.27713	.21895	-.55477	.49455	-.04190	-.94439	-.98626	-.70549	-.19815	-.19
.96241	.92404	.94796	-.71191	-.27461	.04344	-.46442	-.42831	-.71246	-.62750	-.27713	.21895	.86544	.49455	-.04190	-.94439	-.98626	-.70549	-.19815	.13
1.84955	1.24238	.88193	1.95959	-.27461	-.10821	-.47316	-.47937	.30082	-.62750	-.27713	.02699	.86544	.49455	-.04190	-.94439	-.98626	-.70549	-.19815	.10
-.05248	1.81482	.70033	-.46047	-.27461	-.15877	-.47033	-.25811	-.71246	-.62750	-.27713	.21895	.86544	.49455	-.04190	-.94439	-.98626	-.70549	-.19815	.10
1.58024	.41635	.58477	1.95959	-.58450	.54897	-.43684	-.25811	.30082	-.62750	-.27713	-.16496	-.55477	.49455	-.04190	.68915	-.98626	-.70549	-.19815	.07
3.22038	3.10292	2.91251	-.31380	-.27461	.39731	-.48856	-.54745	.30082	-.62750	-.27713	-.93280	.86544	-.94414	-.04190	.68915	-.98626	-.70549	-.19815	.56
2.33357	.52132	2.46677	.12621	-.27461	-.25987	-.45983	-.49639	.30082	-.62750	-.27713	-1.12475	.86544	-.94414	-.04190	.68915	-.98626	-.70549	-.19815	.32
2.99623	1.71279	2.10358	-.31380	-.27461	.54897	-.46377	-.13897	.30082	-.62750	-.27713	-.74084	.86544	-.94414	-.04190	.68915	-.98626	-.70549	-.19815	.46
2.92848	4.30518	3.82049	-.65953	-.27461	-.00711	-.49274	-.58149	.30082	-.62750	-.27713	-1.12475	.86544	-.94414	-.04190	.68915	-.98626	-.70549	-.19815	.65
-.57728	-.71282	-.76895	4.05488	.67719	.59953	-.30870	-.61383	-1.72574	2.71915	-.46929	.21895	-.55477	.49455	.85191	-.94439	-.98626	-.93869	-.15918	-.14
-.57728	-.51711	-.15812	-.26142	.67719	.14455	-.28069	-.15599	-1.72574	2.71915	-.46929	.02699	-.55477	.49455	.85191	-.94439	-.98626	-.93869	-.15918	.12
-.63526	-.41851	-.27368	-.13570	.67719	-.46209	-.38488	-.48958	-1.72574	2.71915	-.46929	.02699	-.55477	.49455	.85191	-.94439	-.98626	-.93869	-.15918	.06
-.43201	-.63581	-.27368	.21002	-.27461	-.31043	-.34779	-.60361	.30082	-.62750	-.46929	.21895	.86544	.49455	.85191	-.94439	-.98626	-.93869	-.15918	-.05
-.43201	-.89137	-.42226	.07383	-1.53630	-.56319	.09286	-.58319	.30082	-.62750	-.46929	.02699	.86544	.49455	.85191	-.94439	-.98626	-.93869	-.15918	-.17
-.43201	-.03247	-.14161	.07383	.67719	.39731	-.38894	-.11344	.30082	-.62750	-.46929	-.16496	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.25
-.43201	-.61766	-.30670	.04240	-.27461	-.46209	-.40473	-.76530	.30082	-.62750	-.46929	.21895	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.02
-.63526	-.20023	-.38925	.16811	-.27461	-.10821	-.41913	-.49809	.30082	-.62750	-.46929	-.16496	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.07
-.43201	-.27724	-.27368	.04240	.67719	-.00711	-.32882	.01591	.30082	-.62750	-.46929	.21895	-.55477	.49455	.85191	.68915	-.98626	-.93869	-.15918	.13
-.43201	-.79425	-.32321	-.72238	-.27461	-.81596	-.34008	-.81125	.30082	-.62750	-.46929	-.54888	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.07
-.43201	-.48620	-.19114	-.26142	-.27461	-.46209	-.41975	-.71765	.30082	-.62750	-.46929	.21895	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.05
-.43201	-.15756	-.12511	-.32428	-.27461	-.15877	-.44446	-.65467	.30082	-.62750	-.46929	.02699	.86544	.49455	.85191	.68915	-.98626	-.93869	-.15918	.10
-.14517	1.04323	.41968	-.13570	.67719	.65008	-.21184	4.20654	.30082	-.62750	.10719	-1.12475	.86544	-2.38282	.85191	.68915	-.98626	-.82209	-.02275	.51
.02369	-.27136	-.85149	-.13570	.67719	.14455	-.32185	.07062	.30082	-.62750	.10719	-.74084	.86544	-2.38282	.85191	.68915	-.98626	-.82209	-.02275	.13
.31795	-.25125	-.53782	-.13570	-.27461	.65008	-.42220	-.55687	.30082	-.62750	.10719	.41091	.86544	-2.38282	.85191	.68915	-.98626	-.82209	-.02275	.00
-.65211	-.46609	-.91753	-.65953	.67719	-1.06872	-.46435	-.90486	-.71246	.20917	-1.41088	1.94657	-.55477	.49455	-.04190	-.94439	-.05136	-.27641	-1.11552	-.30
-.59110	1.26985	-.32321	.91194	2.89068	.70063	-.44235	.15036	-1.72574	-.62750	-1.41088	2.13853	-.55477	.49455	-.04190	-.94439	-.05136	-.27641	-1.11552	.01
-.71346	1.39444	-1.09912	-.65953	.67719	2.92496	-.47412	-.46235	-1.72574	-.62750	-1.41088	1.56266	-.55477	.49455	-.04190	.68915	-.05136	-.27641	-1.11552	.01
-.71346	-.41753	-.98356	.91194	2.89068	-1.06872	-.44596	-.80275	.30082	.20917	-1.41088	.41091	-.55477	-2.38282	-.04190	-.94439	-.05136	-.27641	-1.11552	-.17
-.83615	-.35622	-1.01658	-.31380	2.89068	-.61374	-.46929	-.90486	-1.72574	-.62750	-1.41088	.60287	.86544	-2.38282	-.04190	-.94439	-.05136	-.27641	-1.11552	-.18
-.71346	.34277	-.40575	-.65953	.67719	.44787	-.43971	-.32619	-1.72574	-.62750	-1.41088	.79483	.86544	-.94414	-.04190	.68915	-.05136	-.27641	-1.11552	-.08
-.71346	-.46070	-.93403	-.39761	-1.53630	-1.37204	-.31744	-.22407	-1.72574	-.62750	-1.41088	.60287	.86544	.49455	-.04190	.68915	-.05136	-.27641	-1.11552	-.38
-.37640	-.30716	-.96705	-.65953	2.89068	-.25987	-.46787	-.87082	-1.72574	-.62750	-1.41088	.79483	-.55477	-.94414	-.04190	-.94439	-.05136	-.27641	-1.11552	-.12
-.71346	-.39153	-1.06610	-.31380	.67719	1.30727	-.45228	-.81976	-1.72574	-.62750	-1.41088	.21895	.86544	-2.38282	-.04190	-.94439	-.05136	-.27641	-1.11552	-.28
-.83615	-.59510	-1.11563	-.52333	-1.53630	-.86651	-.40112	-.73467	-1.72574	-.62750	-1.41088	.41091	.86544	-2.38282	-.04190	.68915	-.05136	-.27641	-1.11552	-.54
-.83615	-.41949	-.95054	-.86905	-1.53630	-1.37204	-.35281	-.32619	-1.72574	-.62750	-1.41088	.41091	.86544	-2.38282	-.04190	.68915	-.05136	-.27641	-1.11552	-.50
2.11819	1.36501	1.92198	-.65953	.67719	.75119	-.45098	-.07089	.30082	2.71915	.29935	2.13853	.86544	.49455	-.04190	2.32268	.01421	-1.21036	.03007	.68
.95196	1.62205	1.85595	-.65953	.67719	.65008	-.40086	1.12049	.30082	1.04583	.29935	2.13853	.86544	.49455	-.04190	2.32268	.01421	-1.21036	.03007	.61
-.50246	-.71479	-.80196	-.65953	.67719	.75119	.12187	.30695	.30082	1.04583	.29935	2.13853	.86544	.49455	-.04190	2.32268	.01421	-1.21036	.03007	.27
-.50987	-.51613	-.19114	-.13570	.67719	.65008	.41097	2.45314	.30082	1.04583	.29935	2.33049	.86544	.49455	-.04190	2.32268	.01421	-1.21036	.03007	.40

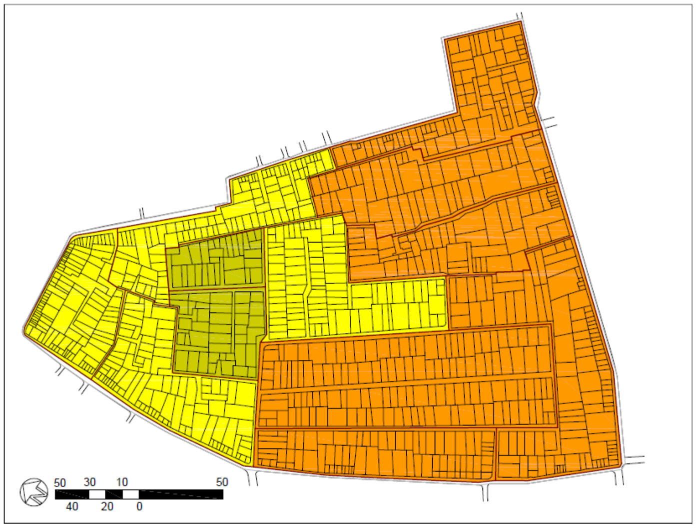
Table 5.3: Environmental Quality Index (EQI)

Colour Code	Value Range	Rank	Level of Environmental Quality
	0.75 to 1.00	1	Extremely Favourable
	0.5 to 0.74	2	Very Favourable
	0.25 to 0.49	3	Quite Favourable
	0.001 to 0.24	4	Favourable
	±0.00	5	Average
	-0.24 to -0.001	6	Unfavourable
	-0.49 to -0.25	7	Quite Unfavourable
	-0.74 to -0.5	8	Very Unfavourable
	-1.00 to -0.75	9	Extremely Unfavourable

Table 5.4: ZAEQ of Study Units, ANEQ and Level of Environmental Quality as per EQI

Study Units	AMRITSAR		CHANDIGARH				GURUGRAM	
	Katra Dullo	Ranjit Avenue	Sec-8	Sec-38W	Marble Arch	Sec-20, Panchkula	World Spa	Uniworld City
1.	0.16	-0.2	0.11	-0.14	0.51	-0.3	0.68	0.27
2.	0.03	-0.37	-0.19	0.12	0.13	0.01	0.61	0.4
3.	0.02	-0.27	0.13	0.06	0.00	0.01		
4.	0.28	-0.05	0.1	-0.05		-0.17		
5.	0.28	-0.09	0.1	-0.17		-0.18		
6.	0.06	-0.4	0.07	0.25		-0.08		
7.	-0.09	-0.16	0.56	0.02		-0.38		
8.	-0.12	-0.23	0.32	0.07		-0.12		
9.	-0.05	-0.21	0.46	0.13		-0.28		
10.	-0.24	-0.39	0.65	0.07		-0.54		
11.	-0.24	-0.18		0.05		-0.5		
12.	-0.09	-0.35		0.1				
ANEQ	**0.000**	**-0.242**	**0.231**	**0.043**	**0.213**	**-0.230**	**0.645**	**0.335**
Level of EQ	**Average**	**Unfavourable**	**Favourable**	**Favourable**	**Favourable**	**Unfavourable**	**Very Favourable**	**Quite Favourable**
Rank	**5**	**6**	**4**	**4**	**4**	**6**	**2**	**3**

Based on the ZAEQ values of the study units as seen in table 5.4, illustrative maps for each of the neighbourhoods showing sections with very favourable, quite favourable, favourable, average, unfavourable, quite unfavourable, very unfavourable and extremely unfavourable environmental quality are generated as indicated in figures 5.1, 5.2, 5.3 and 5.4.



Katra Dullo, Amritsar shows three distinct parts as far as environmental quality is concerned. While northern parts have favourable and quite favourable environmental quality, the southern parts have comparatively unfavourable quality. Northern and central parts have better accessibility from wider peripheral roads and better levels of cleanliness. Southern parts score less because of increased congestion, lack of open spaces, poor level of services and insanitary conditions created due to water logging as a result of choked drains. The distance of community open space is also farther than from northern parts.

Ranjit Avenue, Amritsar has overall unfavourable environmental quality with most areas having unfavourable and some areas having quite unfavourable environmental quality. Those areas that are better have open spaces, less congestion on roads and better level of services in terms of cleanliness observed.

R2, R3 and R6 especially have poorer environmental quality because of higher air pollution and higher noise levels due to the neighbourhood shopping centre (in R6) that employs the use of DG Sets on a large scale, bigger air conditioning units and has a lot of traffic coming into the neighbourhood during daytime.

Two other blocks (R10 and R12) also score less because of the comparative nearness to the main road, poor quality of open spaces, low PGA/Capita and poor condition of streetlights.

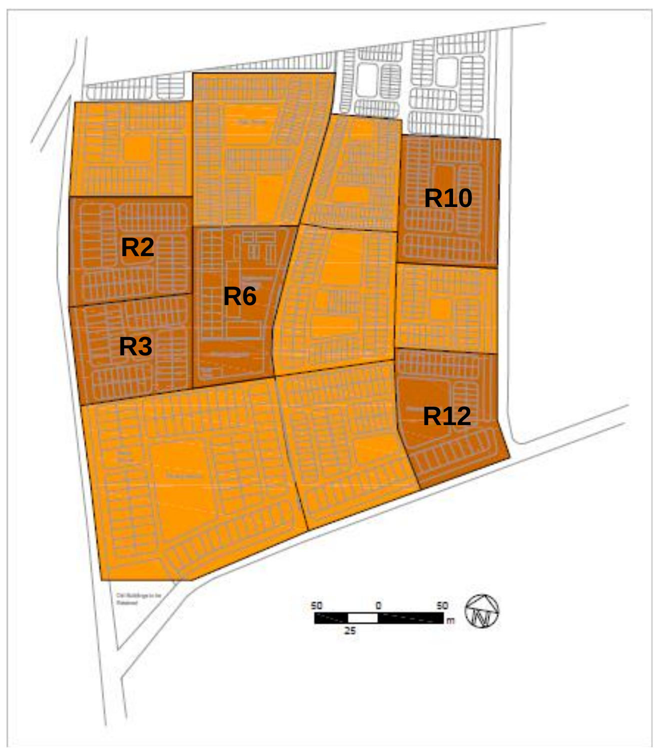


Figure 5.1: Environmental Quality Maps of Katra Dullo and Ranjit Avenue, Amritsar

In **Sector-8, Chandigarh**, it is seen that block (8-1, 8-2, 8-3) that are close to the main commercial belt and 8-5 that has highest population and residential density and neighbourhood shopping have just favourable or unfavourable environmental quality. This is primarily because of less BUA/Capita and PGA/Capita, higher congestion on roads due to on-street parking, less open spaces, less tree cover, higher noise levels and poor condition of sidewalks. The other blocks have favourable environmental quality mainly because of lower people densities with larger plot sizes, lesser congestion, better open spaces, shaded walkways that keep on becoming better as one moves from 8-7 to 8-10.

Sector-38W, Chandigarh has an overall favourable environmental quality as indicated in table 5.4. It mainly scores less in some pockets (38W-1, 38W-4, and 38W-5) because of low PGA/Capita, low PRL/Capita and high M.F. as a result of congestion due to on-street parking and lots of dead ends in the road network. The tree cover is also less in some of the pockets with quite unfavourable environmental quality (38W-5). Blocks that fare well have comparatively lower population and residential density and better open spaces for promoting different types of activities and higher intensity of activities.

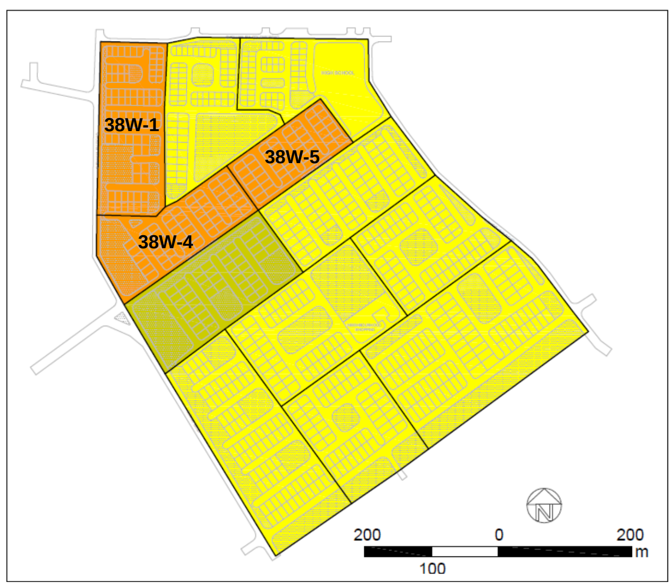
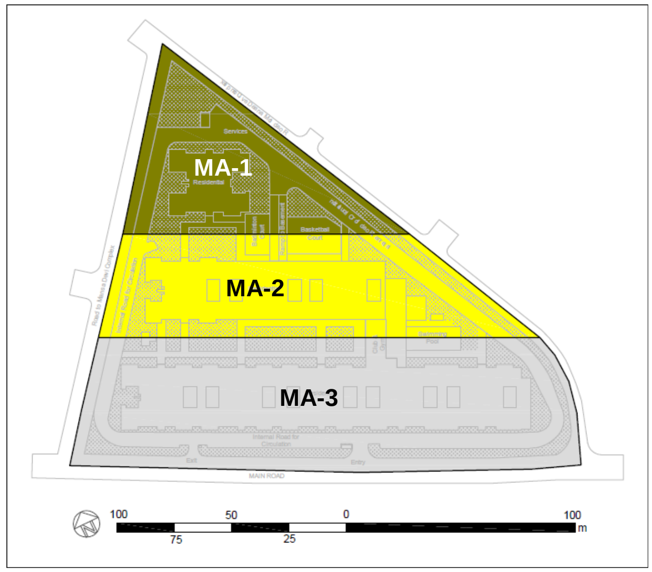


Figure 5.2: Environmental Quality Maps of Sector-8 and Sector-38W, Chandigarh

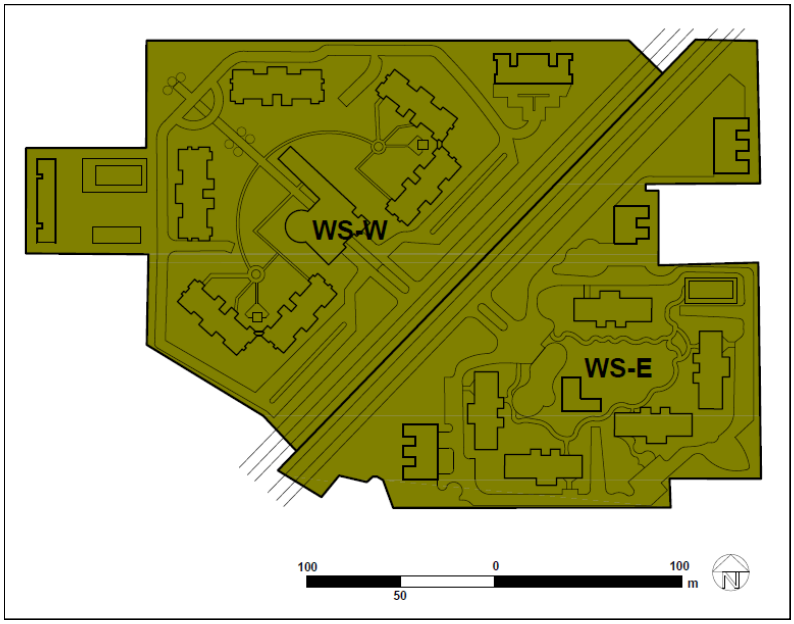
Marble Arch (Manimajra), Chandigarh has three distinct parts having quite favourable, favourable and average environmental quality. The top and middle part (MA-1 and MA-2) score more because of higher PGA/Capita and PRL/Capita, better open spaces, higher activity intensities and lower noise levels being away from the main road.



Sector-20 (Panchkula), Chandigarh has overall unfavourable environmental quality because of increased noise levels, higher air pollution and congestion on roads because of high population and residential density and proximity to Kalka-Zirakpur Highway (20-1). Also certain pockets are far from daily need shops and lack open spaces thus reducing the environmental quality further (20-10 and 20-11).

Figure 5.3: Environmental Quality Maps of Marble Arch (Manimajra) and Sector-20 (Panchkula), Chandigarh

World Spa, Gurugram – a high rise low density neighbourhood scores highest and has very favourable environmental quality. It has most of the desirable qualities for an environmentally conducive neighbourhood. It has ample BUA/Capita, PGA/Capita and PRL/Capita with good parking provision and almost no congestion on roads. This is also shown by the low M.F as indicated in Annexure 2. There are well maintained open spaces and shared facilities and amenities. The distance to daily needs is also within 1km. The pedestrian pathways are shaded and well connected. There is good ventilation in the neighbourhood because of the particular orientation of the building blocks. The only demerits are its location along main road that leads to higher noise levels and the higher RSPM values because of nearby construction activities that deteriorate the quality of air of the neighbourhood.



Uniworld City, Gurugram – a high rise high density neighbourhood follows close behind and has quite favourable environmental quality. It has well maintained open spaces with high activity intensity and shared facilities and amenities. The distance to daily needs is also within 1km. The pedestrian pathways are shaded and well connected. However, it scores less because of comparatively low BUA/Capita, PGA/Capita and PRL/Capita due to high population and residential density. Also UW-E has congestion due to lower road density and more number of vehicles. The ventilation score is also less. The locational aspect leading to higher noise levels and increased RSPM levels in air are similar to World Spa discussed above.

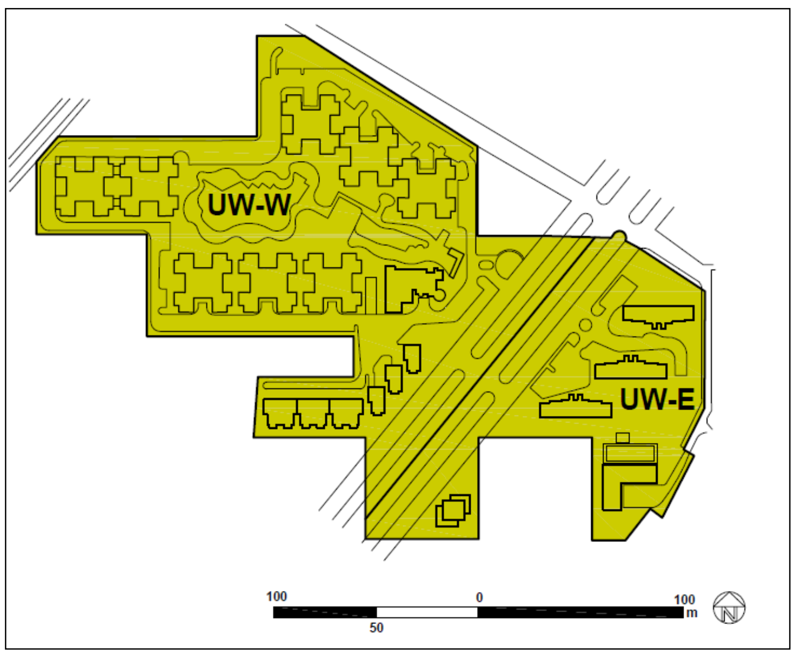


Figure 5.4: Environmental Quality Maps of World Spa and Uniworld City, Gurugram

The maps thus, help in bringing out heterogeneity in environmental quality at the block/neighbourhood level and identify problem/issues at the micro-level. This approach creates the possibility of taking up case-specific local actions by the residents and urban local bodies to improve the environmental quality in existing neighbourhoods as well as control and modify different built-form characteristics during the planning and design phase (by architects, planners and urban designers) to achieve better spatial quality in the upcoming neighbourhoods. The illustrative maps also prove to be useful visual aids that represent and validate the conditions observed on site during the primary survey.

5.3 Environmental Quality Profile of Case Study Neighbourhoods

In the Environmental Quality Profile (EQP), the multivariate data consisting of the different environmental quality indicators - crowding and congestion (CC); nature and use of open spaces (NUOS); shade and ventilation; temperature variations; noise levels; level of cleanliness (LoC); walkability and air quality are represented on different axes. The averages of the z-scores of each of the indicators are assigned scores as per a defined range in table 5.5, table 5.6 and table 5.7 and plotted on the radar chart. Thus, a radar/polar chart as suggested by **Friendly, 1991** is generated for each of the case study neighbourhoods to identify commonalities and differences in the indicators of environmental quality as seen in figure 5.5 and 5.6 and justify the level of aggregated neighbourhood environmental quality (ANEQ).

Table 5.5: ANEQ and average of z-scores of different indicators of environmental quality

Neighbourhoods	ANEQ	CC	NUOS	Shade	Ventilation	Temp. Variations	Noise Levels	LoC	Walkability	Air Quality
Sector 8, Chandigarh	0.231	1.13	-0.30	0.10	-0.63	-0.28	-0.32	0.44	-0.15	-0.63
Ranjit Avenue, Amritsar	-0.242	0.08	0.05	0.30	-0.63	0.11	-0.12	-0.08	0.05	1.77
World Spa, Gurugram	0.645	1.39	0.37	0.30	1.88	0.30	2.14	0.87	0.86	-0.39
Marble Arch, Manimajra	0.213	0.01	0.44	0.30	-0.63	0.11	-0.48	0.87	-0.12	-0.61
Sector 38W, Chandigarh	0.043	-0.38	-0.25	-0.21	0.21	-0.47	0.03	0.39	0.34	-0.69
Sector 20, Panchkula	-0.23	-0.33	-0.06	-1.45	-0.48	-1.41	0.90	0.22	-0.11	-0.48
Uniworld City, Gurugram	0.335	-0.31	0.76	0.30	1.05	0.30	2.23	0.87	0.86	-0.39
Katra Dullo, Amritsar	0.00	-0.52	0.21	0.98	1.05	1.76	-1.08	-1.38	-0.42	0.17
		^	^	^	^	^	v	^	^	v

Legend: ^ indicates positive impact on EQ with increasing value; v indicates negative impact on EQ with increasing value

Table 5.6: Range of values and scores for indicators of environmental quality

Range of values	Score	
	Positive impact on EQ	Negative impact on EQ
greater than 2.00	9	1
1.321 to 2.00	8	2
0.661 to 1.32	7	3
0.001 to 0.66	6	4
±0.00	5	5
-0.66 to -0.001	4	6
-1.32 to -0.661	3	7
-2.00 to -1.321	2	8
less than -2.00	1	9

Table 5.7: Scores of ANEQ and different indicators of environmental quality

Neighbourhoods	ANEQ	CC	NUOS	Shade	Ventilation	Temp. Variations	Noise Levels	LoC	Walkability	Air Quality
Sector 8, Chandigarh	6	7	4	6	4	4	6	6	4	6
Ranjit Avenue, Amritsar	4	6	6	6	4	6	6	4	6	2
World Spa, Gurugram	8	8	6	6	7	6	1	7	7	6
Marble Arch, Manimajra	6	6	6	6	4	6	6	7	4	6
Sector 38W, Chandigarh	6	4	4	4	6	4	4	6	6	7
Sector 20, Panchkula	4	4	4	2	4	2	3	6	4	6
Uniworld City, Gurugram	7	4	7	6	7	6	1	7	7	6
Katra Dullo, Amritsar	5	4	6	7	7	8	7	2	4	4
	As per EQI	As per positive and negative scores in Table 5.6								

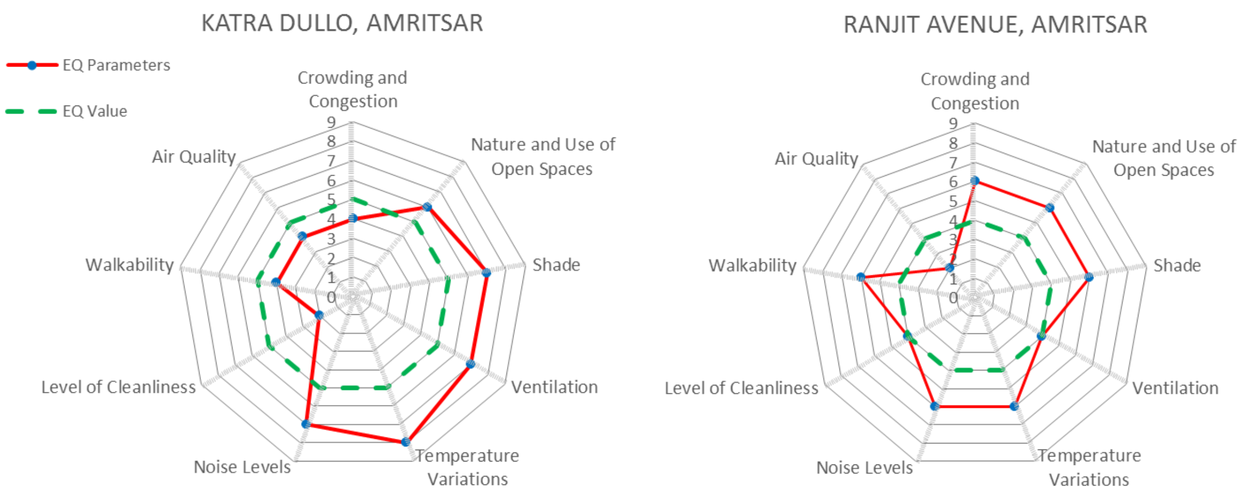


Figure 5.5: EQP of Case Study Neighbourhoods of Amritsar

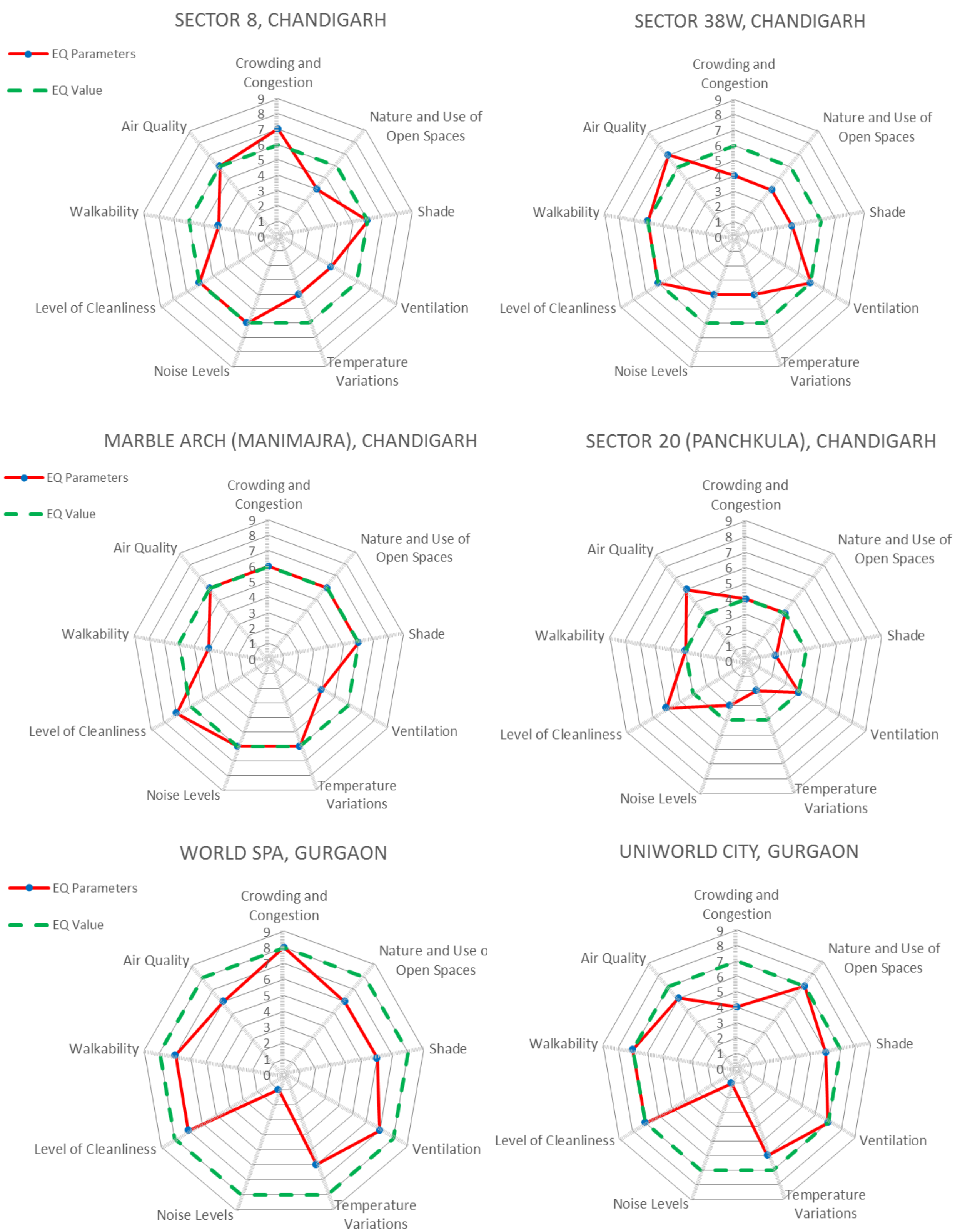


Figure 5.6: EQP of Case Study Neighbourhoods of Chandigarh and Gurugram

A careful study of the EQPs of the different case study neighbourhoods reveal the following points:

1. Two neighbourhoods namely Ranjit Avenue, Amritsar and Sector-20 (Panchkula), Chandigarh have quite unfavourable environmental quality (score=4) due to poor air quality and less ventilation in the former and poor shade and low temperature variations along with high noise levels in the latter.

2. Katra Dullo, Amritsar is slightly better with average score=5. It scores more as a result of better activity intensity in public spaces (streets and squares), good shade and ventilation as a result of compact built-form creating comfortable micro-climate and low noise levels because of absence of vehicular traffic (four wheelers, especially) within the neighbourhood. It loses points because of the poor level of cleanliness.

3. Next, there are three neighbourhoods of Chandigarh that have favourable environmental quality with score=6. They are Sector-8, Sector-38W and Marble Arch (Manimajra). While Sector-8 and Marble Arch (Manimajra) both have less crowding and congestion, low noise levels and good cleanliness; they lose out on the nature and use of open spaces in Sector-8 and less ventilation and walkability in both cases. In case of Sector-38W, higher crowding and congestion, poor nature of open spaces in quite a few study units with less shade and comparatively higher noise levels affect the environmental quality.

4. Lastly the two neighbourhoods of Gurugram, World Spa and Uniworld City score 8 and 7 - the highest points respectively. They have very favourable and quite favourable environmental quality. All parameters except noise are above average in case of World Spa while Uniworld City in addition has more crowding and congestion that reduces the score by one point in comparison to World Spa.

Thus, it is observed that crowding and congestion, nature and use of open spaces, shade and ventilation and associated temperature variations, noise levels, level of cleanliness, walkability and air quality - all have a key role in ascertaining the level of environmental quality in residential neighbourhoods. However, since the study intends to understand the impact of density on environmental quality, it becomes imperative to analyse the association of density with standardized aggregated environmental quality (ZAEQ) before proceeding further.

As stated previously, it is important to understand the association between the independent density variables - people density, building density and spatial density and dependent environmental quality variable (ZAEQ) before undertaking a multiple hierarchical regression analysis to ascertain significant density variables impacting environmental quality and subsequently test the research hypothesis as stated in Chapter 1. However, such parametric statistical tests including analysis of variance, discriminant analysis, correlation, f-tests and t-tests require that the dependent variable is approximately normally distributed. The following numerical and visual outputs are investigated as part of the test of normality:

- Skewness and Kurtosis z-values – should be somewhere in the span of -1.96 to +1.96
- The Shapiro-Wilk test p-value – should be above 0.05
- Histogram and Normal Q-Q plots – should visually indicate that the values are normally distributed

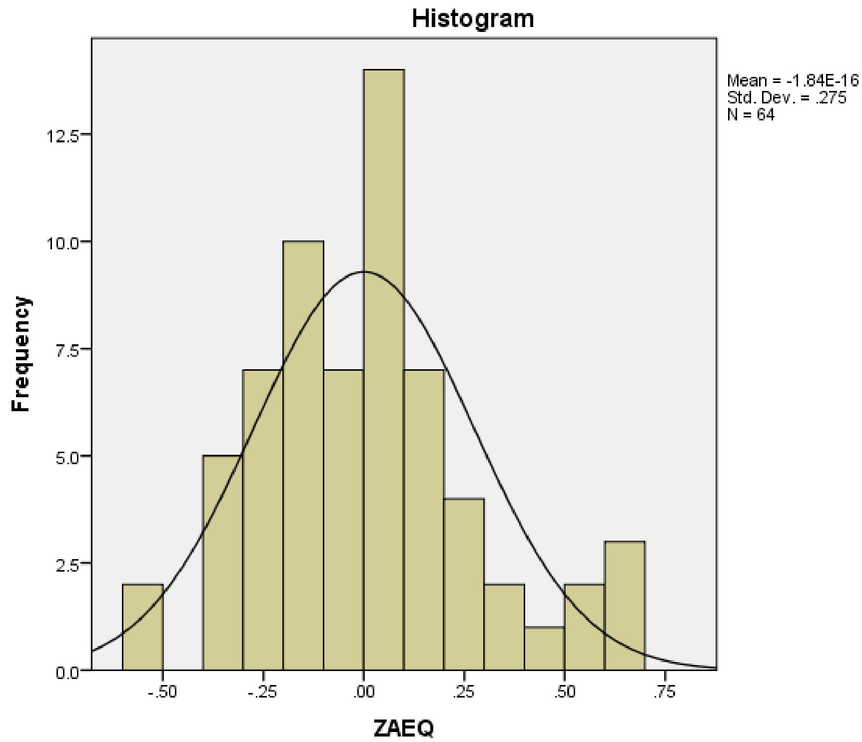
Table 5.8: Descriptive Statistics of ZAEQ

			Statistic	Std. Error
ZAEQ	Mean		.0000	.03436
	95% Confidence Interval for Mean	Lower Bound	-.0687	
		Upper Bound	.0687	
	5% Trimmed Mean		-.0094	
	Median		.0035	
	Variance		.076	
	Std. Deviation		.27489	
	Minimum		-.54	
	Maximum		.68	
	Range		1.22	
	Interquartile Range		.32	
	Skewness		.550	.299
	Kurtosis		.174	.590

Table 5.9: Tests of Normality – ZAEQ

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ZAEQ	.111	64	.048	.968	64	.094

a. Lilliefors Significance Correction



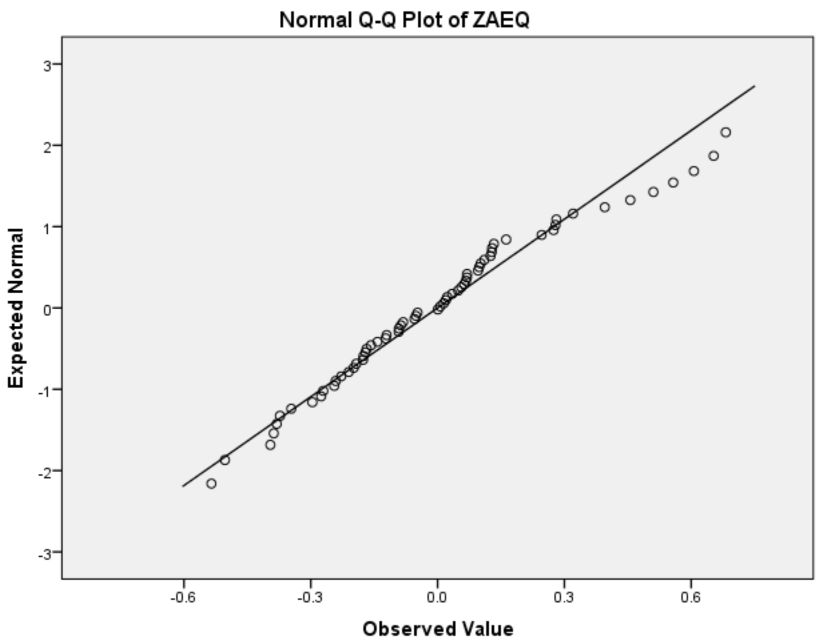


Figure 5.7: Histogram and Normal Q-Q Plot of ZAEQ

A Shapiro-Wilk's test with p>0.05 as seen in table 5.9 **(Shapiro and Wilk, 1965; Razali and Wah, 2011)** and a visual inspection of the histogram and normal q-q plot as seen in figure 5.7 show that the ZAEQ values are approximately normally distributed with a skewness of 0.55 (S.E

= 0.299) and kurtosis of 0.174 (S.E = 0.590) as indicated in table 5.8 **(Cramer, 1998; Cramer and Howitt, 2004; Doane and Seward, 2011)**.

5.4 Relationship between Density and Environmental Quality

To understand the relationship between Density and Neighbourhood Environmental Quality, a correlation analysis is done by taking the density variables like population density measured by persons per hectare, residential density measured by dwelling units per hectare, FAR, plot coverage, etc. and standardized aggregated environmental quality (ZAEQ) of all the study units. Significant correlations at 95% and 99% confidence level are seen between many density variables and neighbourhood environmental quality as indicated in table 5.10.

Table 5.10: Correlation between Density and ZAEQ

Note: Significant correlations (p<0.01 and p<0.05) are highlighted, positive in green and negative in red

Density Variables			ZAEQ
PEOPLE DENSITY	Population Density	Pearson Correlation	-.317**
		Sig. (2-tailed)	.000
	Residential Density	Pearson Correlation	-.183**
		Sig. (2-tailed)	.002
BUILDING DENSITY	FAR	Pearson Correlation	-.194**
		Sig. (2-tailed)	.001
	Plot Coverage	Pearson Correlation	-.429**
		Sig. (2-tailed)	.000
SPATIAL DENSITY	Height to width ratio	Pearson Correlation	.216**
		Sig. (2-tailed)	.000
	Dist. of Open Spaces	Pearson Correlation	.421**
		Sig. (2-tailed)	.000
	Dist. of Roads	Pearson Correlation	-.047
		Sig. (2-tailed)	.433
	Sidewalks	Pearson Correlation	.649**
		Sig. (2-tailed)	.000
	Streetlight Density	Pearson Correlation	.242**
		Sig. (2-tailed)	.000
	Domestic Waste	Pearson Correlation	.142*
		Sig. (2-tailed)	.018
	Stormwater Drainage	Pearson Correlation	.134*
		Sig. (2-tailed)	.025
	Sewerage	Pearson Correlation	.138*
		Sig. (2-tailed)	.021

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

It is observed that while environmental quality varies negatively with population density, residential density, FAR and plot coverage; it shows positive correlation with height, distribution of open spaces, sidewalks and streetlight density as seen in table 5.10. In other words, this means that as population density, residential density, etc. goes on increasing the environmental quality deteriorates whereas with increase in height of buildings, open spaces, sidewalks and streetlights permitting walkable and safe neighbourhoods, the environmental quality starts improving. It is also seen that spatial density of domestic waste collection system, provision of stormwater drainage and sewerage also show positive association with ZAEQ thus reinforcing the assumption that adequacy of services improve the environmental quality.

On the other hand, a closer inspection of the bar charts with trend lines as indicated in figure 5.8 to figure 5.17 reveal some noteworthy findings. The important findings from the density and neighbourhood environmental quality analyses are:

- As people density, building density and spatial density go on increasing across all the different residential patterns, the environmental quality fluctuates becoming positive or improving (favourable to very favourable) for particular combinations of the density variables and again deteriorating (unfavourable to very unfavourable) for other combinations of the variables.
- **People Density –** Neighbourhoods with 40-50pph and 8-10DUs/ha; 160-210pph and 40-50DUs/ha; 500-540pph and 100-110DUs/ha; and 900-950pph and 180-190DUs/ha have favourable environmental quality. These can be suitably classified/bunched as low, medium, high and very high density patterns as indicated in figure 5.8 and figure 5.9.
- **Building Density –** The favourable values of FAR and plot coverage are found to be 1-1.5 with 35-40% coverage; and 2-3 with 11-20% coverage respectively. The first group as observed in the case studies can be the low and medium rise neighbourhoods while the second group corresponds to the high rise residential developments as indicated in figure 5.10 and figure 5.11.
- **Spatial Density –** Height to width ratio of ≈3 (w.r.t high rise developments) and distribution of open spaces greater than equal to 35% is required for favourable environmental quality. Similarly, 60-70% of the neighbourhood should have continuous and good quality sidewalks to promote walkability. Streetlights should be 30m c/c and domestic waste collection, stormwater drainage and sewerage system should be as per the norms laid down (100% coverage of waste collection, drainage and sewerage systems) for good environmental quality.

Figure 5.8: Variation in Environmental Quality with Population Density

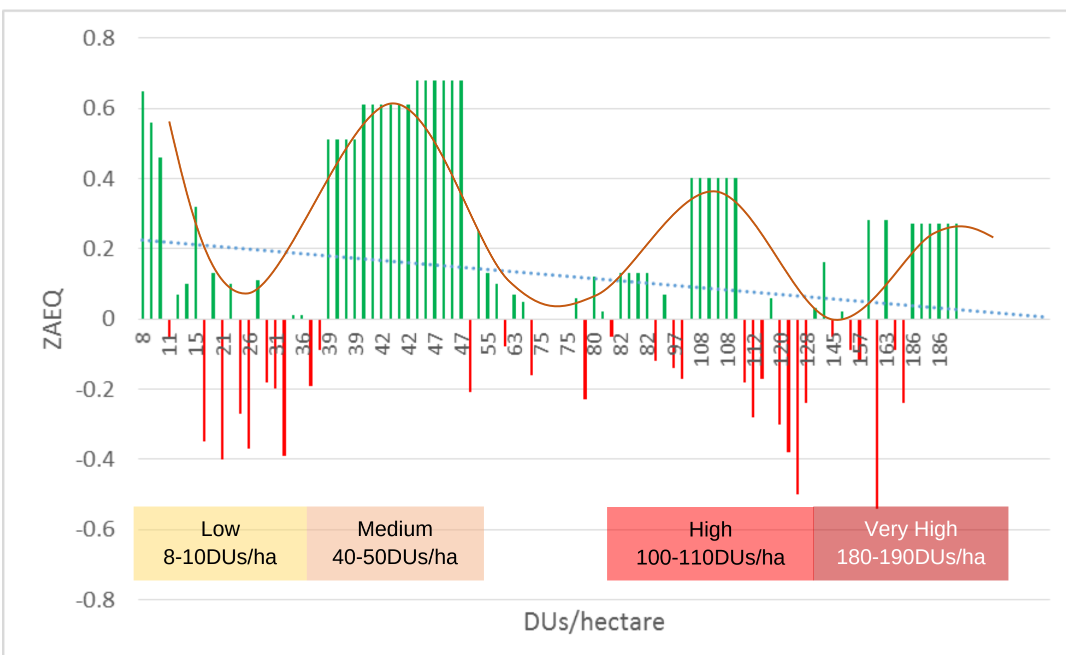


Figure 5.9: Variation in Environmental Quality with Residential Density

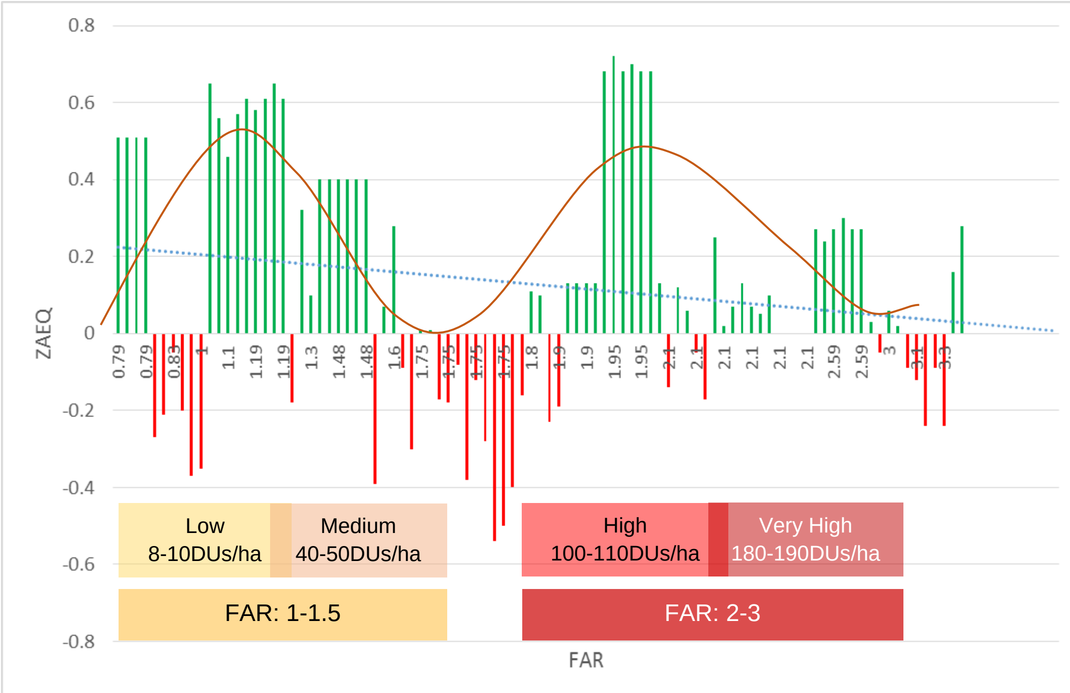


Figure 5.10: Variation in Environmental Quality with Floor Area Ratio (FAR)

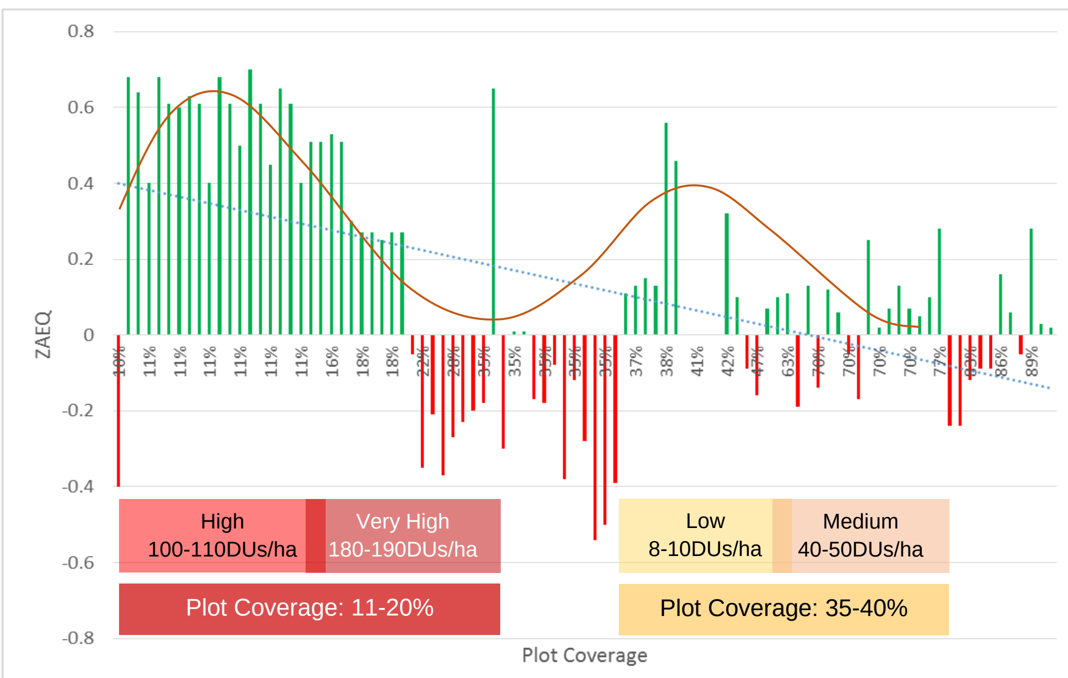


Figure 5.11: Variation in Environmental Quality with Plot Coverage

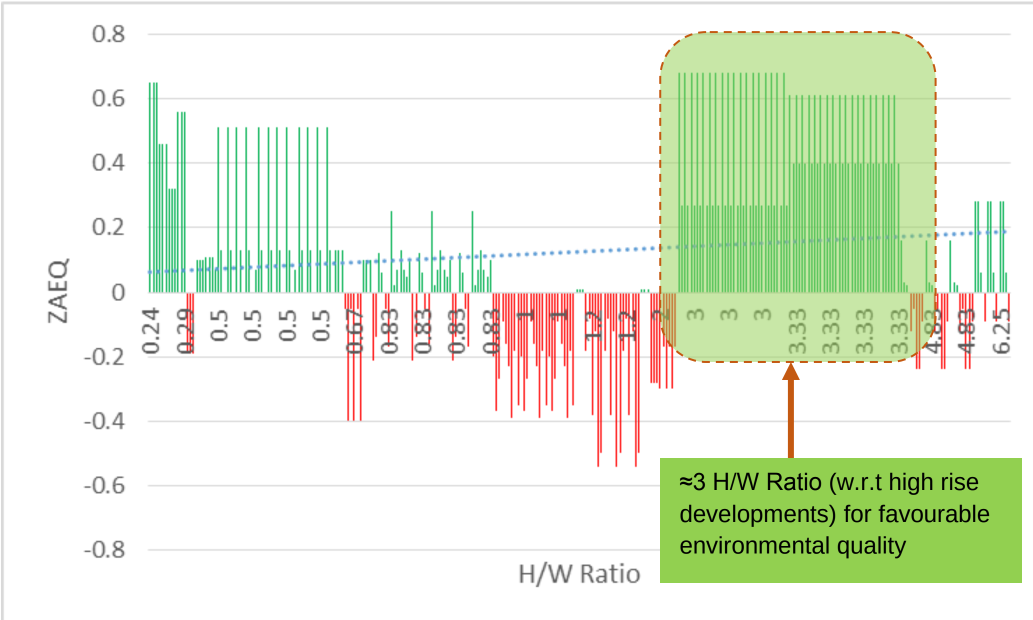


Figure 5.12: Variation in Environmental Quality with Height to Width Ratio

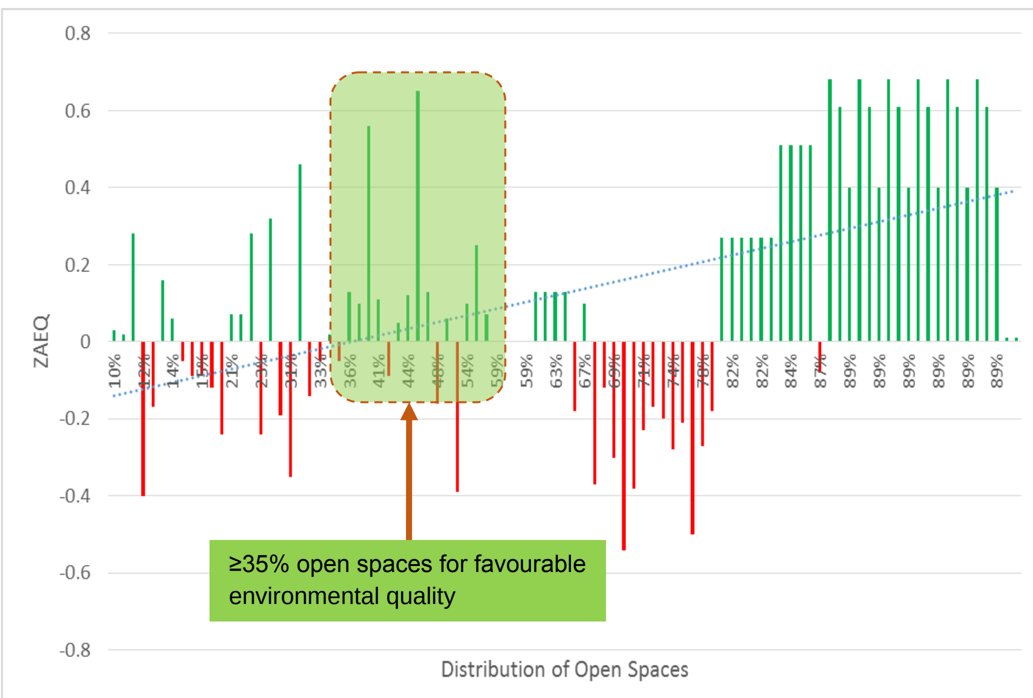


Figure 5.13: Variation in Environmental Quality with Distribution of Open Spaces

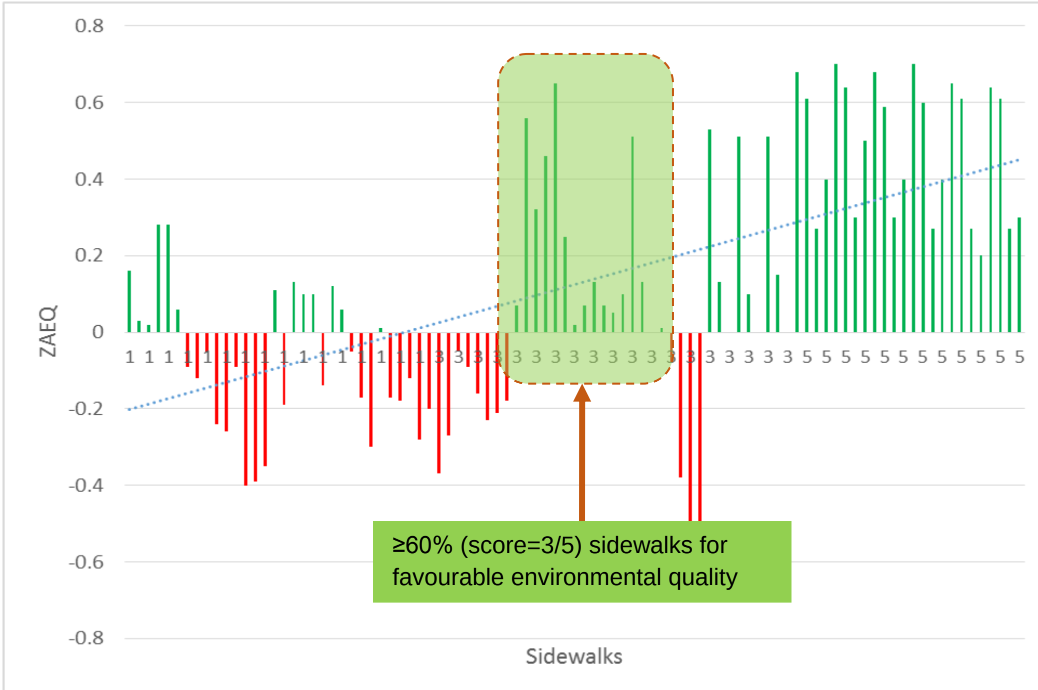


Figure 5.14: Variation in Environmental Quality with Distribution of Sidewalks

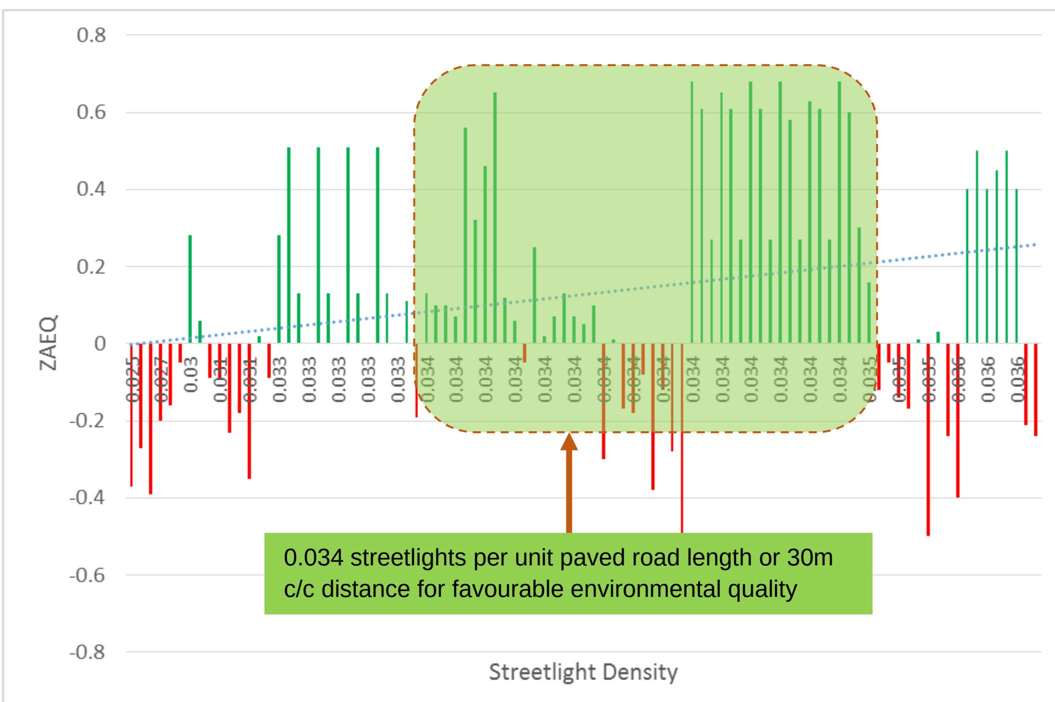


Figure 5.15: Variation in Environmental Quality with Streetlight Density

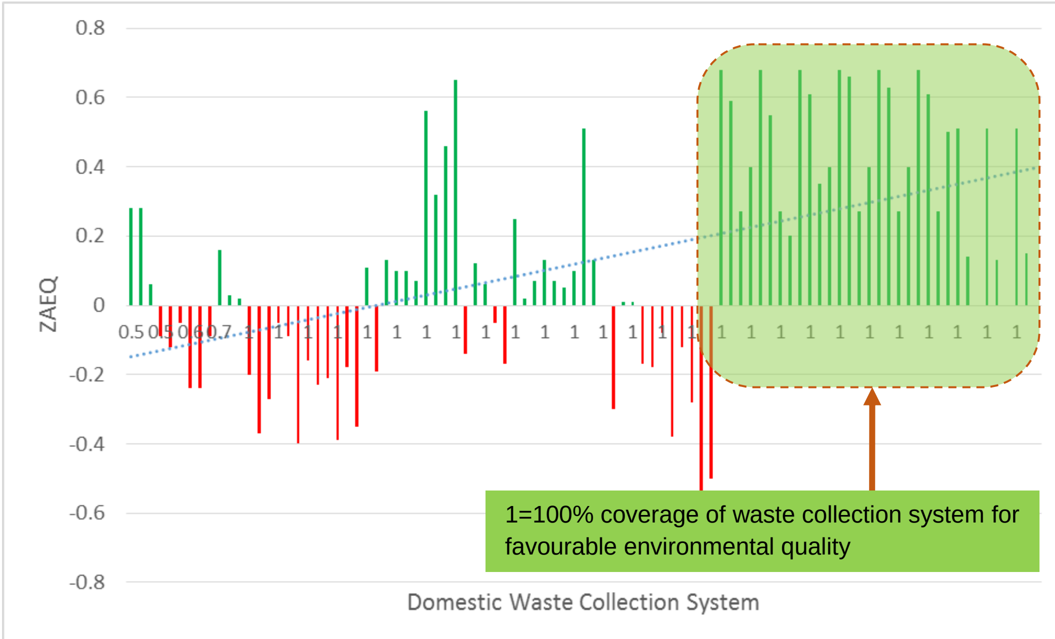


Figure 5.16: Variation in Environmental Quality with Coverage of Domestic Waste Collection System

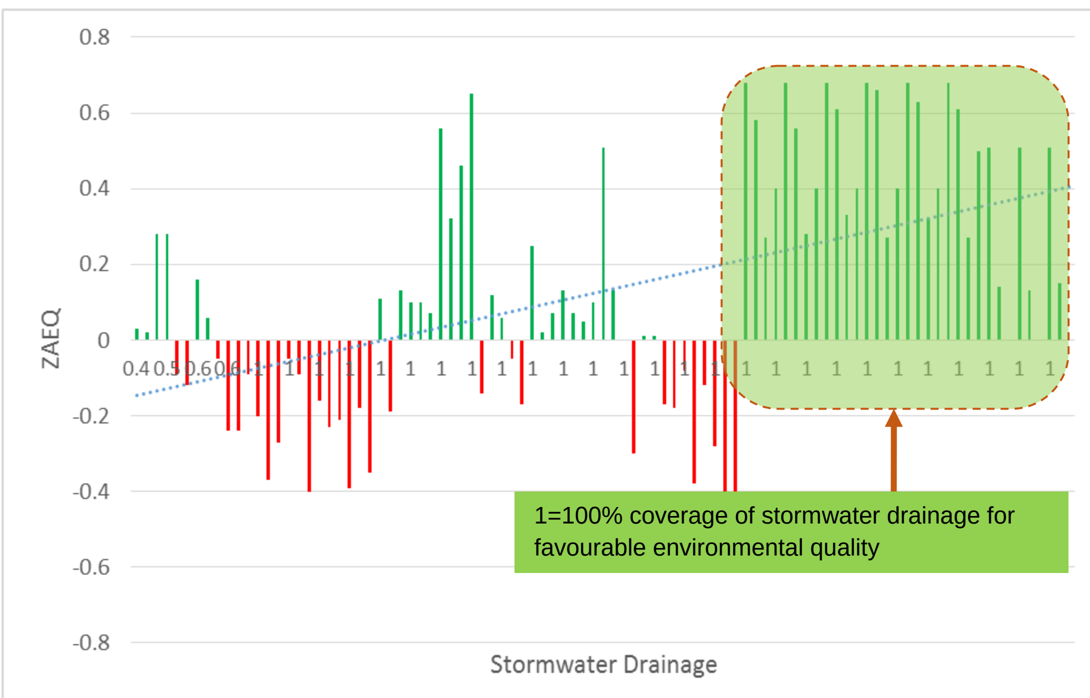


Figure 5.17: Variation in Environmental Quality with Coverage of Stormwater Drainage

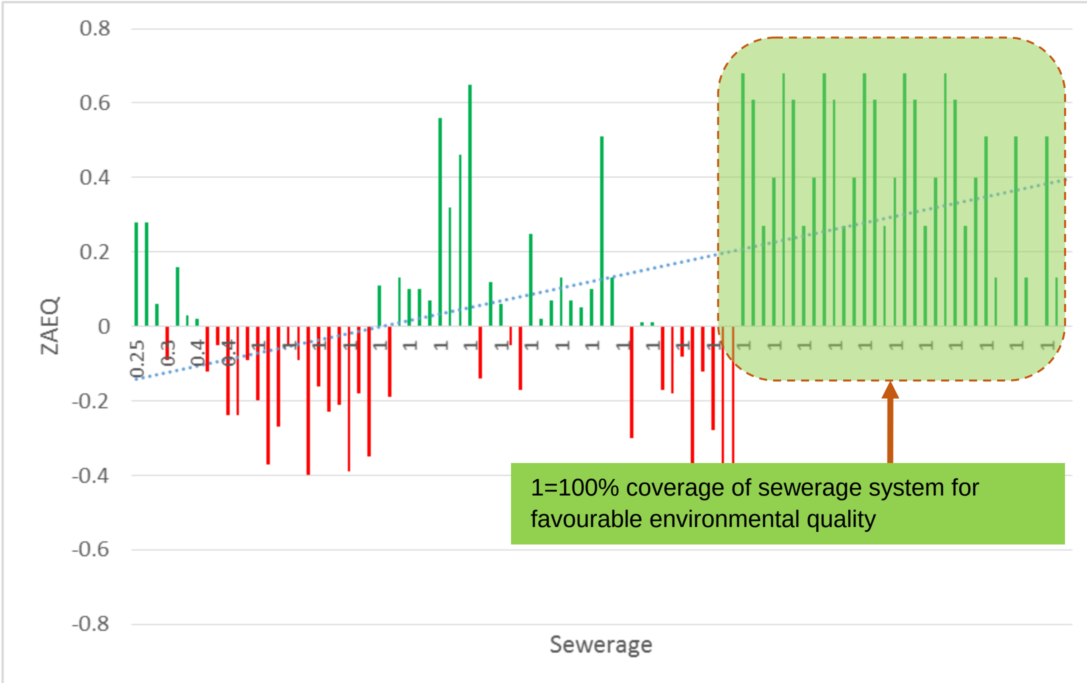


Figure 5.18: Variation in Environmental Quality with Coverage of Sewerage System

It is therefore observed that the different residential patterns identified can primarily be grouped into low, medium, high and very high density based on people density given by population and residential density; building density given by FAR and plot coverage and spatial density given by height to width ratio, distribution of open spaces, sidewalks, streetlights and other services like domestic waste collection, stormwater drainage and sewerage. It is also noteworthy to mention here that the case study data shows that low and medium density neighbourhoods generally comprise of the low and medium rise residential patterns while the high and very high density neighbourhoods comprise of the high rise residential patterns when all the different density variables namely people density, building density and spatial density are taken together as indicated in table 5.11.

5.5 Concluding Remarks

The present chapter assesses the environmental quality at the micro-level by using the multi-criteria approach. The multi-criteria approach helps to consider several density variables that can be controlled and modified during the planning and design phase to achieve better spatial

Table 5.11: Range of Density Variables for favourable Environmental Quality

<table>
<tr><th colspan="3">Density Variables</th><th colspan="2" rowspan="2">Key points for favourable environmental quality (based on trend lines)</th></tr>
<tr><th>People Density</th><th>Building Density</th><th>Spatial Density</th></tr>
<tr><td>Low
40-50pph
8-10DUs/ha</td><td rowspan="2">• FAR = 1-1.5 (Height = Low & Medium Rise)
• Plot Coverage = 30-50%</td><td rowspan="2">• Open Spaces = 35-70%
• Sidewalks = 60-70%
• Services = 100%</td><td rowspan="2">LOW & MEDIUM RISE PATTERN</td><td rowspan="4">• With population density ≥630pph in low/medium rise compact developments environmental quality tends to deteriorate
• Plot Coverage should not exceed 70%
• Open Spaces should be minimum 35%
• Minimum 60-70% of the neighbourhood should have continuous sidewalks
• Waste collection, drainage and sewerage services should be 100%</td></tr>
<tr><td>Medium
160-210pph
40-50DUs/ha</td></tr>
<tr><td>High
500-540pph
100-110DUs/ha</td><td rowspan="2">• FAR = 2-3 (Height = High Rise)
• Plot Coverage = 11-20%</td><td rowspan="2">• H/W Ratio ≈3
• Open Spaces = 80-90%
• Sidewalks = 100%
• Services = 100%</td><td rowspan="2">HIGH RISE PATTERN</td></tr>
<tr><td>Very High
900-950pph
180-190DUs/ha</td></tr>
</table>

quality of the designed space. The 'Environmental Quality Index' formulated serves as a tool to classify different neighbourhoods of the city according to the level of environmental quality. The illustrative maps are useful visual aids that help in bringing out heterogeneity at the block/neighbourhood level by identifying problems/issues at the micro-level. They represent and validate the conditions observed on site during the primary survey. The 'Environmental Quality Profiles' help to identify commonalities and differences in the indicators of environmental quality and justify the level of aggregated neighbourhood environmental quality (ANEQ) ascertained. The study also shows that significant relationships exist between density and neighbourhood environmental quality further propelling one to identify the most important density variables impacting environmental quality and test the research hypothesis for identifying optimum density values to maintain favourable environmental quality in neighbourhoods with different residential patterns.

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IMPACT OF DENSITY ON ENVIRONMENTAL QUALITY

6.1 Introduction

The present chapter tests the research hypothesis – “Density impacts Environmental Quality in Residential Neighbourhoods” through the use of the multiple hierarchical regression (MHR) approach. The multiple regression approach is generally used for prediction. It is a statistical technique to understand the impact of two or more predictor or independent variables (i.e., lower-level attributes) on a single criterion or dependent variable (i.e., higher-level attribute). In this study, the MHR approach is used to understand the extent to which the observed variance in the dependent variable (neighbourhood environmental quality) is explained by the observed variance in the independent variables (density variables), also referred to as the 'model fit'.

The MHR approach is also used to assess the 'standardized regression weights' (β's). In the present study, this is a very important property, since the 'β -coefficients' indicate the relative importance of lower-level attributes and help in assessing which density variables significantly impact environmental quality. In addition, the best-to-fit analysis helps in identifying optimum density ranges/values to maintain favourable environmental quality in different residential neighbourhoods and subsequently arrive at guidelines to achieve environmentally conducive patterns of residential development in our cities.

6.2 The Multiple Hierarchical Regression (MHR) Approach

The correlation analysis between the density variables and standardized aggregated environmental quality, ZAEQ (as indicated in table 5.10, Chapter 5) is taken as the starting point for carrying out the multiple hierarchical regression in IBM SPSS Statistics 22 (Statistical Package for Social Sciences). The hierarchical approach yields estimates of association that are more precise than conventional estimates by controlling for the effects of covariates and enables testing the effects of certain predictors independent of the influence of others. With this understanding, independent variables are entered into the model block wise with variables having low correlations with ZAEQ entering first followed by variables showing high correlations (whether positive or negative) with the dependent variable. The variable(s) showing no significant association with ZAEQ, in this case – Distribution of Roads is left out of the model.

The analysis is initially run with n=279 out of 320 samples (as indicated in section 3.8.1, Chapter 3) as 41 samples are discarded because of the existence of significant amounts of missing data. At this stage multicollinear or highly correlated independent variables are also omitted from the model. Multicollinearity causes difficulties in disentangling the separate effects of the various independent variables on the dependent variable. If two independent variables are highly correlated, the first one entered in the analysis might account for much of the explained variance in the respective higher level criterion variable. Entering the second source, then, may lead to less higher predictive power, due to its covariance, hence, its contribution could become insignificant. In the present analysis, on the basis of the above argument, four variables namely – population density, distribution of open spaces, distribution of sewerage and stormwater drainage are removed from the model due to their high correlation with residential density, plot coverage and domestic waste collection system respectively.

Outliers are also suitably identified from the dataset on the basis of Cook's and Mahalanobis's Distances **(Field, 2009)** and finally the multiple hierarchical regression is carried out with n=258 i.e. 80% of the original dataset which is fairly high.

Table 6.1: Model Summary[d] of Multiple Hierarchical Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.207[a]	.043	.039	.30761	.043	11.431	1	256	.001	
2	.727[b]	.529	.519	.21759	.486	64.913	4	252	.000	
3	.827[c]	.683	.674	.17904	.155	61.103	2	250	.000	1.435

a. Predictors: (Constant), Domestic Waste

b. Predictors: (Constant), Domestic Waste, Streetlight Density, Residential Density, Height to Width Ratio, FAR

c. Predictors: (Constant), Domestic Waste, Streetlight Density, Residential Density, Height to Width Ratio, FAR, Sidewalks, Plot Coverage

d. Dependent Variable: ZAEQ

The model summary (as indicated in table 6.1) shows that the model fits the data significantly at all levels of the hierarchical regression analysis with $p<0.05$. It further shows that R^2 changes significantly when the predictors are entered in model 2 and model 3. In the first stage, model 1, the domestic waste collection system representing adequacy of services accounts for just 4.3% of the variance in neighbourhood environmental quality. However, entering the second set of variables (model 2) - residential density, FAR, height to width ratio and streetlight density causes 48.6% variation in neighbourhood environmental quality while plot coverage and distribution of sidewalks (model 3) further account for 15.5% variation in neighbourhood environmental quality. Summing up all the three models, the following density variables namely – Residential Density (People Density), Plot Coverage and FAR (Building Density) and Height to Width Ratio, Distribution of Sidewalks, Streetlights and Waste Collection Systems (Spatial Density) account for 68.3% variation in neighbourhood environmental quality.

The model also suggests that population density, distribution of open spaces, distribution of sewerage and stormwater drainage that are highly correlated with residential density, plot coverage and domestic waste collection system respectively and are removed from the model due to their overlapping nature, will also show similar results thus signifying that density impacts environmental quality in residential neighbourhoods.

Table 6.2: Analysis of Variance (ANOVA)
of Standardized Aggregated Environmental Quality (ZAEQ)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.082	1	1.082	11.431	.001[b]
	Residual	24.224	256	.095		
	Total	25.306	257			
2	Regression	13.375	5	2.675	56.500	.000[c]
	Residual	11.931	252	.047		
	Total	25.306	257			
3	Regression	17.292	7	2.470	77.065	.000[d]
	Residual	8.014	250	.032		
	Total	25.306	257			

a. Dependent Variable: ZAEQ

b. Predictors: (Constant), Domestic Waste

c. Predictors: (Constant), Domestic Waste, Streetlight Density, Residential Density, Height to Width Ratio, FAR

d. Predictors: (Constant), Domestic Waste, Streetlight Density, Residential Density, Height to Width Ratio, FAR, Sidewalks, Plot Coverage

The analysis of variance (ANOVA) technique (as indicated in table 6.2) further shows that the variance in the means of the Standardized Aggregated Environmental Quality values (ZAEQ) of the sample study units is significant ($p<0.05$) and not just by chance thus rejecting the null hypothesis and confirming the alternative hypothesis that — Density impacts Environmental Quality in Residential Neighbourhoods.

Moving further, the inspection of the 'β -coefficients' indicate the relative importance of the lower-level attributes and help in assessing which density variables significantly impact the environmental quality (as indicated in table 6.3).

Table 6.3: Regression Coefficients (β –coefficients) of independent variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.419	.168		-2.493	.013
	Domestic Waste	.585	.173	.207	3.381	.001
2	(Constant)	-2.770	.313		-8.860	.000
	Domestic Waste	1.716	.199	.607	8.625	.000
	Residential Density	-.004	.000	-.646	-9.267	.000
	FAR	.056	.038	.111	1.491	.137
	Height to Width Ratio	.192	.014	.912	13.571	.000
	Streetlight Density	33.191	7.976	.192	4.161	.000
3	(Constant)	-1.206	.308		-3.915	.000
	Domestic Waste	-.367	.262	-.130	-1.401	.162
	Residential Density	-.004	.000	-.694	-11.393	.000
	FAR	.158	.041	.312	3.832	.000
	Height to Width Ratio	.043	.019	.205	2.331	.021
	Streetlight Density	42.992	6.668	.249	6.447	.000
	Plot Coverage	-.290	.114	-.227	-2.534	.012
	Sidewalks	.116	.014	.559	8.516	.000

It is observed that residential density has the largest impact with β=-0.694 (negative in nature) on neighbourhood environmental quality followed by distribution of sidewalks (β=0.559), FAR (β=0.312), streetlight density (β=0.249), plot coverage (β=-0.227) and height to width ratio (β=0.205) respectively. While plot coverage also has a negative impact like residential density implying that as these (residential density and plot coverage) increase beyond a certain limit the neighbourhood environmental quality deteriorates, all the other density variables of the model have a positive impact (as indicated in figure 6.1). Thus, as FAR, height to width ratio, distribution of sidewalks, etc. increases, neighbourhood environmental quality improves.

High residential density with high plot coverage generally implies low/medium rise compact developments with problems of crowding, congestion, noise and air pollution that deteriorate the environmental quality. On the other hand, higher FAR with higher height to width ratio point towards the high rise residential patterns with lower plot coverage and more open spaces having better environmental quality. The impact of domestic waste is not considered here as it is statistically not significant.

It is also worth noting that in addition to people density given by residential density and building density given by FAR and plot coverage; spatial density depicted by height to width ratio, distribution of sidewalks and streetlight density are amongst the influential attributes impacting neighbourhood environmental quality. This can be understood from the fact that presence of good and continuous sidewalks is one of the prerequisites for an environmentally conducive walkable neighbourhood. Similarly, adequacy of streetlights is important for a safe and secure neighbourhood. Higher height to width ratio affects the shade rating and ventilation score thus increasing outdoor comfort and promoting walkability, activity intensity, etc.

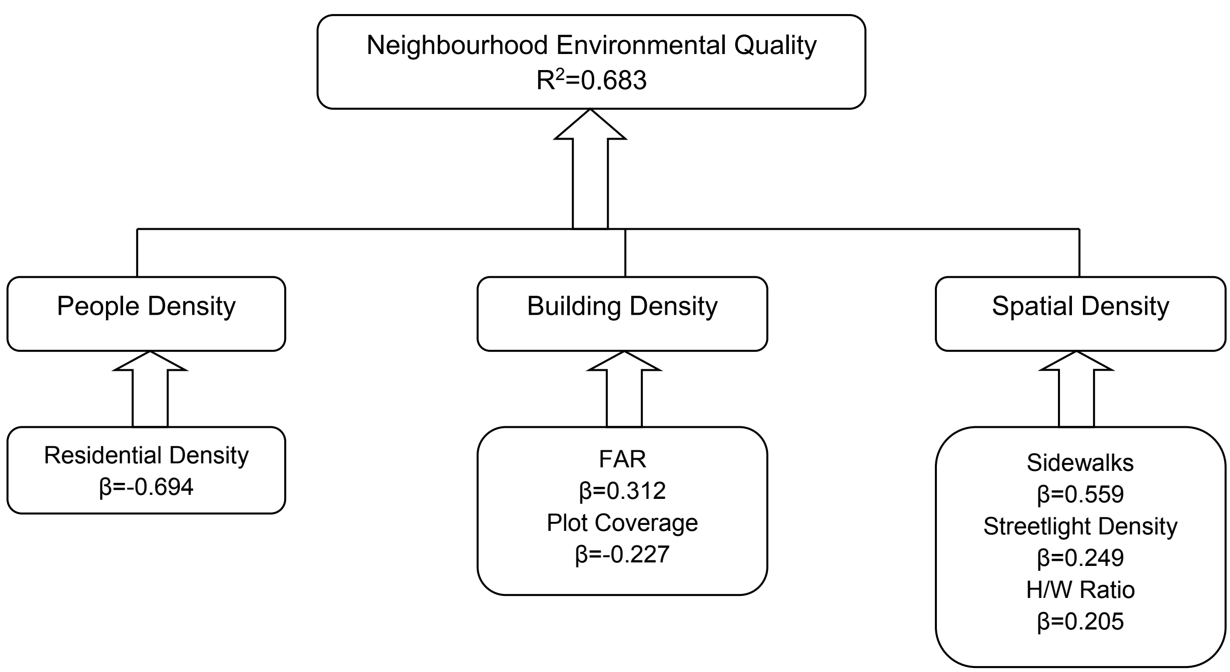

Figure 6.1: Results of the Multiple Hierarchical Regression Analysis

Finally, the accuracy of the model is also confirmed from the fact that the standardized residuals (difference between the observed values and the predicted values by the model) arise from a normal distribution. Further, in this regard, figure 6.2 shows that the histogram of the residuals is consistent with the assumptions of normality.

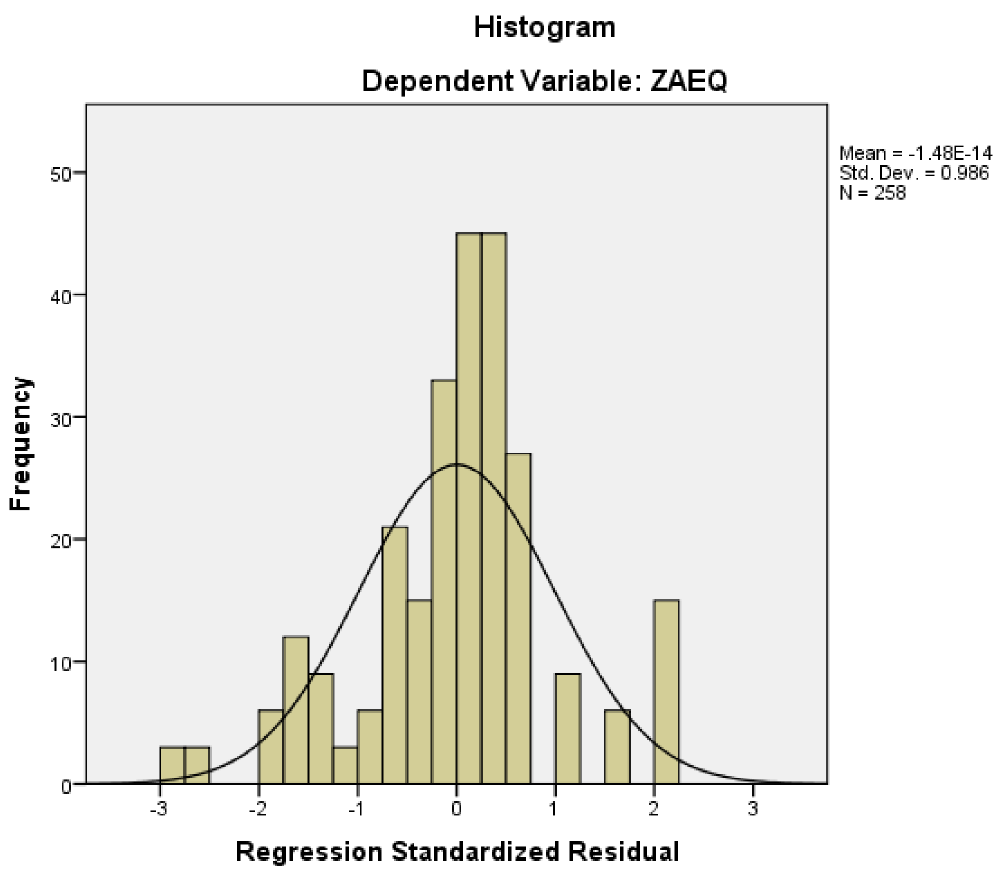

Figure 6.2: Histogram of Standardized Regression Residuals

6.3 The Best-to-Fit Analysis

The study applies the curve-fit function of IBM SPSS Statistics 22 (Statistical Package for Social Sciences) to explore the best-to-fit function between density variables and standardized aggregated environmental quality (ZAEQ) represented by the z-scores. The range of density variables as identified in table 5.11, Chapter 5 are considered to identify the optimum values of the significant density variables for the different residential patterns with the aid of the SOLVER optimization application of MS Excel 2013.

6.3.1 ZAEQ and People Density

The regression analysis between residential density – a type of people density and ZAEQ suggests that residential density accounts for 13.1% of the variance in ZAEQ and this is statistically significant as shown by the ANOVA table (as indicated in table 6.4).

Table 6.4: Model Summary and ANOVA of ZAEQ and Residential Density

R	R Square	Adjusted R Square	Std. Error of the Estimate
.362	.131	.121	.299

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.707	3	1.236	13.807	.000
Residual	24.611	275	.089		
Total	28.318	278			

The independent variable is Residential Density.

The curve-fit function shows that the cubic function fits the data most closely and further reinforces the fact that as residential density goes on increasing, the environmental quality fluctuates becoming positive or improving (favourable to very favourable) for particular density values and again deteriorating (unfavourable to very unfavourable) for other values of residential density (as indicated in figure 6.3).

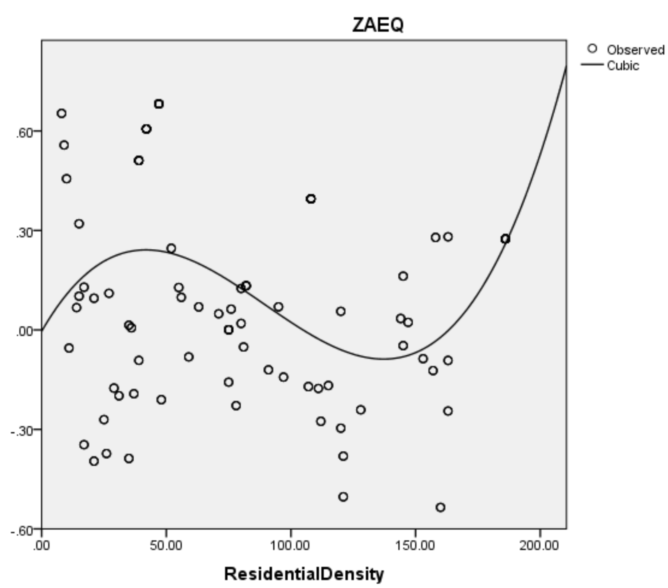

Figure 6.3: Best-to-fit analysis of residential density and ZAEQ

The optimization process using SOLVER optimization application of MS Excel 2013 reveals that there are typical residential density values at which the environmental quality of the neighbourhood is positive (as indicated in figure 6.4 and figure 6.5). These are **11-12 DUs/hectare** that corresponds to the very low density neighbourhoods as found in the northern sectors of Chandigarh or the gated communities generally found in the peripheral areas of different cities with plotted or high rise developments and large size accommodations. The next most typical residential density value is around **40-50DUs/hectare** that corresponds to the low/medium rise medium density neighbourhoods like Ranjit Avenue, Amritsar. The third typical value corresponds to high rise high/very high density neighbourhoods with approximately **170-180 DUs/hectare**. This finding is also in line with **Chen's, 2007** study that tries to establish a relationship between urban compactness and environmental profile of 45 Chinese cities and reveals that environmental efficiency generated by urban compaction is positive only up to a certain level, after which the relationship becomes negative. This finding appears consistent with many established arguments that "an environment has a limit or capacity up to which it can absorb activities without irreparable harm" **(Jenks, 2000)**.

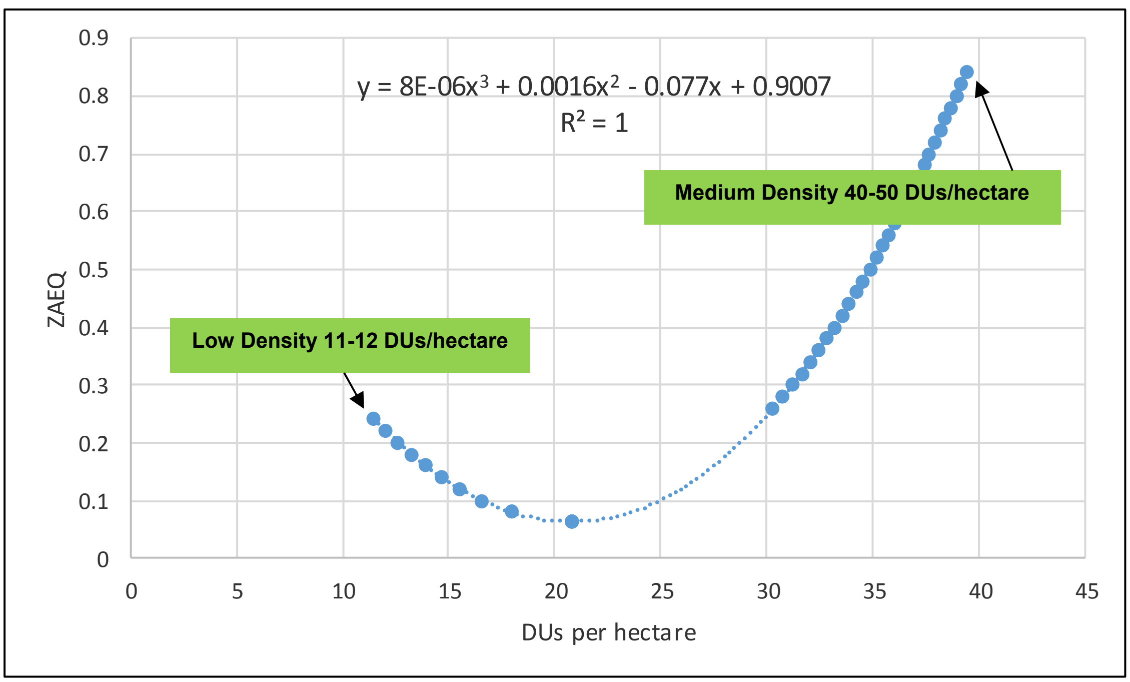

Figure 6.4: Residential density values (Low & Medium) for favourable ZAEQ

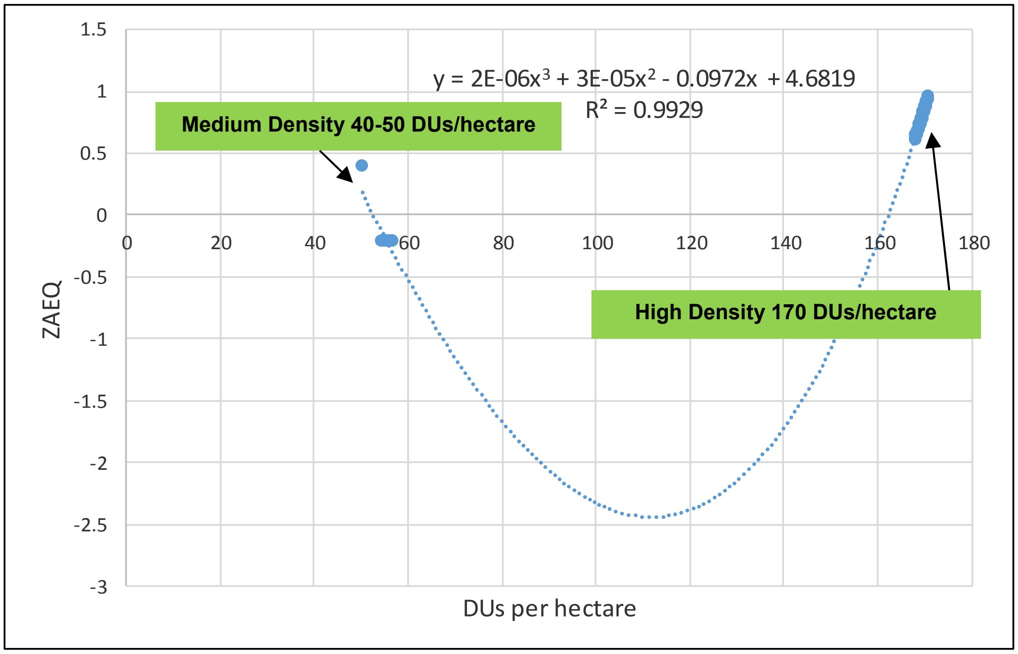

Figure 6.5: Residential density values (Medium & High) for favourable ZAEQ

6.3.2 ZAEQ and Building Density

The multiple hierarchical regression indicates that FAR and plot coverage have significant impact on environmental quality. Based on this, the curve-fit function shows that cubic function fits the data most closely in case of FAR (as indicated in figure 6.6).

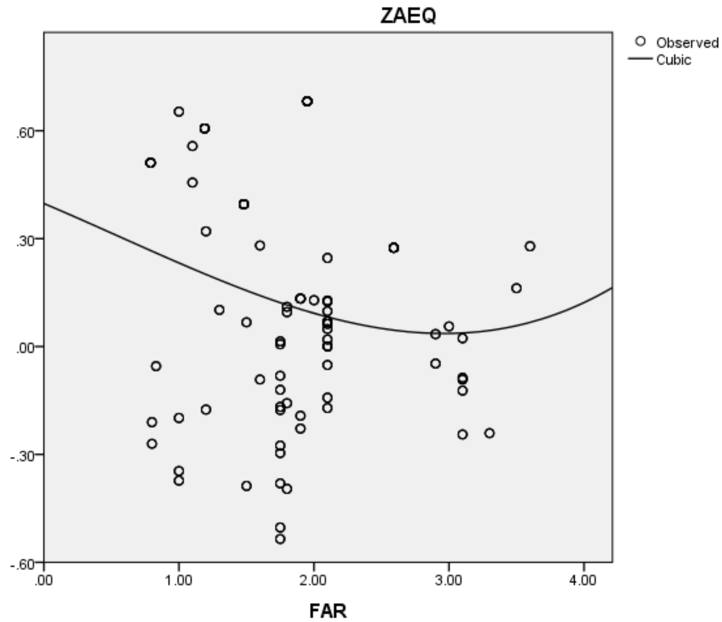

Figure 6.6: Best-to-fit analysis of FAR and ZAEQ

Similarly, the cubic function fits the plot coverage most closely (as indicated in figure 6.7) and helps us to draw conclusions regarding the desirable values of this density variable for favourable environmental quality.

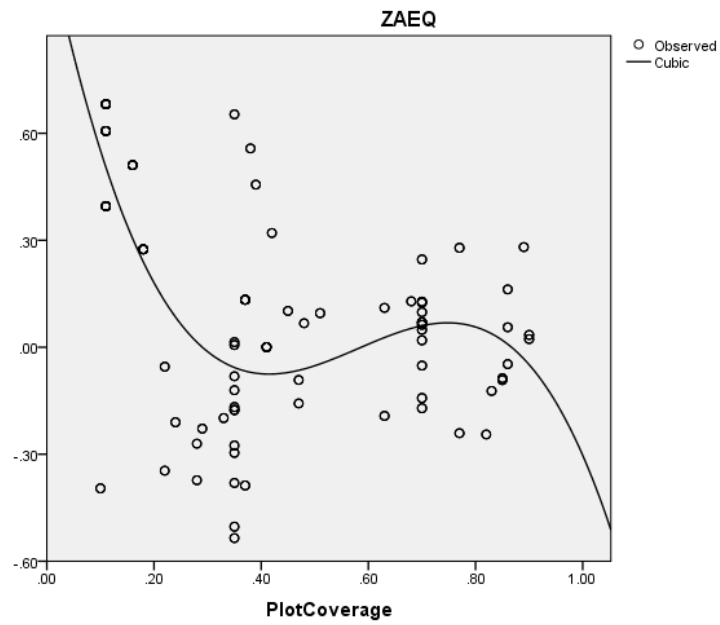

Figure 6.7: Best-to-fit analysis of Plot Coverage and ZAEQ

The regression model of both the variables – FAR and plot coverage are statistically significant and account for 4.4% and 46.4% variance in neighbourhood environmental quality respectively (as indicated in table 6.5 and table 6.6).

Table 6.5: Model Summary and ANOVA of ZAEQ and FAR

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.209	.044	.033	.314

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.237	3	.412	4.188	.006
Residual	27.081	275	.098		
Total	28.318	278			

The independent variable is FAR.

Table 6.6: Model Summary and ANOVA of ZAEQ and Plot Coverage

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.681	.464	.458	.235

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	13.127	3	4.376	79.213	.000
Residual	15.191	275	.055		
Total	28.318	278			

The independent variable is Plot Coverage.

The optimization process indicates and reinforces the findings of Chapter 5 by mathematically showing that the favourable values of FAR and plot coverage are **1-1.5 with 30-45% plot coverage**; and **2-3 with 13-22% plot coverage** respectively. Hence, the first group as observed in the case studies can be the low and medium rise neighbourhoods while the second group can be the high rise residential developments (as indicated in figure 6.8, figure 6.9 and figure 6.10).

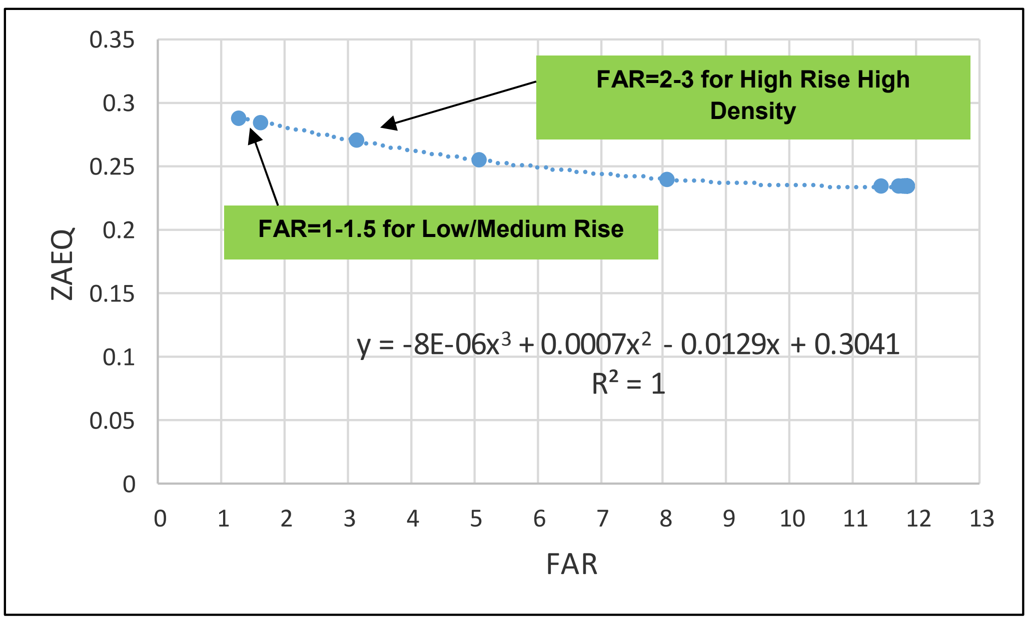

Figure 6.8: FAR for favourable ZAEQ

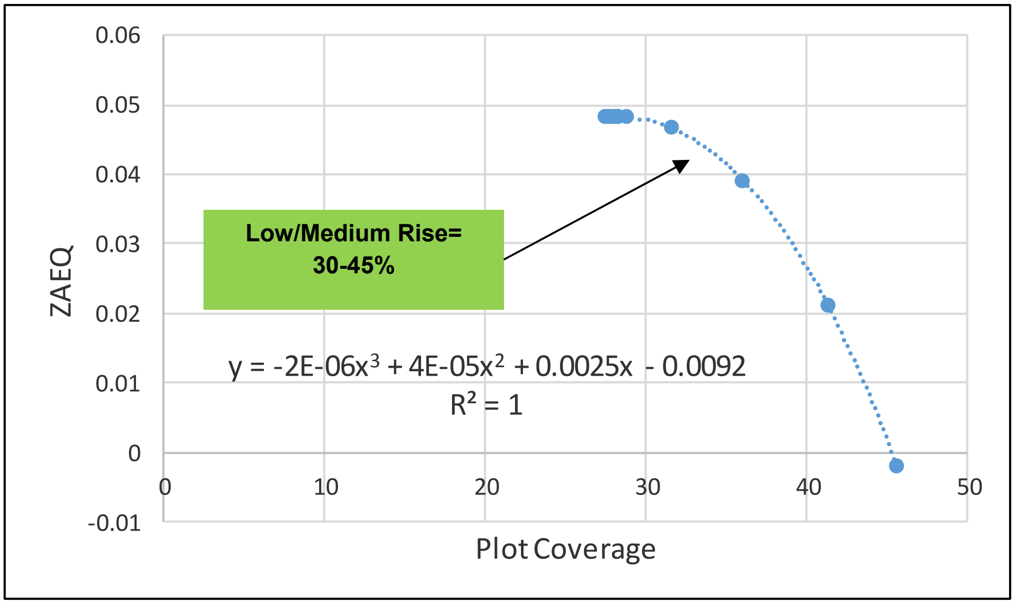

Figure 6.9: Plot Coverage (Low/Medium Rise) for favourable ZAEQ

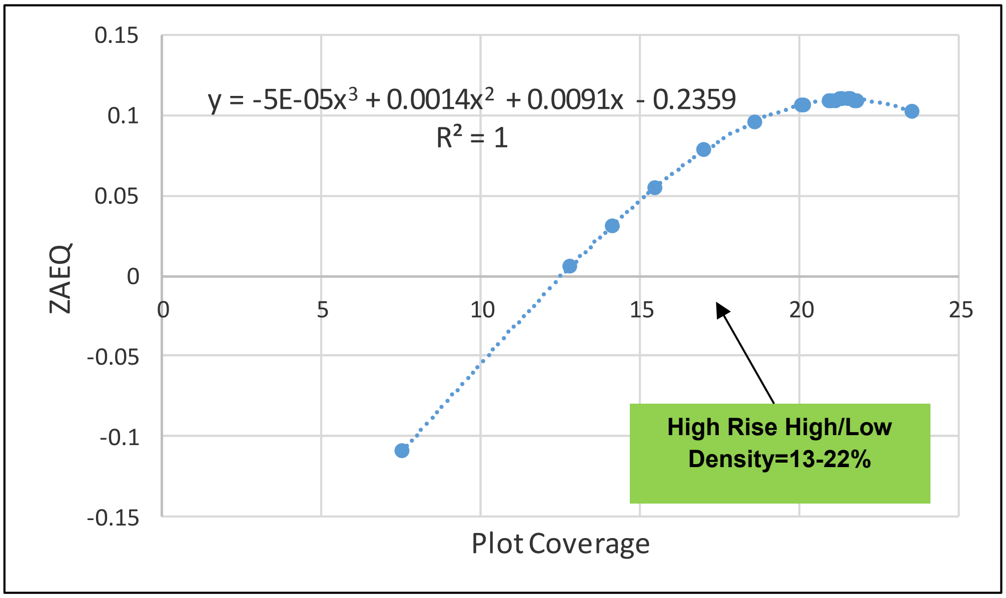

Figure 6.10: Plot Coverage (High Rise Development) for favourable ZAEQ

6.3.3 ZAEQ and Spatial Density

The spatial density variables namely height to width ratio, sidewalks and streetlight density are also subjected to the curve estimation process in IBM SPSS Statistics 22 and it is observed that while the cubic function fits the height to width ratio, the quadratic function fits the datasets of the other two variables most closely (as indicated in figure 6.11, figure 6.13 and figure 6.14). The statistically significant regression model further substantiates the fact that height to width ratio, sidewalks and streetlight density account for 19.7%, 48% and 14.4% of the variance in ZAEQ (as indicated in table 6.7, table 6.8 and table 6.9).

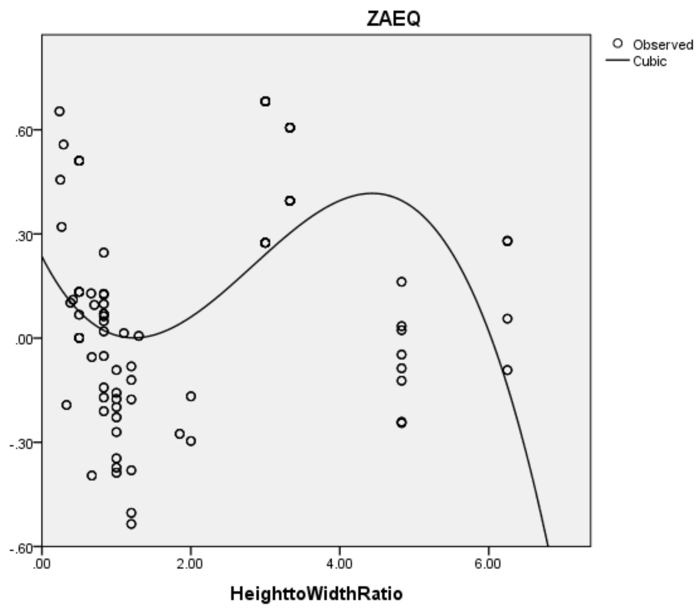

Figure 6.11: Best-to-fit analysis of Height to Width Ratio and ZAEQ

Table 6.7: Model Summary and ANOVA of ZAEQ and Height to Width Ratio

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.444	.197	.189	.287

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.589	3	1.863	22.539	.000
Residual	22.730	275	.083		
Total	28.318	278			

The independent variable is Height to Width Ratio.

Table 6.8: Model Summary and ANOVA of ZAEQ and Sidewalks

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.693	.480	.476	.231

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	13.580	2	6.790	127.163	.000
Residual	14.738	276	.053		
Total	28.318	278			

The independent variable is Sidewalks.

Table 6.9: Model Summary and ANOVA of ZAEQ and Streetlight Density

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.379	.144	.138	.296

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.071	2	2.035	23.169	.000
Residual	24.247	276	.088		
Total	28.318	278			

The independent variable is Streetlight Density.

The optimization for height to width ratio shows that the desirable values are in the range of 1.5-5 with **2.5** being the most optimum. In other words, this implies that the height of the buildings should generally be about 2.5 times the space left in between buildings. If height increases, the space should be increased accordingly to maintain this ratio for proper light, views and ventilation (as indicated in figure 6.12). For dense/compact developments, the ratio may be more but it should be noted that beyond 2.5 the ZAEQ starts falling drastically because of absence of daylight and views particularly even though it might provide shaded streets and pathways due to mutual shading as observed specially in Katra Dullo, Amritsar. Thus, climate of a place given by solar radiation and shade hours, wind and ventilation, etc. are important while assessing environmental quality. The study findings are suggestive values for the composite climate. Similar assessment can be carried out for cities located in other climatic zones.

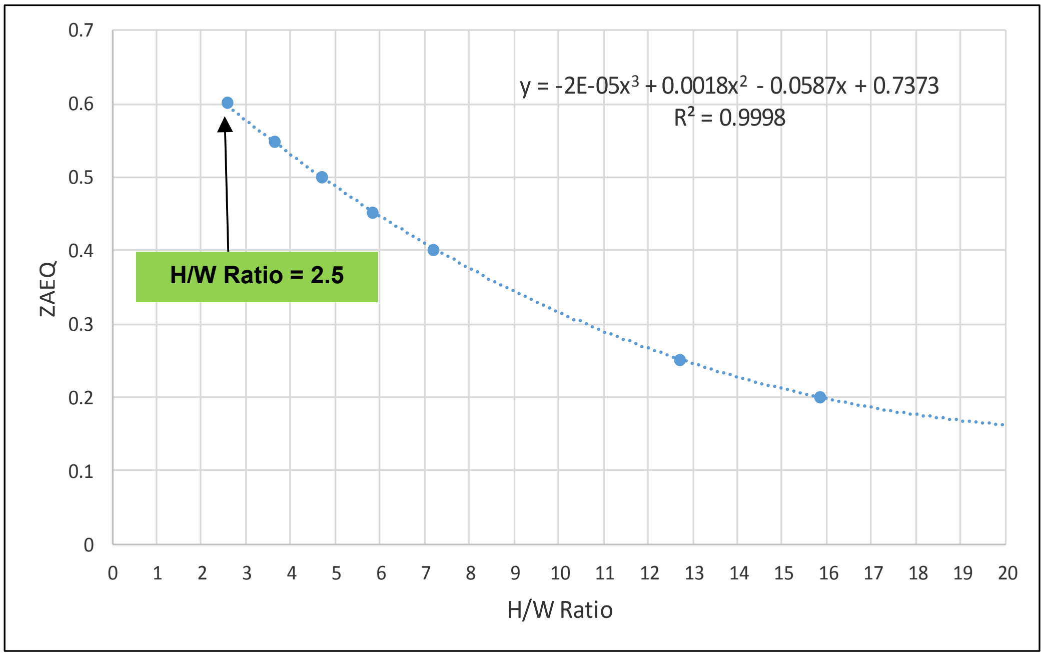

Figure 6.12: Height to Width Ratio for favourable ZAEQ

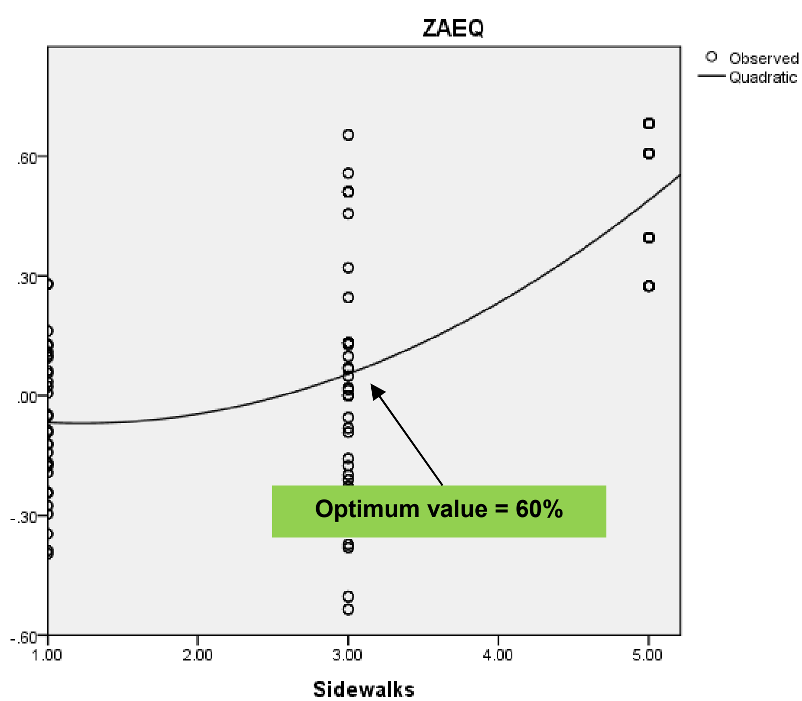

Figure 6.13: Best-to-fit analysis of Sidewalks and ZAEQ

The best-to-fit analysis shows that ZAEQ goes on increasing with the increase in sidewalks, the optimum being **3/5 or 60%** (as indicated in figure 6.13). This implies that 60% of the neighbourhood should have continuous sidewalks for favourable environmental quality. Good sidewalks are also known to encourage people to walk for short trips within and in near proximity of the neighbourhood and in turn reduce vehicular congestion, noise and air pollution in the locality. All these aspects further help in the development of an environmentally conducive walkable neighbourhood.

The streetlight density (with pole height of approximately 8-10m) is also understood to promote walkability and sense of safety in the neighbourhood especially after evening hours. The best-to-fit analysis gives an optimum value of **0.034 streetlights per unit paved road length** that works out to approximately **30m c/c distance** between adjacent streetlights as compared to 35m c/c suggested by the Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011 across various classes of cities.

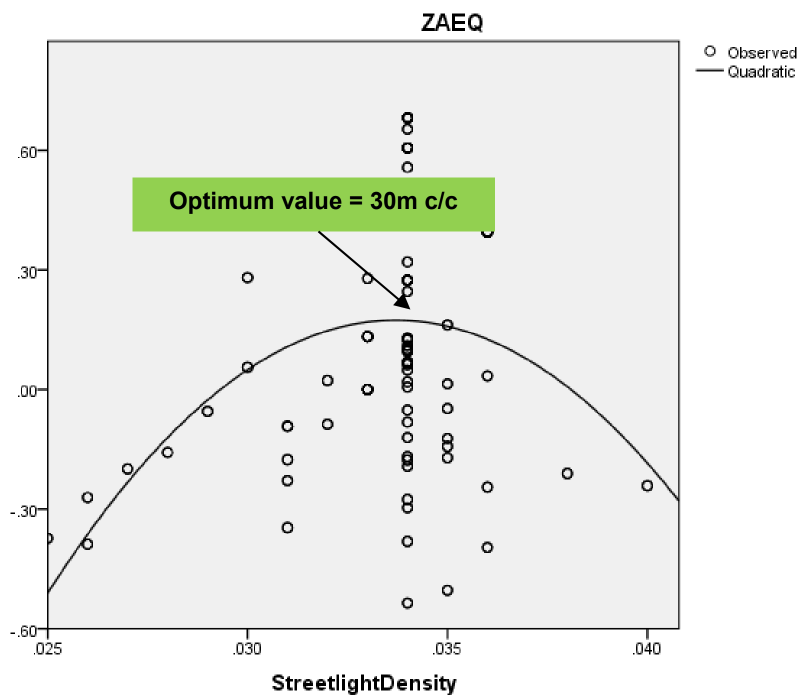

Figure 6.14: Best-to-fit analysis of Streetlight Density and ZAEQ

The best-to-fit analysis of streetlight density and ZAEQ (as indicated in figure 6.14) also shows that streetlight density > 30m c/c causes insufficient street lighting on one hand while streetlight density < 30m c/c causes wastage of infrastructure and energy thus affecting neighbourhood environmental quality.

Based on the assessment of the impact of density on neighbourhood environmental quality and the identification of optimum values of significant density variables for favourable environmental quality, certain measures are suggested for environmentally conducive development of the case study neighbourhoods as follows:

The values of the different significant density variables observed in the case study neighbourhoods are listed in table 6.10 as achieved from the case study findings in Chapter 4. Several spatial and physical characteristics can be modified to improve the overall environmental quality in most of the neighbourhoods. While Sector-8, Chandigarh – a low density neighbourhood has most of the values in the optimum range, it needs considerable improvement in the provision of good and continuous sidewalks to transform it into a more walkable neighbourhood.

Table 6.10: Values for different density variables of Case Study Neighbourhoods

Neighbourhood	People Density	Building Density		Spatial Density		
	Residential Density (DUs/ha)	**FAR**	**Plot Coverage** (%)	**H/W Ratio**	**Sidewalks** (Score)	**Streetlight Density** (streetlights/paved road length)
Sector 8, Chandigarh	17	1.00	49%	0.40	2	0.034
Ranjit Avenue, Amritsar	36	1.00	30%	0.93	3	0.030
World Spa, Gurugram	44	2.00	11%	3.17	5	0.034
Marble Arch (Manimajra), Chandigarh	65	1.57	31%	0.50	3	0.033
Sector 38W, Chandigarh	76	2.00	70%	0.83	2	0.034
Sector 20 (Panchkula), Chandigarh	98	2.00	35%	1.40	2	0.034
Uniworld City, Gurugram	147	2.03	15%	3.17	5	0.035
Katra Dullo, Amritsar	149	3.00	85%	5.30	1	0.034

In the medium density category as per the revised classification, Ranjit Avenue, Amritsar still has some scope of intensification by increasing the residential density marginally because population density (256pph) is already more than the optimum range (160-210pph) because of larger household size. Alongside the condition of the sidewalks can be improved as mentioned for Sector-8, Chandigarh. Marble Arch (Manimajra), Chandigarh also needs improvement in the provision of sidewalks especially in the study unit close to the main road. Thus provision and condition of sidewalks proves to be a really significant density variable for the creation of sustainable and walkable neighbourhoods as also shown by the multiple hierarchical regression analysis ((β=0.559) – the second most significant density variable having a positive impact on neighbourhood environmental quality.

Sector-38W, Chandigarh cannot be further intensified even by raising the FAR as the plot coverage is already quite high i.e. 70% and further intensification will have negative impact on the neighbourhood environmental quality by increasing crowding and congestion, noise pollution and air pollution. However, some improvement can be achieved by provision of sidewalks and improving the condition of the open spaces. For Sector-20 (Panchkula), Chandigarh along with improvement of the sidewalks, the level of cleanliness especially solid waste management will have to be taken up rigorously. Also the noise levels have to be controlled by increasing tree cover thus creating a sort of buffer/noise barrier between the roads and the dwelling units, controlling/managing vehicular movement (goods vehicles coming for delivery to the shopping area catering to the entire district as well as private vehicles using Sector-20 as a thoroughfare for accessing the large number of gated communities coming up beyond the sector boundary) and encouraging and promoting pedestrian movement – the latter being management practices to improve the quality. Certain time zoning/time clocking may be adopted forbidding goods vehicles movement during the day time. Also alternative road/bypass should be developed to cater to other residential areas lying beyond the sector boundary.

In the high density category, gated communities like Uniworld City, Gurugram can improve by increasing the road density to increase paved road length per capita (PRL/Capita) and avoiding dead ends that lead to congestion. Also, the FAR can be increased to raise the built-up area per capita (BUA/Capita) and reduce crowding. Finally, for core areas like Katra Dullo, Amritsar the most feasible solution is to develop open spaces, public squares etc. on vacant plots or by removal of dilapidated and structurally unsafe buildings from the neighbourhood. Such spaces at times may also be utilized as parking lots and thus help in decongesting the narrow streets which may then be more conveniently used by the pedestrians or non-motorized vehicles. This shall also help in reducing noise and air pollution and improve the environmental quality. Other interventions in compliance with local building regulations and HRIDAY, 2015 may include appropriate infill strategies and improvement of existing infrastructure and provision of adequate services to cater to the needs (of the residents) of such areas. Thus, it can be concluded that the present research methodology can help in suggesting case-specific solutions and pave the way for future sustainable cities.

6.4 Concluding Remarks

The present chapter proves the research hypothesis (alternative hypothesis) with the help of the multiple hierarchical regression (MHR) approach and conclusively shows that different density variables in varying degrees impact environmental quality in residential neighbourhoods. The hierarchical regression model indicates that the density variables namely – Residential Density (People Density), Plot Coverage and FAR (Building Density) and Height to Width Ratio, Sidewalks, Streetlight Density and Waste Collection Systems (Spatial Density) account for nearly 68.3% variation in neighbourhood environmental quality which is quite high. The β coefficients give the relative importance of each of the significant density variables affecting neighbourhood environmental quality. Residential density is found to have a high negative impact whereas sidewalks have a considerable positive impact on neighbourhood environmental quality. The best-to-fit analysis and optimization technique enables identification of optimum values of the significant density variables that can be used as measures to attain favourable environmental quality in neighbourhoods with different residential patterns in the composite climate. The important findings are summated in table 6.11 below.

Table 6.11: Optimum Density Values for favourable Environmental Quality in different Residential Patterns

<table>
<tr><th colspan="3">Density Variables</th><th rowspan="2">Key points for favourable environmental quality
(based on Optimization)</th></tr>
<tr><th>People Density
(Residential Density)</th><th>Building Density
(FAR and Plot Coverage)</th><th>Spatial Density
(H/W Ratio, Sidewalks and Streetlight Density)</th></tr>
<tr><td>Low
11-12DUs/ha</td><td rowspan="2">• FAR = 1-1.5
• Height = Low & Medium Rise
• Plot Coverage = 30-45%</td><td rowspan="3">• H/W Ratio = 2.5
• Sidewalks = 60%
• Streetlight Density = 0.034 streetlights per unit paved road length or 30m c/c</td><td rowspan="3">• Residential density for favourable environmental quality varies with residential pattern
• Plot Coverage should not exceed 70% or open spaces should not be less than 30%
• Minimum 60% of the neighbourhood should have continuous sidewalks
• Streetlights should be spaced 30m c/c for optimum utilization assuming other parameters constant</td></tr>
<tr><td>Medium
40-50DUs/ha</td></tr>
<tr><td>High
170-180DUs/ha</td><td>• FAR = 2-3
• Height = High Rise
• Plot Coverage = 13-22%</td></tr>
</table>

The study convincingly shows that all the parameters of physical density (people density, building density and spatial density) have significant impact on neighbourhood environmental quality thus justifying their adoption for planning/design or retrofitting/revitalization in the residential pattern under consideration.

References:

1. Chen, H., Jiaa, B. and Laua, S.S.Y. (2008) Sustainable urban form for Chinese compact cities: Challenges of a rapid urbanized economy. *Habitat International*, 32 (1), 28-40.
2. Field, A. (2009) *Discovering Statistics using SPSS*. London: SAGE.
3. Jenks, M. (2000) The Acceptability of Urban Intensification. In: K. Williams et al., (Eds.), *Achieving Sustainable Urban Form* (pp. 242-250). E & FN Spon.

SUMMARY, FINDINGS AND RECOMMENDATIONS

7.1 Introduction

The previous chapters help to identify typical residential patterns in Indian cities and assess the environmental quality at the micro-level – the level of the residential neighbourhoods which are the basic unit of urban planning. The novelty of the research lies in the fact that it considers the neighbourhood as an important unit for the assessment of environmental quality in urban areas hitherto generally evaluated at the level of the city. Secondly, it details out the process of assessing the environmental quality at the micro-level using the multi-criteria approach that helps to consider several density variables like people density, building density and spatial density. All these variables can be controlled and modified during the planning and design phase to achieve better spatial quality of the designed spaces. This further creates the possibility of taking up local actions at the street/cluster level by the residents, residents' welfare associations or 'mohalla sudhar committees' and the urban local bodies (ULBs) to improve the neighbourhood environmental quality that in turn can help in improving the overall quality of the urban environment.

The study model devised can be applied to diagnose case-specific issues in existing neighbourhoods and suggest remedial/retrofitting options to improve the environmental quality. For newly developing areas policy recommendations and design guidelines with respect to the residential pattern and density can be suggested so that favourable environmental quality can be attained/maintained.

The research also attempts to give objectivity to an otherwise abstract and subjective term called 'environmental quality'. Environmental quality at the neighbourhood level is assessed on the basis of crowding and congestion given by built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita), paved road length per capita (PRL/Capita) and mobilization factor (M.F); nature and use of open spaces given by type and condition of open spaces, tree cover, activity intensity and activity diversity; shade rating; ventilation score; temperature variations within and outside the neighbourhood; average noise levels; level of cleanliness; neighbourhood walkability given by proximity to daily needs, condition of sidewalks, condition of streetlights and type and condition of open spaces; and air quality given by levels of

SO_2, NO_x and $RSPM_{10}$. All these indicators are objectively measured or gathered from secondary sources, standardized and summated to get the aggregated neighbourhood environmental quality (ANEQ) – an objective value.

The 'Environmental Quality Index' (EQI) formulated from the objective values serves as a tool to classify different neighbourhoods of the city according to the level of environmental quality. The illustrative maps generated on the basis of the EQI can be used as useful visual aids that can help in bringing out heterogeneity at the neighbourhood level by identifying problems/issues at the micro-level.

The 'Environmental Quality Profiles' (EQPs) show the multivariate data consisting of different environmental quality indicators - crowding and congestion; nature and use of open spaces; shade and ventilation; temperature variations; noise levels; level of cleanliness; walkability and air quality on different axes of a radar chart. These help to identify commonalities and differences in the indicators of environmental quality and justify the level of neighbourhood environmental quality ascertained.

Overall, the present research attempts to provide a useful and simple approach for assessing neighbourhood environmental quality on the basis of the physical characteristics of the residential neighbourhoods. Further, it is envisaged that the process can be easily adapted by taking socio-economic variables to conduct cross-case and cross-time comparisons at a meaningful level. This in turn shall lead to a better understanding of the relationship between environmental quality and physical and/or socioeconomic conditions and expedite the realization of the long term and holistic goal of achieving urban sustainability in lines with the United Nations Sustainable Development Goals: Goal 11 – Sustainable Cities and Communities.

7.2 Summary of the Studies

There are many ways in which density helps limit environmental damage by reducing use of land, encouraging people to live in apartments, clustering of civic amenities and public transportation, supporting walkability, etc. However, most of the discussion about urban sustainability in India centres on "green codes" for buildings. The problem with the so-called green codes is that they exclusively focus on maximising an individual building whereas real gains come from the overall urban form. In short, the factors that matter are: Is the city dense or sprawled? Do people live in apartments or free-standing houses? Is the city designed for public transport? For instance, energy use drops by over 30% just by moving people from houses to apartments even if the green codes are ignored **(World Wide Fund for Nature (WWF), 2010)**. Similarly, public transport systems do not work efficiently when the city is spread out and commuters cannot easily walk to the bus/metro stop. Thus, it is seen that one of the enduring themes behind the search for more sustainable urban forms is that of the density of development. Also, TERI's (The Energy and Resources Institute, New Delhi) Green Guidelines for Large Developments 2012 **(Jia, 2012)** and GRIHA (Green Rating for Integrated Habitat Assessment) for Large Development 2015 **(Vij, 2015)** consider several parameters for development and evaluation of sustainable neighbourhoods but somehow do not give much idea about the optimum values of the physical density variables. With this intent the research proposes a tool that can be used by decision makers and physical planners, architects and urban designers to assess the effects of urbanisation on the environmental quality of a neighbourhood and classify localities based on physical density and corresponding environmental quality. The research also expects to assist in adopting optimum people, building and spatial densities in neighbourhoods with varying residential patterns for environmentally conducive development in existing as well as future cities.

7.2.1 Answers to the Research Questions

The study attempts to answer some pertinent research questions that are necessary to understand the nature of impact of different density variables on neighbourhood environmental quality. The different research questions and the important findings are as follows:

Research Question No. 1

What are the different residential patterns identifiable in rapidly urbanising Indian cities?

The urban form of the city is characterized by different configuration and types of built form and related population distribution across the geographical extent of the city. Alternatively, it can be stated that distribution of buildings, their typology and geometry, layout patterns, distribution / availability of open spaces, quality of infrastructure, etc. vary from one locality to the other within the city. Based on these parameters, rapidly urbanising cities generally have compact built-forms in the core/old areas with 70% ground coverage and 30% of the area occupied by pedestrian streets and courtyards. These characterise the low rise high density areas. Outside these core areas, either low rise low density British annexes like cantonment, civil lines or railway colonies dominate the city or haphazardly developed medium/high rise high density areas are found in and around commercial and industrial zones offering jobs to resident and migrant population or along transport corridors that promote easy accessibility to and from the place of work. Finally, the residential development seen in most city outskirts are the gated communities dominated by high rise apartment blocks, community open space and shared facilities and amenities. Thus, based on these findings, the study helps to identify eight different residential patterns based on building height and gross population density namely – Low Rise Low Density (LRLD), Low Rise Medium Density (LRMD), Low Rise High Density (LRHD), Medium Rise Medium Density (MRMD), Medium Rise High Density (MRHD), High Rise Low Density (HRLD) and High Rise High Density (HRHD) in different case study neighbourhoods of three rapidly urbanising cities namely, Amritsar, Chandigarh and Gurugram and enables the assessment of neighbourhood environmental quality categorically.

Research Question No. 2

How does People Density measured by Population Density and Residential Density impact environmental quality in different residential patterns?

The research finds that there is a strong correlation (multicollinearity) between population density (persons per hectare) and residential density (DUs per hectare) and hence similar relationships of both these variables with environmental quality. Therefore, the findings here mainly describe residential densities in terms of DUs per hectare and its impact on neighbourhood environmental quality.

The correlation analysis indicates that there is a strong negative impact of residential density on crowding and congestion, an important indicator of neighbourhood environmental quality. Generally the built-up area per capita (BUA/Capita), public ground area per capita (PGA/Capita) and paved road length per capita (PRL/Capita) decrease with increasing people density, $r = -0.50$, -0.80 and -0.70 as indicated in figure 4.14, 4.15 and 4.16, Chapter 4 respectively. The association is strongest and statistically significant between residential density and PGA/Capita ($p<0.05$). This suggests that increasing people density causes more crowding and congestion and hence deteriorates the environmental quality.

Also, it is found that generally there is a decrease in the level of environmental quality with increasing residential density. Hence, a blanket residential or population density range or value cannot be suggested across different residential patterns. Every type – whether low, medium or high density has optimum values of residential density that differ from the other and help in maintaining/attaining favourable neighbourhood environmental quality. While low density neighbourhoods can have 11-12DUs/ha, medium density neighbourhoods can have 40-50DUs/ha and high density neighbourhoods can have approximately 170-180DUs/ha for favourable environmental quality. These findings appear consistent with many established arguments that "an environment has a limit or capacity up to which it can absorb activities without irreparable harm" **(Jenks, 2000)**.

Research Question No. 3

How does Building Density measured by FAR and Plot Coverage impact environmental quality in different residential patterns?

It is known that plot ratio or FAR is often controlled in the master plan in order to govern the extent of built-up and to prevent overdevelopment. Similarly, site or plot coverage and height of individual developments is often controlled in order to prevent over-build and to preserve areas for greenery and landscaping. For a particular residential density on a given site, the proportion of open areas for communal facilities, etc. goes on increasing as the urban form transforms from a low rise to medium rise to high rise residential pattern **(Cheng, 2010)**. Thus, plot coverage particularly shapes the quality and amount of open spaces that further impact the neighbourhood environmental quality.

The present study clearly shows that in case both these density variables show an increasing trend, then environmental quality deteriorates i.e. if both FAR and plot coverage are high as in the case of Katra Dullo, Amritsar – it leads to a very compact and dense sort of residential pattern that loses out on many other factors like distribution of open spaces, proper roads and sidewalks, etc. and hence becomes unable to have favourable environmental quality.

Thus, it is concluded that low FAR (1-1.5) with higher plot coverage (30-45%) and higher FAR (2-3) with comparatively lower plot coverage (13-22%) works best for favourable environmental quality. While the first group corresponds to the low and medium rise neighbourhoods, the second group is most suitable for the high rise residential developments.

Research Question No. 4

How does Spatial Density impact environmental quality in different residential patterns?

Spatial density refers to the perception of density with respect to the relationship among spatial elements such as height to width ratio, spacing and juxtaposition. The present research finds that most of the spatial density variables like distribution of open spaces, sidewalks, services (domestic waste collection, stormwater drainage, sewerage) etc. have a positive correlation with neighbourhood environment quality. The greater the distribution of the open spaces, sidewalks and services, the better is the environmental quality.

The study also brings forth the optimum requirements of these variables for favourable environmental quality. While any neighbourhood should have atleast 30% area under open spaces and 60-70% of the commuting routes with sidewalks, it should have 100% coverage of domestic waste collection system, stormwater drainage and sewerage i.e. all the houses of the locality should have door-to-door collection of domestic waste on a regular basis and should be connected to the underground sewerage system. Similarly when the height to street width ratio and streetlight density are considered, they are found to have an overall positive impact on neighbourhood environmental quality. However, the detailed analysis and subsequent optimization shows that for certain specific values of the above mentioned variables, the environmental quality is favourable and tends to deteriorate with either an increase or decrease from the optimum value. Desirable values for height to width ratio are in the range of 1.5-5 with 2.5 being the most optimum. In other words, this implies that the height of the buildings should generally be about 2.5 times the street width or space in between buildings. If height increases, the street width/space should be increased accordingly to maintain this ratio for favourable light, views and ventilation. In case of streetlight density, 30m c/c distance between adjacent streetlights keeping other parameters constant works out to be the most optimum distance for adequate lighting promoting a safe and secure residential environment in the type of cities under consideration. Anything substantially over or under either causes insufficient street lighting or wastage of infrastructure and energy thus affecting neighbourhood environmental quality.

Research Question No. 5

What are the optimum ranges of density for neighbourhoods with different patterns to maintain favourable environmental quality?

In the present study, residential patterns are identified by the physical density variables namely – people density, building density and spatial density. The emerging relationships of the study are consistent with the mainstream arguments of density and environmental quality. The influence of density on the studied environmental quality attributes is found to be significant as expected. Significant correlations at 95% confidence level are seen between many density variables and (indicators of) neighbourhood environmental quality. While environmental quality varies negatively with population density, residential density, FAR and plot coverage; it shows positive correlation with height to street width ratio, distribution of open spaces, sidewalks and streetlight density. In other words, this means that as population density, residential density, etc. goes on increasing the environmental quality tends to deteriorate whereas with increase in height to width ratio, open spaces, sidewalks and streetlights permitting walkable and safe neighbourhoods, the environmental quality starts improving. It is also seen that spatial density of domestic waste collection system, provision of stormwater drainage and sewerage also show positive association with ZAEQ thus reinforcing the assumption that adequacy of services improve the environmental quality. It is also observed that as people density, building density and spatial density go on increasing across all the different residential patterns, the environmental quality fluctuates becoming positive or improving (favourable to very favourable) for particular combinations of the density variables and again deteriorating (unfavourable to very unfavourable) for other combinations of the variables. Thus, the desired ranges of density for neighbourhoods with different patterns work out as:

- ✓ **People Density** – Based on people density, the residential patterns with favourable environmental quality can be suitably divided into three categories – low density with 11-12DUs/ha, medium density with 40-50DUs/ha and high density with 170-180DUs/ha.
- ✓ **Building Density** – The favourable values of FAR and plot coverage are found to be 1-1.5 with 30-45% coverage; and 2-3 with 13-22% coverage respectively. The first group as observed in the case studies can be the low and medium rise neighbourhoods while the second set of values can be suitably adopted for the high rise residential developments.
- ✓ **Spatial Density** – The distribution of open spaces greater than equal to 30% is required for favourable environmental quality. Similarly, 60-70% of the roads/streets in the neighbourhood should have continuous and good quality sidewalks to promote walkability. Streetlights should be 30m c/c for optimum lighting and coverage of waste collection, drainage and sewerage systems should be 100% for good environmental quality. The important findings as stated above are already summated in table 6.11, Chapter 6.

7.3 Policies and Guidelines for Environmentally Conducive Development of Residential Neighbourhoods

The research findings amply show that physical aspects of the neighbourhood can be effectively regulated to enhance the neighbourhood environmental quality. This further offers an opportunity to frame policies and development control regulations for spatial and physical aspects of urban neighbourhoods to attain favourable environmental quality and tread towards sustainability.

1. Accordingly, first of all, it is important to understand that a city has a heterogeneous spatial structure and there is a need to revise the density regulations depending on the residential pattern observed/envisaged for future sustainable growth and development of the city. Blanket density values for e.g. as suggested by URDPFI – 125 to 175pph (developed area average densities for metropolitan cities) may not work and it is important for policy makers to avoid a ‘one policy fits all’ approach.

2. Secondly, equally distributed low FAR throughout the city is detrimental for the sustainable growth of the city. Low FAR causes shortage of floor space within city limits and raises real estate prices thus forcing people to move outwards leading to urban sprawl and unsustainable growth in the absence of infrastructure and services and destruction of agricultural fields, forests and environmentally sensitive areas in most cases. Therefore, the FAR should be regulated in accordance with the residential pattern envisaged for future sustainable development.

3. Thirdly, one should note that Master Plans do not incorporate density as a tool for development even though some large urban programs like JNNURM (Jawaharlal Nehru National Urban Renewal Mission 2005) are promoting densification of inner cores and trying to fill the gaps in policies. The present research suggests that land-use plan and urban form should be intensively analysed to understand the location of activity nodes, movement of people, distribution of population and residential densities, typology of built forms, etc. in core, intermediate and peripheral areas of the city. This in turn may be utilized to decide the people, building and spatial densities for specific areas/neighbourhoods of the city. In line with **Ray’s (2012)** findings, conical massing with high density high rise areas in the centre and tapering towards the edges of the city interspersed with open/public spaces may be promoted.

4. Fourthly, it is apparent from the study that neighbourhood environmental quality assessed on the basis of the physical attributes of the built environment gives different outcomes for different residential patterns. This indicates that environmental policies and guidelines should be contextual and made at the neighbourhood/local level to cater to

the issues at hand promptly and make communities safe, resilient and sustainable as envisioned in the United Nations Sustainable Development Goals: Goal 11 – Sustainable Cities and Communities.

5. Last but not least, by facilitating the participation of people and local communities along with the government agencies, inclusive neighbourhoods that continue to thrive and grow, while improving resource use and reducing pollution and poverty can be built at a much faster pace. People should be involved in the future planning process also by being given a chance to assess their built environment based on socio-cultural, economic and psychological needs in addition to physical attributes.

7.4 Conclusion

It can be concluded that the neighbourhood is a valid level of aggregation for the assessment of environmental quality and several policies, guidelines and development control regulations need to be formulated at this level for environmentally conducive growth and development in rapidly urbanising Indian cities. Consequently, some of the effective ways can be as follows:

1. Moderate to high density neighbourhoods (40-50 DUs/ha or 170-180DUs/ha) should be promoted as they would use land efficiently to accommodate more people, have better access to services and facilities, feel more secure and develop as vibrant and active social units in the overall city structure.
2. Horizontal and vertical randomisation of buildings coupled with high FAR and low plot coverage (FAR 2-3 and Plot Coverage – 13-22%) should be adopted for environmentally conducive sustainable development.
3. Streets and sidewalks well-connected to services and facilities like public transportation stops at the neighbourhood edges and open spaces supporting pedestrian access (taking lighting, paving, safety etc. into account) should be designed. Relatively small design and planning decisions such as the width and design of streets, the size of blocks etc. can have huge implication on urban sustainability. Hence, they should be designed accordingly and integrated with emerging concepts of mixed land use, smart neighbourhoods, etc.
4. Management of shared greens or open spaces in high and very low density neighbourhoods is problematic as observed in Sector-8, Sector-38W and to some extent in Sector-20 (Panchkula), Chandigarh. Design of such neighbourhoods should frame certain guidelines for maintenance and supervision of open/public spaces.

5. Creating a range of attractive open spaces centrally located and visually more integrated with other neighbourhood spaces may be taken up as an integral part of neighbourhood planning. This in turn may influence the number of social contacts, quality of social network and frequency of social interaction in the neighbourhood as also shown by **Raman's (2010)** study.
6. Additionally children play areas etc. may be provided near medium and high rise buildings to provide comfortable micro-climate by ensuring natural sun protection from mutual shading that may further enhance activity intensity and diversity **(Shekhar and Tripathi, 2015)**.
7. For old areas of historical cities as seen in case of Katra Dullo, Walled City – Amritsar, the built forms reflect the history, culture, traditions, climate responsiveness and socio-economic patterns of the period in which they developed. In such cases, links to the past can be maintained by retaining the integrity of the urban form and benefitting from centuries of experience while adopting changes through appropriate retrofitting and revitalization strategies.

Thus, it can be summarised that action policies and strategies with proper land use and infrastructure planning, urban design, investment and efficient management at the neighbourhood level may be adopted for sustainable development of rapidly urbanising Indian cities.

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AVENUES FOR FUTURE WORK

8.1 Introduction

The present research helps to prove that physical density has significant impact on the neighbourhood environmental quality in our cities. It shows that there is lot of scope for architects, urban designers, urban planners, decision makers and local stakeholders to adopt suitable strategies for environmentally conducive design, development and maintenance of residential neighbourhoods that in turn can be the catalysts for future sustainable development of Indian cities.

The present research also reinforces the fact that a blanket density range/value cannot be suggested across different residential patterns and the ‘one policy fits all’ approach is not justified. Every type – whether low, medium or high density has optimum values of density that differ from the other and help in maintaining/attaining favourable neighbourhood environmental quality. These findings appear consistent with many established arguments like **Carl’s (2000)** statement that ‘Sustainable cities are a matter of density’. The research enables assessment of optimum values of different density variables for varying residential patterns that is seldom found in the literature. This further facilitates the formulation of case specific policies and guidelines for environmentally conducive development of residential neighbourhoods in Indian cities.

8.2 Limitations and Parallel Challenges

The background studies reveal that references are scanty and there is very little work reported in this domain especially in the Indian context. **Leidelmijer et al. (2002)** argue that there is no coherent system to measure and evaluate aspects of, and trends in, environmental quality though concepts of urban environmental quality and related terms such as livability, quality of life and sustainability enjoy great public popularity and form a central issue in research programs, policy making and urban development. It follows that there is a need to evaluate several physical aspects of the urban form from a new perspective in order to gain detailed insights into the spatial components that influence environmental quality. Based on these views, the present research provides an immense possibility of advancing the derived methodology of assessing environmental quality at the neighbourhood level and understanding the variations (if at all) in optimized densities for residential patterns in cities of different sizes, classes, types, regions, climatic zones, etc. to derive case-specific solutions and suggest suitable measures to improve the environmental quality.

The present work is limited to a number of physical aspects of neighbourhoods from cities of a particular size and class due to the boundary conditions of the research, constraints of time and resources, availability of data, etc. However, further studies can be conducted in more detail with certain aspects for e.g. analyzing the impact of car traffic volume of the neighbourhood on crowding and congestion, noise levels and air quality – all extremely important indicators of neighbourhood environmental quality.

Factors like the role of urban governance in the taxation and maintenance of municipal services and variations in socio-economic status of people and its effect on the type of facilities and amenities in a residential neighbourhood and the resultant impact on environment quality should also be considered for future study and analyses. Similarly, social density – one of the types of perceived density **(Chan, 1999)** should be made part of the analyses to understand the level of social interaction among the people and its implication on neighbourhood environmental quality.

Slums and squatter settlements pose a constant threat to the sustainable development of our cities. They are kept out of the scope of the present study. These could be taken up in future studies by team of researchers from educational institutions, government and non-government organizations (NGOs), urban local bodies (ULBs), etc. to assess the environmental quality by applying the methodology developed and upgradation/redevelopment measures with peoples' participation can be undertaken to make them desirable for human habitation. The governments should strive to create an 'enabling environment', under which people by using their own resources can find unique local solutions for their housing and shelter problems.

8.3 Directions for Future Research

For holistic understanding of the several forces shaping the 'neighbourhoods' – the primary urban morphological unit, the research can encompass the social, economic, political, historical, and psychological aspects and assess their impact on the environmental quality. This in turn will open multidisciplinary avenues for future researchers not only from the design field but for people from different backgrounds and expertise like sociologists, economists, historians, psychologists, etc.

It is also expected that further research may be undertaken to explore alternative methods along with application of advanced mathematical modeling and optimization techniques, geographic information system (GIS) and urban simulation softwares to systematically assess and predict the environmental quality of entire cities. Action research on actual design and execution of model neighbourhoods with different residential patterns according to peoples' needs and aspirations based on such techniques should be put to test against time and actual use for future sustainable cities.

Finally, it is well understood that if the various parameters of density like number of dwelling units, floor area ratio (FAR), plot coverage or the built form, layout, minimum standard of living and outdoor space, etc. are linked together, environmentally conducive neighbourhoods can be developed in our existing and future cities. However, densities can be delivered in many different forms and it is important that these forms match the needs and aspirations of the residents, to deliver the best possible quality of life **(Dave, 2010)**. In this regard, the present research can serve as a foundation for formulation of policies, guidelines and development control regulations for the planning and design of sustainable neighbourhoods with different residential patterns suitable for different parts of the city.

In addition, a re-examination of the national and regional urban growth policies to tackle urban-rural migration may be considered along with such guidelines and regulations in place as mentioned above, so that before long we are able to deal with the complex challenge of achieving sustainability in rapidly urbanising Indian cities.

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Glossary

Analysis of Variance (ANOVA)	This is an extremely useful technique when multiple sample cases are involved. It is used to determine the significance of difference of more than two sample means at the same time. Thus, through ANOVA technique one can, in general, investigate any number of factors which are hypothesized or said to influence the dependent variable.
Correlation Analysis	This is a method of statistical evaluation used to study the strength of a relationship between two, numerically measured, continuous variables (e.g. height and weight).
Histogram and Q-Q Plots	Both histograms and q-q plots are graphical methods to assess whether the data is normally distributed or not. A close to bell shaped curve in case of the histogram and points approximately falling on a straight line in case of a q-q plot shows that the data is normally distributed.
Outliers	In statistics, an outlier is an observation point that is distant from other observations. An outlier may be due to variability in the measurement or it may indicate experimental error. It is generally excluded from the data set as it can cause problems in statistical analyses.
p-value	In a hypothesis test in statistics, a p-value helps to determine the significance of the results. The p-value is a number between 0 and 1 and interpreted in the following way: A small p-value (typically ≤ 0.05) indicates strong evidence against the null hypothesis, so one can reject the null hypothesis.
Regression Analysis	This is used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables.
Shapiro Wilk Test p-value	The test is one of the important normality tests designed to detect all departures from normality. The test rejects the hypothesis of normality when the p-value is less than or equal to 0.05. Passing the normality test is prerequisite for carrying out parametric statistical tests.
Skewness and Kurtosis	Skewness is asymmetry in a statistical distribution, in which the curve appears distorted or skewed either to the left or to the right. Skewness can be quantified to define the extent to which a distribution differs from a normal distribution. In probability theory and statistics, kurtosis (from Greek: κυρτός, kyrtos or kurtos, meaning "curved, arching") is a measure of the "tailedness" of the probability distribution of a real-valued random variable. That is, data sets with high kurtosis tend to have heavy tails, or outliers. Data sets with low kurtosis tend to have light tails, or lack of outliers.
Standardized Regression Residuals	The difference between the observed value of the dependent variable (y) and the predicted value ($\hat{y}$) from the model is called the residual (e). Each data point has one residual. Residual = Observed value - Predicted value or $e = y - \hat{y}$. Standardized Residuals arising from a normal distribution confirm the accuracy of the model.

Source: www.wikipedia.org

Annexure 1

DEPARTMENT OF ARCHITECTURE
Jadavpur University, Kolkata

ACADEMIC SURVEY for Ph.D. THESIS
Residential Neighbourhood Survey

The following survey is being undertaken as part of a doctoral thesis to understand the pattern of physical development and environmental quality of a locality. The findings will help in determining the kind of association between physical density and neighborhood environmental quality and further enable the planning and design of better and more livable urban localities. Please do not feel obliged to answer a question if you do not wish to, though it is assured that any information you provide will be treated with strict confidentiality.

Investigator : ______________________ Date : ____________________

General Information

1.	Name of Locality	: __________________	2. House No.	: ___________________
3.	Head of Family	: __________________	4. Age	: ___________________
5.	Occupation	: __________________	6. Area of work place	: ___________________

7. Mode of travel to work : ☐ Walk ☐ Cycle ☐ 2-wheeler ☐ Rickshaw ☐ Car ☐ Bus
8. Type of occupancy : Rented / Owned
9. Rent Paid : ☐1000-2500 ☐2501-5000 ☐5001-7500 ☐7501-10,000 ☐>10,000
10. Family Structure : Joint / Nuclear
11. Total no. of family members : ____
12. No. of families / dwelling unit : ____

I. Physical Features of the Building / Built Form

a) Type of housing : Row / Detached / Flatted
b) Total Plot Area : 30sqm or less / 31-50sqm / 51-100sqm / 101-250sqm / >250sqm
c) Total plinth area : 30sqm or less / 31-50sqm / 51-100sqm / 101-250sqm / >250sqm
d) No of stories : G / G+1 / G+2 / G+3
e) Material of Construction : Pucca / Semi - Pucca
f) Stay since (in years) : 1-5, 6-10, 11-20, 21-30, 31-40, 41-50, >50
g) Age of building (in years) : <10, 10-19, 20-49, 50-70, >70
h) Condition of building : ☐ Very Good ☐ Good ☐ Fair ☐ Bad ☐ Very Bad
i) Light and ventilation : ☐ Very Good ☐ Good ☐ Average ☐ Bad ☐ None

II. Infrastructure Available

a) Storm Water Drains : ☐ Open ☐ Underground

b) Percentage of drains – open v/s underground : ____________________

c) Sewage disposal : ☐ Sewer ☐ Septic tank

d) Garbage disposal point : Door to door collection / M.C. Waste Bin / other

e) Frequency of collection : ☐ Daily ☐ 2-3 times a Week ☐ Weekly once

f) Road type : ☐ Metalled ☐ Brick or Stone Paved

g) Width in metres : ____________________

h) Rate the cleanliness of the roads : ☐ Good ☐ Satisfactory ☐ Poor

i) Rate the sidewalks in your locality : ☐ Good ☐ Satisfactory ☐ Poor

j) Provision of Street Lights : Yes / No

k) Provision of Parking Lots : Yes / No

l) If yes, approx. capacity : _______ Cars and _______ Scooters

III. Amount and Distribution of Open Spaces

a) Open area at plot level : Yes / No

b) Percentage of open area in the plot : ____________________

c) Open area at cluster level : Yes / No

d) Cluster level use and approx. area : ____________________

e) Open area at locality level : Yes / No

f) Approx. area : ____________________

g) Nature of openness : ☐ Incidental ☐ Organised

h) If organised : ☐ Maintained ☐ Unattended

i) Locality level use of open space : Parks / Playgrounds / Fairs and Festivals

IV. Other factors contributing to overall Environment of the Locality

a) Traffic congestion on roads : ☐ None ☐ Some ☐ Lots

b) Outdoor noise level (traffic, loudspeakers, etc.) : ☐ Quiet ☐ Reasonable ☐ Loud

c) Air pollution level (smoke and dust) : ☐ None ☐ Some ☐ Lots

d) Foul smell from garbage / litter / open drains : ☐ None ☐ Some ☐ Lots

e) No. of trees in the locality : ☐ None ☐ Some ☐ Lots

f) Presence of birds and butterflies : ☐ None ☐ Some ☐ Lots

g) Landscaping features in the locality : ☐ None ☐ Some ☐ Lots

h) Temperature difference observed : ☐ None ☐ Some ☐ Lots

Please rank sections I – IV above priority wise that according to you affect the environmental quality of the neighbourhood most.

V. Open Questions

1. What do you like about your locality?

____

____

____

2. What do you don't like about your locality?

____

____

____

3. Do you think your locality is getting crowded and losing its ambience over time?

____

____

4. Do you think certain guidelines and rules would help to improve the place? Specify.

____

____

____

5. What are your suggestions for improvement?

____

____

____

Thank You!

Annexure 2

Data Sheet 1: Katra Dullo, Amritsar – Crowding and Congestion

STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
K1	2767	3.5	171	625	40	145	54.70	392	2.24	80	0.46	1	3	3.00
K2	3388	2.9	208	621	48	144	45.18	322	1.50	98	0.46	1	3	3.00
K3	4139	3.1	258	630	60	147	48.72	434	1.66	110	0.42	2	2	1.00
K4	1462	1.6	101	700	24	163	24.85	168	1.82	83	0.89	2	2	1.00
K5	2242	3.6	151	680	35	158	57.05	523	3.69	75	0.53	3	3	1.00
K6	4682	3.0	238	515	55	120	47.13	655	2.21	115	0.39	2	3	1.50
K7	8610	3.1	596	700	139	163	48.29	1303	2.39	257	0.47	1	3	3.00
K8	3611	3.1	242	677	56	157	48.98	610	2.67	172	0.75	2	2	1.00
K9	3558	2.9	220	625	51	145	45.97	515	2.29	194	0.86	2	3	1.50
K10	4727	3.1	327	700	76	163	49.26	840	2.81	139	0.46	1	3	3.00
K11	4047	3.3	220	550	51	128	52.86	924	3.61	151	0.59	1	3	3.00
K12	6587	3.1	430	660	100	153	48.40	970	2.33	174	0.42	2	3	1.50
	Total= 49820	3	Total= 3161	Average = 640	Total= 735	Average= 149	**47.62**		**2.43**		**0.56**			**1.96**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 2: Ranjit Avenue, Amritsar – Crowding and Congestion														
STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
R1	28134.5	1.0	946	340	86	31	18.39	20700	21.88	773	0.82	12	4	0.33
R2	31210.6	1.0	880	285	80	26	20.00	21300	24.20	832	0.95	12	4	0.33
R3	28288.8	0.8	781	279	71	25	19.33	22200	28.43	820	1.05	12	4	0.33
R4	88390.9	0.83	1056	121	96	11	35.42	30985	29.34	1656.8	1.57	20	5	0.25
R5	47620.1	1.6	1480	314	185	39	27.97	19990	13.51	1766	1.19	42	7	0.17
R6	34034.2	1.8	360	107	72	21	28.00	4028	11.19	223	0.62	1	2	2.00
R7	23461.7	1.8	865	373	173	75	26.25	11215	12.97	1132	1.31	30	6	0.20
R8	39063.8	1.9	1500	388	300	78	22.40	27842	18.56	1119	0.75	30	6	0.20
R9	41609.6	0.8	990	241	198	48	19.19	31549	31.87	839	0.85	20	5	0.25
R10	31482.8	1.5	1188	382	108	35	20.71	17040	14.34	878	0.74	30	6	0.20
R11	21414.5	1.2	682	322	62	29	19.53	13975	20.49	686	1.01	12	4	0.33
R12	30630.9	1	561	185	51	17	20.46	9451	16.85	614	1.10	12	4	0.33
	Total= 445346	1	Total= 11289	Average = 256	Total= 1482	Average= 36	**23.14**		**20.30**		**0.99**			**0.41**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 3: Sector 8, Chandigarh – Crowding and Congestion

STUDY UNIT	Area of Study Unit (sqm)	Avg. FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
8-1	58571	1.8	855	148	155	27	72.52	24081	28.17	981	1.15	14	6	0.43
8-2	48231	1.9	982	206	179	37	62.71	14325	14.59	978	1.00	6	10	1.67
8-3	134401	2.0	1247	94	227	17	71.54	48589	38.95	1791	1.44	20	9	0.45
8-4	104542	1.3	843	82	153	15	97.86	38312	45.44	1185	1.40	2	6	3.00
8-5	100086	1.8	1167	118	212	21	41.43	66619	57.11	1503	1.29	16	11	0.69
8-6	137142	1.5	1016	75	185	14	89.87	29073	28.60	1239	1.22	2	6	3.00
8-7	86204	1.1	404	47	74	9	138.53	33704	83.37	1064	2.63	6	5	0.83
8-8	94079	1.2	751	81	137	15	112.22	23079	30.74	1769	2.36	8	10	1.25
8-9	87330	1.1	497	58	90	10	131.88	27330	55.03	1064	2.14	6	5	0.83
8-10	71397	1.0	300	43	55	8	129.87	32397	107.88	954	3.18	6	3	0.50
	Total= 921982	1	Total= 8062	Average = 95	Total= 1466	Average= 17	**94.84**		**48.99**		**1.78**			**1.26**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 4: Sector 38W, Chandigarh – Crowding and Congestion														
STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
38w-1	26160	2.1	1462	565	252	97	25.86	8160	5.58	584	0.40	1	5	5.00
38w-2	26687	2.1	1218	462	210	80	25.86	11659	9.57	944	0.77	8	7	0.88
38w-3	23958	2.1	1044	441	180	76	24.14	12093	11.58	733	0.70	4	4	1.00
38w-4	22470	2.1	1044	470	180	81	30.17	7469	7.15	735	0.70	3	4	1.33
38w-5	14190	2.1	870	620	150	107	30.17	1690	1.94	534	0.61	5	6	1.20
38w-6	29374	2.1	870	300	150	52	30.17	16919	19.45	678	0.78	5	6	1.20
38w-7	27419	2.1	1253	462	216	80	30.17	9419	7.52	854	0.68	6	7	1.17
38w-8	40235	2.1	1462	368	252	63	24.14	23435	16.03	925	0.63	7	9	1.29
38w-9	33363	2.1	1044	317	180	55	30.17	15093	14.46	735	0.70	6	7	1.17
38w-10	25488	2.1	1392	553	240	95	30.17	5456	3.92	933	0.67	18	8	0.44
38w-11	25645	2.1	1044	412	180	71	30.17	10645	10.20	788	0.75	8	7	0.88
38w-12	52235	2.1	1670	324	288	56	30.17	28235	16.90	1318	0.79	11	9	0.82
	Total= 347224	2	Total= 14372	Average = 441	Total= 2478	Average= 76	**28.45**		**10.36**		**0.68**			**1.36**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 5: Marble Arch (Manimajra), Chandigarh – Crowding and Congestion

STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
MA1	5206	0.79	106	206	20	39	38.68	4386	41.38	119	1.12	2	2	1.00
MA2	7167	1.9	307	434	58	82	43.69	4481	14.58	108	0.35	2	2	1.00
MA3	12208	2.1	477	395	90	75	52.42	7151	14.99	260	0.54	2	2	1.00
	Total= 24581	1.57	Total= 890	Average = 345	Total= 168	Average= 65	**44.93**		**23.65**		**0.67**			**1.00**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 6: Sector 20 (Panchkula), Chandigarh – Crowding and Congestion														
STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
20-1	70086	1.75	4568	660	831	120	23.64	48489	10.61	1396	0.31	8	4	0.50
20-2	73982	1.75	1447	198	263	36	25.45	66576	46.00	972	0.67	2	4	2.00
20-3	146496	1.75	2773	192	504	35	21.82	134587	48.54	550	0.20	2	1	0.50
20-4	93103	1.75	5809	631	1056	115	21.82	67359	11.60	1549	0.27	4	8	2.00
20-5	105000	1.75	6348	612	1154	111	18.18	81559	12.85	1562	0.25	6	5	0.83
20-6	41887	1.75	1345	325	245	59	21.82	36455	27.10	840	0.62	8	4	0.50
20-7	44385	1.75	2916	665	530	121	21.82	31255	10.72	867	0.30	8	6	0.75
20-8	66968	1.75	3299	498	600	91	31.82	45690	13.85	914	0.28	8	4	0.50
20-9	63698	1.75	3868	614	703	112	21.82	46903	12.13	859	0.22	6	5	0.83
20-10	50887	1.75	4413	877	802	160	18.18	35212	7.98	851	0.19	8	5	0.63
20-11	32810	1.75	2160	666	393	121	18.18	24956	11.56	627	0.29	10	3	0.30
	Total= 789301	2	Total= 38946	Average = 540	Total= 7081	Average= 98	**22.23**		**19.36**		**0.33**			**0.85**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 7: World Spa and Uniworld City, Gurugram – Crowding and Congestion

STUDY UNIT	Area of Study Unit (sqm)	FAR	Popula-tion	Gross Popln. Density (pph)	No. of Households	Gross Residential Density (DUs/ha)	BUA/Capita (sqm/person)	Public Ground Area (sqm)	PGA/Capita (sqm/person)	Paved Road Length Available (m)	PRL/Capita (m/person)	No. of Vias (V)	No. of Exits (E)	Mobilization Factor (E/V)
WS-W	44196	1.95	816	187	204	47	105.83	39117	47.94	1657.4	2.03	2	1	0.50
WS-E	37805	1.19	632	169	158	42	71.23	33613	53.18	1260.2	1.99	2	1	0.50
	Total= 82002	2	Total= 1448	Average = 178	Total= 362	Average= 44	**88.53**		**50.56**		**2.01**			**0.50**
UW-W	24312	2.59	2240	932	448	186	28.08	12399	5.54	850.9	**0.38**	2	1	0.50
UW-E	7897	1.48	420	538	84	108	27.86	4028	9.59	315.9	**0.75**	1	1	1.00
	Total= 32209	2.03	Total= 2660	Average = 735	Total= 532	Average= 147	**27.97**		**7.56**		**0.57**			**0.75**
							20-30		**12**		**0.91**			**≤1**
							Analyzing Urban Layouts – SB Patel 2011		*URDPFI 2014*		*Amritsar Master Plan 2010-31*			*Env. Quality Indicators – WIT Press 2000*

Green indicates threshold values as per secondary sources.

Explanation of Terms:

BUA/Capita – Built-up Area per Capita or Built floor area per person in the unit of study.

PGA/Capita – Public Ground Area per Capita or all the open-to-sky area that is accessible to a person. It includes streets, parks, school play grounds etc.

PRL/Capita – Paved Road Length per Capita or all the paved road area in the unit of study that is accessible to a person.

Mobilization Factor (M.F) > 1 will imply more no. of exits from (entry into) the area compared to via routes thus indicating more traffic and greater chances of congestion.

Data Sheet 8: Katra Dullo, Amritsar – Nature and Use of Open Spaces														
	Nature of Open Space										**Use of Open Space**			
	Type of Open Space (Ti)				**Condition of Open Space (Ci)**									
STUDY UNIT	4 = Square	3 = Vacant Plot	2 = Cul-de-sac	1 = Dead-end	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
K1	4	3		1x3	5	3	1	28	0.27	0%	38	392	981	0.22
K2		**3**		1x4	5	3		29	0.28	0%	23	322	723	0.11
K3		**3**		1x4	5	3		29	0.28	0%	39	434	909	0.15
K4		**3**		1x2	5 5			25	0.24	0%	23	168	1385	0.23
K5		**3**		1x5	5	3		34	0.32	41%	21	523	406	0.14
K6		**3**		1x2	5	3		19	0.18	0%	31	655	479	0.13
K7								0	0.00	0%	22	1303	171	0.04
K8								0	0.00	0%	32	610	531	0.13
K9		**3**		1x3	5	3		24	0.23	0%	20	936	216	0.09
K10	4			1x2	5 5			30	0.29	0%	11	840	133	0.03
K11				1x4	5			20	0.19	0%	28	924	307	0.13
K12		**3**		1x2	5		1	13	0.12	0%	37	970	386	0.09
								Average= 21	**Average= 0.20**	**Average= 3%**			**Average= 552**	**Average= 0.12**
								Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 9: Ranjit Avenue, Amritsar – Nature and Use of Open Spaces													
	Nature of Open Space									**Use of Open Space**			
	Type of Open Space (Ti)			**Condition of Open Space (Ci)**									
STUDY UNIT	6 = Park	5 = Playground	3 = Vacant Plot	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
R1	6			5			30	0.29	60%	38	20700	19	0.04
R2	6			5			30	0.29	47%	36	21300	17	0.04
R3	6			5			30	0.29	60%	27	22200	12	0.03
R4		5		5			25	0.24	46%	63	30985	21	0.06
R5	6	5		5, 5			55	0.52	39%	58	19990	29	0.04
R6	6			5			30	0.29	50%	23	4028	58	0.06
R7	6			5			30	0.29	45%	42	11215	38	0.05
R8	6			5			30	0.29	41%	56	27842	20	0.04
R9	6			5			30	0.29	50%	23	31549	7	0.02
R10	6			5			30	0.29	58%	43	17040	26	0.04
R11	6			5			30	0.29	60%	18	13975	13	0.03
R12		5	3	5	3		34	0.32	34%	69	9451	74	0.12
							Average= 32	**Average= 0.30**	**Average = 49%**			**Average= 28**	**Average= 0.05**
							Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 10: Sector 8, Chandigarh – Nature and Use of Open Spaces												
	Nature of Open Space								**Use of Open Space**			
	Type of Open Space (Ti)		**Condition of Open Space (Ci)**									
STUDY UNIT	6 = Park	5 = Playground	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
8-1	6	5	5 5			55	0.52	13%	26	24081	11	0.03
8-2						0	0.00	26%	40	14325	28	0.04
8-3	6			3		18	0.17	28%	49	48589	10	0.04
8-4	6			3		18	0.17	25%	30	38312	8	0.04
8-5	6			3		18	0.17	24%	57	66619	9	0.05
8-6		5	5			25	0.24	38%	50	29073	17	0.05
8-7	6		5			30	0.29	35%	13	33704	4	0.03
8-8	6		5			30	0.29	22%	26	23079	11	0.03
8-9	6		5			30	0.29	38%	28	27330	10	0.06
8-10	6		5			30	0.29	27%	9	32397	3	0.03
						Average= 25	**Average= 0.24**	**Average= 28%**			**Average= 11**	**Average= 0.04**
						Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 11: Sector 38W, Chandigarh – Nature and Use of Open Spaces

	Nature of Open Space								Use of Open Space			
	Type of Open Space (Ti)		Condition of Open Space (Ci)									
STUDY UNIT	6 = Park	5 = Playground	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
38w-1	6	5	5 5			55	0.52	39%	41	8160	51	0.03
38w-2	6	5	5 5			55	0.52	30%	67	11659	58	0.06
38w-3	6	5	5 5			55	0.52	18%	37	12093	31	0.04
38w-4	6		5			30	0.29	21%	30	7469	41	0.03
38w-5						0	0.00	16%	26	1690	156	0.03
38w-6	6	5	5 5			55	0.52	35%	50	16919	30	0.06
38w-7	6		5			30	0.29	18%	24	9419	26	0.02
38w-8	6		5			30	0.29	25%	51	23435	22	0.03
38w-9	6	5	5 5			55	0.52	27%	68	15093	46	0.07
38w-10	6		5			30	0.29	11%	23	5456	43	0.02
38w-11	6		5			30	0.29	18%	23	10645	22	0.02
38w-12	6		5			30	0.29	24%	43	28235	15	0.03
						Average= 38	**Average= 0.36**	**Average= 23%**			**Average= 45**	**Average= 0.03**
						Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 12: Marble Arch (Manimajra), Chandigarh – Nature and Use of Open Spaces												
	Nature of Open Space								**Use of Open Space**			
	Type of Open Space (Ti)		**Condition of Open Space (Ci)**									
STUDY UNIT	6 = Park	5 = Playground	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
MA1	6	5	5 5			55	0.52	40%	33	4386	76	0.31
MA2	6	5	5 5			55	0.52	30%	21	4481	47	0.07
MA3	6		5			30	0.29	40%	15	7151	21	0.03
						Average= 47	**Average= 0.44**	**Average= 35%**			**Average= 48**	**Average= 0.14**
						Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 13: Sector 20 (Panchkula), Chandigarh – Nature and Use of Open Spaces													
	Nature of Open Space								**Use of Open Space**				
	Type of Open Space (Ti)		**Condition of Open Space (Ci)**										
STUDY UNIT	6 = Park	5 = Playground	5 = Maintained	3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
20-1	6		5			30	0.29	6%	49	48489	10	0.01
20-2	6x2		5			60	0.57	41%	105	66576	16	0.07
20-3	6		5			30	0.29	85%	102	134587	8	0.04
20-4	6x2		5			60	0.57	6%	100	67359	15	0.02
20-5	6x2		5			60	0.57	15%	72	81559	9	0.01
20-6	6		5			30	0.29	36%	60	36455	17	0.04
20-7						0	0.00	0%	150	31255	49	0.05
20-8	6x2		5			60	0.57	22%	42	45690	9	0.01
20-9	6		5			30	0.29	53%	62	46903	13	0.02
20-10						0	0.00	10%	93	35212	27	0.02
20-11						0	0.00	0%	97	24956	39	0.04
						Average= 33	**Average= 0.31**	**Average= 25%**			**Average= 19**	**Average= 0.03**
						Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 14: World Spa and Uniworld City, Gurugram – Nature and Use of Open Spaces													
	Nature of Open Space									**Use of Open Space**			
	Type of Open Space (Ti)		**Condition of Open Space (Ci)**										
STUDY UNIT	6 = Park	5 = Playground	5 = Maintained		3 = Unattended	1 = Encroached	SCORE ∑TiCi	RATIO (Score / Max. Score)	TREE COVER (%)	Total People involved in different activities	Public Ground Area (sqm)	ACTIVITY INTENSITY (persons/ha)	ACTIVITY DIVERSITY (no. of activities / population)
WS-W	6	5	5	5			55	0.52	42%	53	39117	14	0.06
WS-E	6	5	5	5			55	0.52	40%	89	33613	27	0.13
							Average= 55	**Average= 0.52**	**Average= 41%**			**Average= 20**	**Average= 0.10**
							Maximum Score = 105						
UW-W	6	5	5	5			55	0.52	42%	200	12399	163	0.08
UW-E	6	5	5	5			55	0.52	40%	95	4028	239	0.21
							Average= 55	**Average= 0.52**	**Average= 41%**			**Average= 201**	**Average= 0.15**
							Maximum Score = 105						

Explanation of Terms:

Nature of Open space – It is given by Score of Open Space given by type and condition of open space and Tree Cover given by area under tree crowns divided by total area of open space.

Use of Open Space – It is given by Activity Intensity and Activity Diversity,

- **Activity Intensity –** No. of persons per square area
- **Activity Diversity –** No. of different types of activities taking place in an open space

Data Sheet 15: Katra Dullo, Amritsar – Shade and Ventilation, Temperature Variations & Noise Levels

STUDY UNIT	Light and Ventilation					Temperature Variations		Noise Levels			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
						At random 6 locations					
K1	2:1, 5:1, 7.5:1	4.83	5hrs	3	3			56	48	65	56
K2	2:1, 5:1, 7.5:1	4.83	5hrs	3	3	28.1°C	30.1°C	55	48	56	53
K3	2:1, 5:1, 7.5:1	4.83	5hrs	3	3	28.1°C	30.0°C	55	48	65	56
K4	5:1, 7.5:1	6.25	6hrs	5	3			45	45	45	45
K5	5:1, 7.5:1	6.25	6hrs	5	3	28.0°C		45	45	45	45
K6	5:1, 7.5:1	6.25	6hrs	5	3			45	45	45	45
K7	5:1, 7.5:1	6.25	6hrs	5	3	27.8°C	30.0°C	47	47	47	47
K8	2:1, 5:1, 7.5:1	4.83	5hrs	3	3			65	46	65	59
K9	2:1, 5:1, 7.5:1	4.83	5hrs	3	3	27.8°C	29.7°C	52	48	50	50
K10	2:1, 5:1, 7.5:1	4.83	5hrs	3	3			48	45	50	48
K11	2:1, 5:1, 7.5:1	4.83	5hrs	3	3	28.1°C	29.9°C	48	46	50	48
K12	2:1, 5:1, 7.5:1	4.83	5hrs	3	3			53	46	55	51
Average H/W Ratio of Locality= **5.30**				**Average= 4**	**Average= 3**	**Average= 27.98°C**	**Average= 29.94°C**	**Average Noise Level of the Locality=**			**50**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 1.96°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			

Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.

Data Sheet 16: Ranjit Avenue, Amritsar – Shade and Ventilation, Temperature Variations & Noise Levels											
STUDY UNIT	Light and Ventilation					Temperature Variations		Noise Levels			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality at random 6-7 locations	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
R1	1:1	1	2-5hrs	3	1	31.3°C	31.6°C	61	45	59	58
R2	1:1	1	2-5hrs	3	1	31.3°C		60	43	61	70
R3	1:1	1	2-5hrs	3	1	29.9°C	31.6°C	63	43	61	70
R4	1:1.5	0.67	2-5hrs	3	1	27.2°C		60	45	62	58
R5	1:1	1	2-5hrs	3	1	31.3°C		53	50	60	60
R6	1:1.5	0.67	2-5hrs	3	1	31.6°C	31.6°C	60	51	61	75
R7	1:1	1	2-5hrs	3	1	31.2°C	33.1°C	56	45	61	60
R8	1:1	1	2-5hrs	3	1	32.6°C	33.1°C	55	50	61	60
R9	1:1.5, 1:1	0.83	2-5hrs	3	1	32.6°C	33.1°C	60	45	61	65
R10	1:1	1	2-5hrs	3	1	31.6°C		60	45	61	70
R11	1:1	1	2-5hrs	3	1	32.1°C	32.1°C	61	44	61	65
R12	1:1	1	2-5hrs	3	1	32.1°C		60	46	63	72
Average H/W Ratio of Locality= **0.93**				**Average= 3**	**Average= 1**	**Average= 31.2°C**	**Average= 32.3°C**	**Average Noise Level of the Locality=**			**65**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 1.1°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			
Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.											

Data Sheet 17: Sector 8, Chandigarh – Shade and Ventilation, Temperature Variations & Noise Levels

STUDY UNIT	Light and Ventilation					Temperature Variations		Noise Levels			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality at random 5 locations	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
8-1	1:2,1:3	0.42	< 2hrs	3	1	32.6°C		60	50	62	57
8-2	1:3	0.33	< 2hrs	3	1	32.6°C	33.5°C	61	50	59	57
8-3	1:1.5	0.66	< 3hrs	2	1	32.6°C		60	50	61	57
8-4	1:2,1:3.75	0.40	< 2hrs	3	1	31.6°C	33.5°C	55	55	58	56
8-5	1:1.25, 1:1.65	0.70	2-3hrs	2	1	33.4°C	33.4°C	56	58	58	57
8-6	1:2	0.50	< 2hrs	3	1	32.5°C	33.1°C	55	50	59	55
8-7	1:3, 1:4	0.29	< 2hrs	3	1	31.6°C		54	48	52	51
8-8	1:3, 1:5	0.27	< 2hrs	3	1	32.6°C		54	45	51	50
8-9	1:3, 1:6	0.25	< 2hrs	3	1	32.1°C	32.5°C	54	50	52	52
8-10	1:3, 1:7	0.24	< 2hrs	3	1	31.3°C		53	46	52	50
Average H/W Ratio of Locality= **0.40**				**Average= 3**	**Average= 1**	**Average= 32.3°C**	**Average= 33.2°C**	**Average Noise Level of the Locality=**			**54**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 0.9°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			

Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.

Data Sheet 18: Sector 38W, Chandigarh – Shade and Ventilation, Temperature Variations & Noise Levels											
STUDY UNIT	**Light and Ventilation**					**Temperature Variations**		**Noise Levels**			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality at random 6-7 locations	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
38w-1	1:1.2	0.83	< 2hrs	1	5	32.6°C		60	48	62	57
38w-2	1:1.2	0.83	< 2hrs	1	5	32.6°C	31.6°C	61	48	59	56
38w-3	1:1.2	0.83	< 2hrs	1	5	32.6°C		60	46	61	56
38w-4	1:1.2	0.83	2-5hrs	3	1	31.6°C	31.6°C	63	48	61	57
38w-5	1:1.2	0.83	2-5hrs	3	1	31.6°C	31.1°C	60	46	61	56
38w-6	1:1.2	0.83	2-5hrs	3	1	31.6°C	31.1°C	55	50	61	55
38w-7	1:1.2	0.83	2-5hrs	3	1	31.6°C		60	48	63	57
38w-8	1:1.2	0.83	2-5hrs	3	1	32.6°C		60	45	61	55
38w-9	1:1.2	0.83	2-5hrs	3	1	32.1°C	32.1°C	61	50	61	57
38w-10	1:1.2	0.83	2-5hrs	3	1	31.3°C			46	60	53
38w-11	1:1.2	0.83	2-5hrs	3	1	32.6°C	31.0°C		50	61	57
38w-12	1:1.2	0.83	2-5hrs	3	1	32.6°C	31.0°C		51	61	56
Average H/W Ratio of Locality= **0.83**				**Average= 3**	**Average= 2**	**Average= 32.12°C**	**Average= 31.36°C**	**Average Noise Level of the Locality=**			**56**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 0.8°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			
Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.											

Data Sheet 19: Marble Arch (Manimajra), Chandigarh – Shade and Ventilation, Temperature Variations & Noise Levels

STUDY UNIT	Light and Ventilation					Temperature Variations		Noise Levels			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
MA1	1:1.5	0.66	2-5hrs	3	1	31.3°C	32°C	NA	45	55	50
MA2	1:1.5	0.66	2-5hrs	3	1	31.3°C	31.6°C	NA	45	59	52
MA3	1:1.5	0.66	2-5hrs	3	1	31.3°C	32°C	62	50	61	58
Average H/W Ratio of Locality= **0.66**				**Average= 3**	**Average= 1**	**Average= 31.2°C**	**Average= 32.3°C**	**Average Noise Level of the Locality=**			**53**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 1.1°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			
Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.											
NA – not applicable as MA1 and MA2 are inner parts of the gated community.											

Data Sheet 20: Sector 20 (Panchkula), Chandigarh – Shade and Ventilation, Temperature Variations & Noise Levels

STUDY UNIT	Light and Ventilation					Temperature Variations		Noise Levels			
	Shade				Orientation of Street Network						
	Building Ht. to Street Width Ratio (H/W)	Average H/W Ratio	No. of hours of Shade	Shade Rating	Ventilation Score	Within Locality	Outside Locality at random 6-7 locations	At Entry / Exit Points	Inside the Locality	On Main Roads	**Avg. Noise Level (dB)**
20-1	1:1,3:1	2	2-3hrs	2	2	37.6°C		70	62	65	66
20-2	1.4:1,1.2:1	1.3	< 2hrs	1	1	37.6°C		70	65	65	67
20-3	1:1,1.2:1	1.1	< 2hrs	1	1	37.6°C	38.0°C	68	60	65	64
20-4	2:1	2	2-6hrs	3	2	38.0°C	38.0°C	60	56	57	58
20-5	1:1,1.4:1	1.2	< 2hrs	1	1	37.4°C	38.0°C	60	56	60	59
20-6	1:1,1.4:1	1.2	< 2hrs	1	1	37.2°C	38.0°C	60	56	63	60
20-7	1:1,1.4:1	1.2	< 2hrs	1	1	38.0°C		60	56	62	59
20-8	1:1,1.4:1	1.2	< 2hrs	1	1	37.5°C	38.0°C	60	55	66	60
20-9	1.2:1,2.5:1	1.85	< 2hrs	1	1	37.0°C	37.6°C	58	56	58	57
20-10	1:1,1.4:1	1.2	< 2hrs	1	1	38.0°C	38.0°C	57	57	60	58
20-11	1:1,1.4:1	1.2	< 2hrs	1	1	38.0°C		57	57	60	58
Average H/W Ratio of Locality= **1.40**				**Average= 1**	**Average= 1**	**Average= 37.63°C**	**Average= 37.94°C**	**Average Noise Level of the Locality=**			**61**
								55 dB			
	Green indicates threshold value as per secondary sources.					**Mean Temp. Difference= 0.31°C**		CPCB, New Delhi - Daytime noise level in Residential Areas			

Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.

<table>
<tr><th colspan="13">Data Sheet 21: World Spa and Uniworld City, Gurugram – Shade and Ventilation, Temperature Variations & Noise Levels</th></tr>
<tr><th rowspan="3">STUDY UNIT</th><th colspan="5">Light and Ventilation</th><th colspan="2" rowspan="2">Temperature Variations</th><th colspan="4" rowspan="2">Noise Levels</th></tr>
<tr><th colspan="4">Shade</th><th>Orientation of Street Network</th></tr>
<tr><th>Building Ht. to Street Width Ratio (H/W)</th><th>Average H/W Ratio</th><th>No. of hours of Shade</th><th>Shade Rating</th><th>Ventilation Score</th><th>Within Locality</th><th>Outside Locality</th><th>At Entry / Exit Points</th><th>Inside the Locality</th><th>On Main Roads</th><th>Avg. Noise Level (dB)</th></tr>
<tr><td>WS-W</td><td>1:1,5:1</td><td>3</td><td>2-6hrs</td><td>3</td><td>5</td><td>37.6°C</td><td>39.0°C</td><td>70</td><td>60</td><td>70</td><td>67</td></tr>
<tr><td>WS-E</td><td>1:1,4:1,5:1</td><td>3.33</td><td>2-6hrs</td><td>3</td><td>3</td><td>38.0°C</td><td>39.0°C</td><td>70</td><td>60</td><td>70</td><td>67</td></tr>
<tr><td colspan="3" rowspan="2">Average H/W Ratio of Locality= 3.165</td><td rowspan="2"></td><td rowspan="2">Average= 3</td><td rowspan="2">Average= 4</td><td rowspan="2">Average= 37.8°C</td><td rowspan="2">Average= 39.0°C</td><td colspan="3">Average Noise Level of the Locality=</td><td>67</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td></td><td colspan="5"></td><td colspan="2">Mean Temp. Difference= 1.2°C</td><td colspan="4"></td></tr>
<tr><td colspan="12"></td></tr>
<tr><td>UW-W</td><td>1:1,5:1</td><td>3</td><td>2-6hrs</td><td>3</td><td>3</td><td>37.6°C</td><td>39.0°C</td><td>70</td><td>62</td><td>70</td><td>67</td></tr>
<tr><td>UW-E</td><td>1:1,4:1,5:1</td><td>3.33</td><td>2-6hrs</td><td>3</td><td>3</td><td>38.0°C</td><td>39.0°C</td><td>70</td><td>65</td><td>70</td><td>68</td></tr>
<tr><td colspan="3" rowspan="2">Average H/W Ratio of Locality= 3.165</td><td rowspan="2"></td><td rowspan="2">Average= 3</td><td rowspan="2">Average= 3</td><td rowspan="2">Average= 37.8°C</td><td rowspan="2">Average= 39.0°C</td><td colspan="3">Average Noise Level of the Locality=</td><td>68</td></tr>
<tr><td colspan="4">55 dB</td></tr>
<tr><td></td><td colspan="5">Green indicates threshold value as per secondary sources.</td><td colspan="2">Mean Temp. Difference= 1.2°C</td><td colspan="4">CPCB, New Delhi - Daytime noise level in Residential Areas</td></tr>
<tr><td colspan="12">Shade Rating and Ventilation Score – As discussed in Chapter 4, 4.6.3 Shade and Ventilation, page no. 151.</td></tr>
</table>

Data Sheet 22: Katra Dullo, Amritsar – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network	
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties connected to the network/ Total no. of properties	Sewage Indicator
K1	5	1	33	5	0.27	200	140	0.70	120	0.60	39/97	0.40
K2	5	1	35	5	0.28	140	98	0.70	56	0.40	31/78	0.40
K3	5	1	37	3	0.28	220	154	0.70	88	0.40	31/77	0.40
K4	5	1	41	1	0.24	165	82.5	0.50	66	0.40	8/30	0.25
K5	5	1	38	3	0.32	150	75	0.50	75	0.50	8/33	0.25
K6	5	1	38	3	0.18	230	115	0.50	138	0.60	20/79	0.25
K7	5	1	34	5	0.00	642	321	0.50	321	0.50	27/90	0.30
K8	5	1	31	5	0.00	343	205.8	0.60	172	0.50	28/71	0.40
K9	5	1	31	5	0.23	430	258	0.60	258	0.60	26/65	0.40
K10	5	1	31	5	0.29	277	166.2	0.60	166	0.60	18/45	0.40
K11	5	1	27	5	0.19	302	181.2	0.60	181	0.60	20/50	0.40
K12	5	1	34	5	0.12	436	261.6	0.60	262	0.60	24/60	0.40
Average	**5**	**1**	**34**	**4**	**0.20**			**59%**		**53%**		**35%**

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

Data Sheet 23: Ranjit Avenue, Amritsar – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network		
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties connected to the network/ Total no. of properties	Sewage Indicator	
R1	5	3	38	3	0.29	1104	1104	1	1104	1	86/86	1	
R2	5	3	41	1	0.29	1188	1188	1	1188	1	82/82	1	
R3	5	3	40	3	0.29	1172	1172	1	1172	1	71/71	1	
R4	5	3	35	5	0.24	2071	2071	1	2071	1	96/96	1	
R5	5	1	33	5	0.52	1962	1962	1	1962	1	185/185	1	
R6	5	3	32	5	0.29	223	223	1	223	1	72/72	1	
R7	5	1	37	3	0.29	1257	1257	1	1257	1	143/143	1	
R8	5	1	33	5	0.29	1598	1598	1	1598	1	100/100	1	
R9	5	3	27	5	0.29	1049	1049	1	1049	1	90/90	1	
R10	5	3	40	3	0.29	1254	1254	1	1254	1	108/108	1	
R11	5	3	34	5	0.29	980	980	1	980	1	62/62	1	
R12	5	3	41	1	0.32	768	768	1	768	1	51/51	1	
Average	**5**	**3**	**35**	**4**	**0.30**			**100%**		**100%**		**100%**	

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

Data Sheet 24: Sector 8, Chandigarh – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network	
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties connected to the network/ Total no. of properties	Sewage Indicator
8-1	5	1	30	5	0.52	1401	1401	1	1401	1	74/74	1
8-2	5	1	30	5	0.00	1397	1397	1	1397	1	85/85	1
8-3	5	1	30	5	0.17	2239	2239	1	2239	1	108/108	1
8-4	5	1	30	5	0.17	1692	1692	1	1692	1	7373	1
8-5	5	1	30	5	0.17	2506	2506	1	2506	1	101/101	1
8-6	5	3	30	5	0.24	1770	1770	1	1770	1	88/88	1
8-7	3	3	30	5	0.29	1182	1182	1	1182	1	35/35	1
8-8	3	3	30	5	0.29	1966	1966	1	1966	1	65/65	1
8-9	3	3	30	5	0.29	1182	1182	1	1182	1	43/43	1
8-10	3	3	30	5	0.29	1060	1060	1	1060	1	26/26	1
Average	**4**	**2**	**30**	**5**	**0.24**			**100%**		**100%**		**100%**

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

Data Sheet 25: Sector 38W, Chandigarh – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network	
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties connected to the network/ Total no. of properties	Sewage Indicator
38w-1	5	1	30	5	0.52	834	834	1	834	1	84/84	1
38w-2	5	1	30	5	0.52	1179	1179	1	1179	1	70/70	1
38w-3	5	1	30	5	0.52	916	916	1	916	1	60/60	1
38w-4	5	1	30	5	0.29	1050	1050	1	1050	1	60/60	1
38w-5	5	1	30	5	0.00	763	763	1	763	1	50/50	1
38w-6	5	3	30	5	0.52	969	969	1	969	1	50/50	1
38w-7	5	3	30	5	0.29	1220	1220	1	1220	1	72/72	1
38w-8	5	3	30	5	0.29	1321	1321	1	1321	1	84/84	1
38w-9	5	3	30	5	0.52	1225	1225	1	1225	1	60/60	1
38w-10	5	3	30	5	0.29	1167	1167	1	1167	1	80/80	1
38w-11	5	3	30	5	0.29	985	985	1	985	1	60/60	1
38w-12	5	3	30	5	0.29	1648	1648	1	1648	1	96/96	1
Average	**5**	**2**	**30**	**5**	**0.36**			**100%**		**100%**		**100%**

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

Data Sheet 26: Marble Arch (Manimajra), Chandigarh – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network	
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties connected to the network/ Total no. of properties	Sewage Indicator
MA1	1	3	30	5	0.52	149	149	1	149	1	20/20	1
MA2	1	3	30	5	0.52	120	120	1	120	1	58/58	1
MA3	1	3	30	5	0.29	289	289	1	289	1	90/90	1
Average	**1**	**3**	**30**	**5**	**0.44**			**100%**		**100%**		**100%**

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

Data Sheet 27: Sector 20 (Panchkula), Chandigarh – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network	
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of properties* connected to the network/ Total no. of properties	Sewage Indicator
20-1	5	1	30	5	0.29	1396	1396	1	1396	1	17/17	1
20-2	5	1	30	5	0.57	1215	1215	1	1215	1	4/4	1
20-3	5	3	30	5	0.29	687	687	1	687	1	7/7	1
20-4	1	1	30	5	0.57	1722	1722	1	1722	1	14/14	1
20-5	1	1	30	5	0.57	1953	1953	1	1953	1	11/11	1
20-6	3	3	30	5	0.29	933	933	1	933	1	7/7	1
20-7	5	3	30	5	0.00	963	963	1	963	1	16/16	1
20-8	3	1	30	5	0.57	1016	1016	1	1016	1	1/1	1
20-9	1	1	30	5	0.29	954	954	1	954	1	6/6	1
20-10	1	3	30	5	0.00	945	945	1	945	1	20/20	1
20-11	1	3	30	5	0.00	784	784	1	784	1	10/10	1
Average	**3**	**2**	**30**	**5**	**0.31**			**100%**		**100%**		**100%**

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

* Here properties refer to no. of Gated Communities or Group Housing Societies in a study unit.

Data Sheet 28: World Spa and Uniworld City, Gurugram – Walkability and Level of Cleanliness													
STUDY UNIT	Walkability					Level of Cleanliness							
	Proximity to Daily Needs	Condition of Sidewalks	Adequacy of Streetlights		Type & Condition of Open Space	Paved Road Length (m)	Domestic Waste Mgmt.		Coverage of Stormwater Drainage		Coverage of Sewage Network		
	SCORE (0.1-0.5km = 5, 0.51-1km = 3, >1km = 1)	SCORE (Good = 5, Fair = 3, Poor = 1)	Centre to centre dist.	SCORE (≤35m = 5, 35.1-40m = 3, >40m = 1)	RATIO (Score/ Max. Score)		Road Length attended by Primary/ Sec. Waste Collection Service	Cleanliness Indicator	Road Length covered by Drains	Drainage Indicator	No. of blocks connected to the network/ Total no. of blocks	Sewage Indicator	
WS-W	5	5	30	5	0.52	1842	1842	1	1842	1	10/10	1	
WS-E	5	5	30	5	0.52	1575	1575	1	1575	1	8/8	1	
Average	**5**	**5**	**30**	**5**	**0.52**			**100%**		**100%**		**100%**	
UW-W	5	5	30	5	0.52	1216	1216	1	1216	1	15/15	1	
UW-E	5	5	30	5	0.52	395	395	1	395	1	5/5	1	
Average	**5**	**5**	**30**	**5**	**0.52**			**100%**		**100%**		**100%**	

Spacing Norm for Streetlights= 35m c/c across all class of cities
Source: Report on Indian Urban Infrastructure and Services, HPEC Committee, March 2011

Cleanliness Indicator, Drainage Indicator and Sewage indicator – As mentioned in Chapter 2, 2.4.4 Spatial Density in Indian Cities, footnotes, page no. 51.

List of Publications

Journal Publications:

1. Dutta, S., Bardhan, S. and Bhaduri, S. (2013) **Patterns of Urbanization and Environmental Quality in the Context of Indian Cities**. *Environment and Urbanization ASIA*, 4 (2), 287 – 299.

2. Dutta, S., Bardhan, S. and Bhaduri, S. (2013) **Urban Environment Studies for a Sustainable Future: An Alternative Approach**. *ABACUS (Journal of BITs, Mesra)*, 8 (1), 38 – 49.

3. Dutta, S., Bardhan, S. and Bhaduri, S. (2017) **Residential Density and Neighbourhood Environmental Quality – A Comparative Study in the context of Indian Cities**. *SPECIAL ISSUE of International Journal on Emerging Technologies (IJET)*, 8 (1), 315 – 323.

Conference Presentations and Publications:

4. Dutta, S., Bardhan, S. and Bhaduri, S. (2015) **A Model Framework for Assessing Urban Environmental Quality** in proceedings of *National Conference on Re-discovering Cities (NCRC – 2015)* organized by School of Architecture, MM University, Sadopur, Ambala, India and Indian Institute of Architects (Chd-Pb Chapter), 10–11 April 2015, (pp. 331-339).

5. Dutta, S., Bardhan, S. and Bhaduri, S. (2017) **Multi-criteria Approach for Assessing Neighbourhood Environmental Quality - A Way towards Future Sustainable Development of Indian Cities** presented at *International Conference on Sustainable Built Environment 2017 (SBE 2017)* organized by Department of Architecture and Planning, IIT Roorkee, 03-05 February 2017.
   Received "Best Paper Award" under the theme 'Planning for Resilience'.

6. Dutta, S., Bardhan, S. and Bhaduri, S. (2017) **Residential Density and Neighbourhood Environmental Quality – A Comparative Study in the context of Indian Cities** presented at *National Conference on Urban Environmental Management: Problems and Prospects* organized by Department of Architecture and Planning, MNIT Jaipur, 13-14 February 2017.

Patterns of Urbanization and Environmental Quality in the Context of Indian Cities

印度城市背景下城市化和环境质量的模式

Environment and Urbanization ASIA
4(2) 287–299

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Abstract

The link between quality of urban development and its impact on environment has for long been debated. The authors attempt to assess the impact that India's rapidly urbanizing cities and related development are having on urban environment. The authors emphasize on the 'quality' of development while attempting to answer this question and indicate that quality factors, such as, density, urban massing and spatial pattern of land use, as well as socio-economic and cultural factors resulting from these, have an important bearing on the quality of urban environment in Indian cities. The authors conclude that several physical and human environmental factors need to be further evaluated from a new perspective to gain insights into perceived and measured components that influence environmental quality.

城市发展质量及其对环境的影响之间的联系，是长久以来一直争论不休的话题。作者试图评估印度城市的快速城市化及其相关开发对城市环境的影响。作者强调发展的?质量?，并试图回答这个问题，作者还指出与质量有关因素（比如密度、城市体量、土地使用的空间模式以及由此形成的社会经济和文化因素）对印度城市环境的质量产生了重要影响。作者的结论是一些空间和人居环境的因素需要从一个新的视角进一步评估，从而深入了解可感知和可测量的、影响环境质量的因素。

Keywords

Environmental quality, quality of development, urban pattern, density, configuration of built environment

Introduction

The year 2008 was a milestone in the process of urbanization that began several thousand years ago, but accelerated greatly in recent times. For the first time, there were as many people living in towns and cities as in rural areas. By 2050—when the world population is projected to reach over 9 billion—around 75 per cent will be living in urban areas (AGS, 2009).

Urbanization has many causes and many faces. In underdeveloped countries, already about 1 billion people live in slums without basic necessities, such as, clean water and sanitation, and lack secure tenure of the land they occupy. In rapidly industrializing countries, such as, China and India, urban growth is fuelled by economic development outstripping the capacity of cities to provide basic infrastructure. The results are traffic congestion, environmental pollution, increasing stress levels and acute health problems. At the other extreme, in some of the richest countries, a demand for larger houses and gardens is seen to produce vast areas of urban sprawl, with people using an ever denser transport network to commute long distances to their places of work. Huge megapolitan regions emerge in the process consuming small towns as they grow, causing fundamental changes to local, regional and global environments. In this context, visions of how cities will develop in future are quite diverse. With the urban populations of Asia and Africa set to double between 2000 and 2030,[1] future urbanization is predicted to be a largely developing world phenomenon.[2] India, projected to be an urban majority country[3,4] by 2040–2045, is expected to be at the forefront of this massive socio-economic shift. It is believed that the manner in which the subcontinent responds to urbanization over the next two to three decades shall define the social, economic and environmental future of not just the country, but given its size, also of the world.

Patterns of Urbanization in Developing Countries

It is generally seen that current trends and patterns of urbanization point towards an uncertain future. Therefore, cities need to manoeuvre themselves to a position where they can improve life for people who flock to them and be environmentally sustainable also. The different patterns of urbanization found in developing countries are as follows:

1. **Peri-urbanization or Suburban Sprawl and Formation of City Regions:** At present low- and middle-income countries are increasingly identified by the process of peri-urbanization. In the peri-urban interface, the boundaries between the 'urban' and the 'rural' are continuously renegotiated, and rather than being clearly defined are characterized by transition zones. These interfaces are affected by some of the most serious problems of urbanization, including intense pressures on resources, slum formation, lack of adequate services, such as, water and sanitation, poor planning and degradation of farmlands. In most cases, planning regulations are weak or weakly enforced, and result in areas with complex patterns of land tenure and land use (McGregor et al., 2006; Tacoli, 2006). Although these areas provide a variety of activities and services for urban centres, they are generally beyond the legal and administrative boundaries of the cities, with the result that the process of urbanization in most cases is unplanned and informal with frequent struggles over land use. Some scholars refer to these emerging urban configurations as 'city regions' emphasizing the fact that cities are growing not just in terms of population size, they are also changing their economic character and spatial form.
2. **Low Density Urbanism or Restrictive Residential Enclave:** Low-density urbanism, on the other hand, is a model equated with what is considered as destructive selfishness of the gated community and the environmentally disastrous results of low-density car-orientated suburbs, which are highly unsustainable and do nothing to support the traditional energy and vitality of urban life.

3. **Urban Compaction and High Density:** This refers to the compact city model which is often proposed for the sustainable development of our cities. However, in developing countries, cities generally have high densities and are characterized by high proportions of informal development lacking the infrastructure and urban management structures required to make the system work. Most of the people live in deplorable conditions with extreme compromises made on the standard of living. Any attempt at further densifying/intensifying these cities aggravates a range of problems like:

   - infrastructure overload,
   - housing shortage,
   - overcrowding,
   - congestion,
   - air and noise pollution,
   - health hazards,
   - lack of public and green spaces and
   - environmental degradation.

As Figure 1 illustrates, generally Indian cities have high density patterns as compared to the relatively dispersed and flat density pattern found in London, Berlin or Johannesburg. Mumbai is a typical example where within the city limits, the average density surpasses the mark of 27,000 people per km²—a figure that rises to well above 50,000 people per km² (taking only the built-up area into account), a level higher than even the highest density peaks in New York City's Manhattan area. Furthermore, it is not rare for

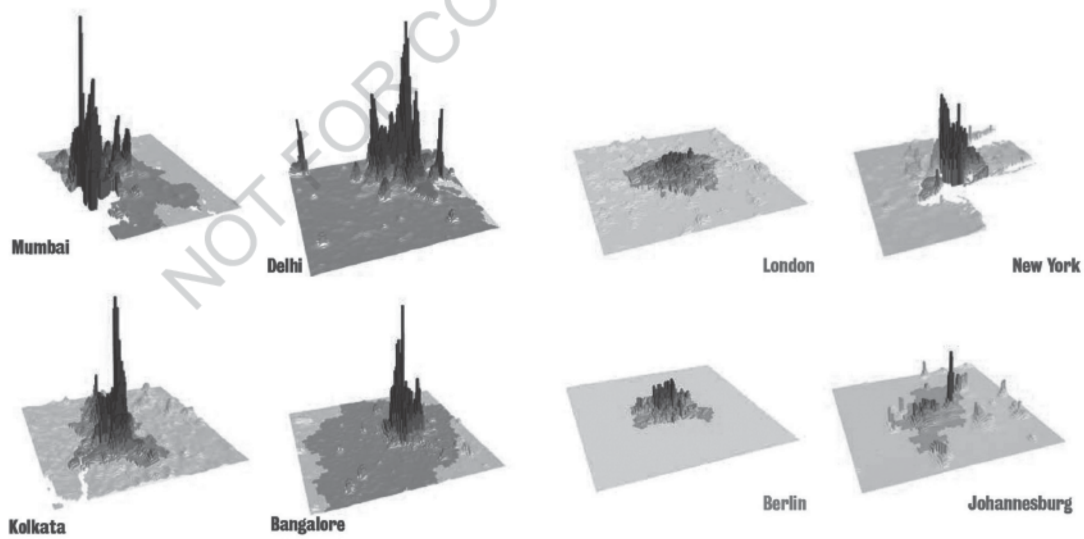

Figure 1. Urban Densities of Indian Cities Compared with some World Cities

Source: Integrated City Making Report (2008) of Urban Age, London School of Economics and Political Science.

the densest neighbourhoods of Mumbai to accommodate as many as 100,000 residents per km^2. Similarly Delhi, the capital city, has a high average density of 9,340 people per km^2 inspite of its legacy of parks and other open spaces, as well as non-residential buildings and built forms that cannot be converted to residential uses.

Effects of Urbanization on Our Cities

The high rate of increase in the urban population creates many problems in our urban areas. Doubling and tripling of urban population practically in all major cities and towns and the consequent strain on the existing system gets manifested in an environmental chaos. Every major city of India faces the same proliferating problems of urban expansion, inadequate housing, poor transportation system, poor sewerage, erratic electric supply, insufficient drinking water supplies etc. An increasing number of trucks, buses, cars, three-wheelers and motorcycles, all spewing uncontrolled fumes, surging through haphazard city streets jammed with jaywalking pedestrians, rickshaw, cattle and goats are not an uncommon sight. The phenomena of accelerated urbanization becomes the main culprit for bringing in problems like growth of dense and unplanned residential areas, increasing environmental pollution, non-availability of services and amenities, large amounts of solid waste generation and growth of slums (Rahman et al., 2011).

These conditions lead to the deterioration of the urban environment so fast that the sustainability of the cities is threatened. In metro cities, land and environment are especially under stress due to the pressure of rapid urbanization. Population growth and in-migration of people, industrial growth, inefficient and inadequate traffic corridors, poor environmental infrastructure, etc., are the main factors that deteriorate the overall quality of the city. As the cities expand and population increases, the resources, which are limited, are shared. Housing, water supply, roads, drainage, transport, education, health services, police and fire services, etc., are not able to keep pace with the prevailing urban growth rate that leads to further degradation of the urban environment.

While the more conventional challenges of providing adequate housing, public transportation and other civic amenities to urbanizing societies are recognized to some extent, it is felt that the impact of India's urbanization on the overall environment is not yet fully understood or studied. This view is corroborated by independent research, which confirms that issues focusing on maintaining urban environmental quality do not figure very high on the agenda of city planners and local/national development authorities in India.

According to Urban Age, London School of Economics and Political Science (2008), 'Integrated City Making—Governance, Planning and Transport Report', only 12 per cent of the respondents drawn from every level of Indian government and civil society point out environment as one of the three key challenges of urban India (Figure 2). The other key challenges include planning (47 per cent), transport (41 per cent), governance (32 per cent), infrastructure (24 per cent), migration (18 per cent), housing (18 per cent) and inequality (12 per cent). Hence, there arises a need to assess and maintain the environmental quality of our cities.

While India can, and should, draw a variety of lessons from the developed world that has already urbanized, it should base its tomorrow on fresh thinking and original ideas relevant to the local context. What follows is a thoughtful attempt to challenge mindsets and provide practical solutions for our common urban future—a future that is not only economically stable or socially equitable but most importantly, environmentally sustainable.[5]

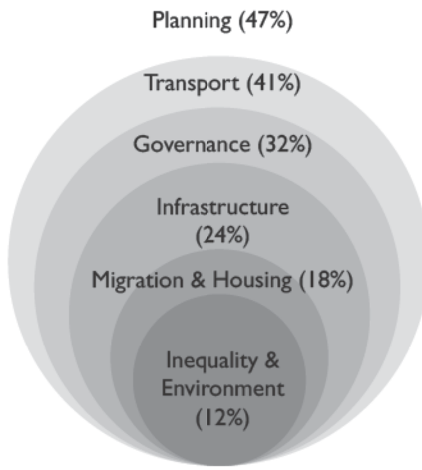

Figure 2. Key Challenges of Urban India

Source: Author's elaboration.

Quality of Development and its Effect on the Urban Environment

The urban environment is shaped by both human and natural factors operating at different spatial scales. In urban areas the local scale is dominated by individual buildings, streets and trees, etc., but regional scale influences may include the whole city and beyond (Nichol and Wong, 2005). While certain aspects like liveability and quality of place defined by the quality of natural resources (levels of air and water pollution), infrastructure and open space availability and other amenities of the built environment are quantifiable, there are several other aspects of the urban environment that can be assessed only on a qualitative basis depending on the daily, local and sensory experiences of the city's residents. Therefore, in principle, all attributes of the environment and all characteristics of people are relevant domains in the person–environment relationship (Mitchell et al., 2001). However, the important point is that generally the total domain is never too strictly defined leaving a scope for multidisciplinary intervention and evaluation of physical, spatial, social and environmental parameters.

Taking into account both aspects mentioned earlier, the quality of urban environment is generally determined from two approaches—one is the 'Total City Environment' and the other is the 'Appraisal of Built Forms', that is, quality of life and quality of development respectively (Nichol and Wong, 2004). In other words, spatial and physical features in addition to socio-economic factors affect the environmental quality. Generally, most of the studies look into the social aspect of the urban environment from the sociologist's viewpoint in terms of human well-being and quality of life indicators. This leaves a considerable gap in the design and planning field when it comes to policy formulation and plan implementation by architects, urban designers and planners who are faced with important questions such as:

- What is the effect of rapid urbanization on the quality of development in our cities?
- Does quality of development have an impact on the urban environment?

- Is urban environmental quality uniform over the geographical extent of the city?
- Can urban environment studies help in designing sustainable cities?

Answers to these questions can only be found if one tries to first understand how the quality of development governed by various urban processes affects the city environment. Environmental challenges faced by cities around the world are more complex now than at any other time in history. In many parts of the world, and notably in Asia Pacific, rapid economic growth, decentralization, privatization and related socio-cultural changes have impacted the local, regional and global ecosystems in varying magnitudes (Figure 3). Some activities have environmental impacts within small sections of cities while others impact ecosystems that are planetary in size.

In the Western context, it is often seen that small- or low-income cities with unplanned development have environmental problems that are localized, immediate and health threatening for the local residents because of the poor environmental quality within the city. The environmental problems in middle-income cities are somewhat city-wide or regional, while affluent cities generally have fewer environmental problems and hence good environmental quality but because of their high rate of consumption and resource use pose a threat to environment and ecological sustainability at the global level. Also as cities transform from one level to another, the type of environmental problems they have to deal with change (Figure 4).

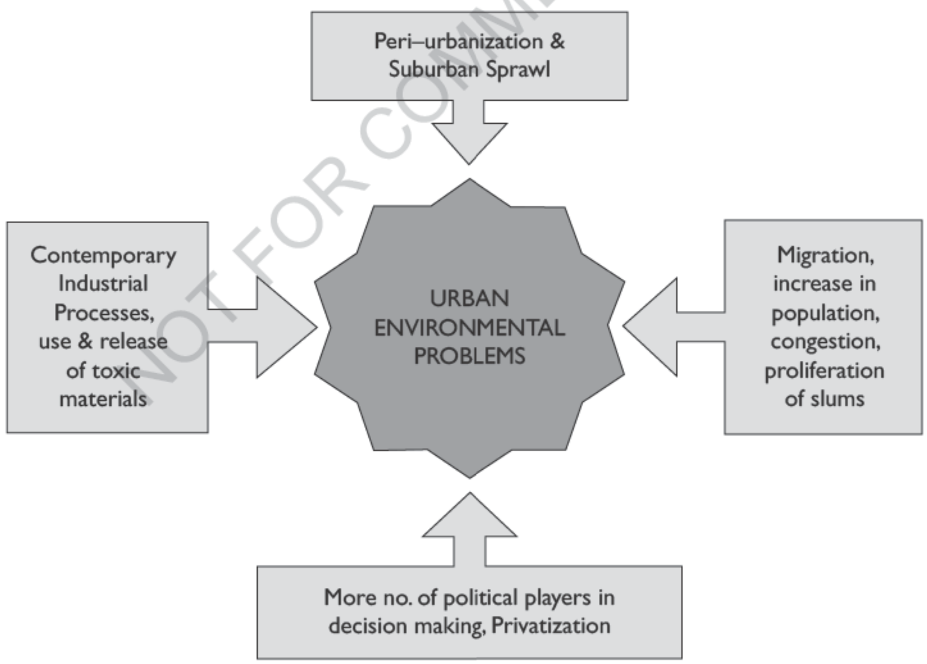

Figure 3. Urban Processes Adding to Environmental Burdens

Source: Author's elaboration.

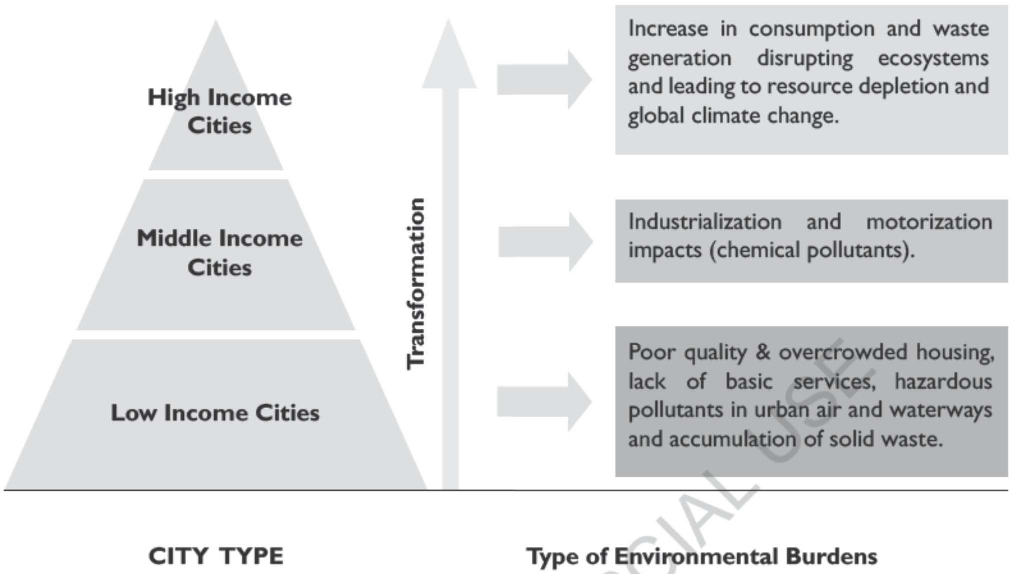

Figure 4. Environmental Issues in Different Types of Cities

Source: Author's elaboration from UNU/IAS Report—Urban Ecosystem Analysis: Identifying Tools and Methods.

The Indian scenario though somewhat similar for smaller cities is different in terms of the growth and development patterns and subsequent environmental problems faced especially by the larger cities. The small and medium towns continue to face local environmental problems as a result of lack of infrastructure and provision of basic services. The larger cities and metropolises, on the other hand, continue to grow undesirably in most cases accompanied by transformations and transgressions that adversely affect the city environment and its inhabitants. As more and more people from small cities and rural areas migrate to these cities in hope of better jobs and comfortable lives, the city and its hinterland become an object to plunder for personal gains. The profiteering tendencies of the development authorities capped with political and bureaucratic jargon become responsible for the negative physical growth of the city. Zoning regulations and building byelaws are relaxed to enable the private players to produce development of their liking. Land use changes are allowed without giving a thought to the impact that would follow. Lung spaces disappear in the city and ironically the city has hardly any green space left with most of the parks converted to other land uses, primarily the commercial uses. Land prices shoot up as a result of profit oriented privatized urban development and the poor are completely alienated from the development process. With no choice left, they are forced to grab the nearest available open patch of land. Thus starts the proliferation and growth of slum and squatter settlements in the urban landscape (Sandhu and Gill, 2010).

Slums are found to be overcrowded, often polluted and lack basic civic amenities like clean drinking water, sanitation, solid waste collection and disposal facilities, drains, paved roads and other forms of infrastructure and services necessary for a healthy environment. Most of the slum dwellers are involved in informal sector activities where there is constant threat of eviction, removal, confiscation of goods and almost non-existent social security cover. 54.71 per cent of urban slums have no toilet facility (as per the

National Sample Survey Organisation's 58th Round). Most free community toilets built by state government or local bodies are rendered unusable because of the lack of maintenance. As such the road sides, rail reservation areas and other vacant plots are used for open defecation by poor segments of the city. As per 2001 census report, the slum population of India in cities and towns with a population of 50,000 and above was 42.6 million, which was 22.6 per cent of the urban population of the states/union territories reporting slums.

Away from the inner city, the periphery presents an equally dismal scene with the agricultural land fast converted to residential plots by both licensed and unlicensed private colonizers. The absence of appropriate periphery control and regulations result in unabated informal and chaotic developments on the fringe area leaving little scope for planned and orderly expansion in the future.

Thus, overall this type of unregulated growth and poor quality development results in bad water and air quality, unmanaged or mismanaged waste and increasing noise pollution because of increasing traffic especially in the already congested core of the city. In several instances, controlling encroachment into public spaces and degradation of cultural and heritage sites also becomes a major problem. All these become a threat to the environment and people's lives and eventually cause deterioration of urban environmental quality. Therefore, it is important to note that growth and development patterns result in a particular quality of development that has a definite impact on the urban environmental quality.

Urban Pattern of Indian Cities

By and large, it is seen that patterns of urbanization within a city differ from one location to another depending on local topography, land use regulations, socio-economic and cultural preferences of people, political and historical developments and so on and so forth. It is also understood that these varying patterns of urban development from one place to another result in differences in levels of population density, concentration of residential or commercial uses within specific areas, mixing of residential and commercial land uses, amount of open spaces and amount of intervening land devoted to non-urban uses (Galster et al., 2001). This fact is best understood by carefully observing our Indian cities.

In most of the cases, the inner core or walled city in a traditional Indian city is found to be a compact city largely designed for pedestrian use and cycle rickshaws supported by horse-driven carts (*tonga*s) on certain marked routes. The entire built-up mass is more or less a compact monolithic volume with small punctures for the purpose of light, ventilation and movement. Domestic life revolves around an organically grown settlement pattern, closely knit to a physical density that permits the essential public open spaces in the form of streets and chowpals (public squares) and large courtyards. It is estimated that courtyards and pedestrian streets occupy nearly 30 per cent of the area with the remaining area constituting the built-up volume. The compact ground coverage of nearly 70 per cent with ground plus two or three stories high buildings ensure that streets are shielded from the heat of the sun. Thus, the pedestrian streets remain cool during hot summers and much cooling is also obtained by natural wind currents because of the particular orientation of the streets. Old parts of Shahjahanabad (Delhi), Jaisalmer, Jaipur, Ahmedabad, Vadodara, Indore, Surat and many other cities exhibit these characteristics. Being predominantly pedestrian entities, the towns ensure an interactive social community and since social, cultural and religious customs play a huge role in peoples' lives, they are seen expressed in special architectural details and in use of space at the residential and neighbourhood level (Kapadia, 2010).

The city outside the walled area is dominated by the British annexes in many cases. While the indigenous or traditional city that grew around or alongside a fortress, royal palace or holy place or emerged from a village is irregular and amorphous in composition, the annexes (cantonment, civil lines and railway colonies), though in varying degree, are found to be much more organized with regular settlements that are spacious and sanitary with buildings far more clearly distinguished and grouped according to their function (Smailes, 1986).

Leaving aside the British annexes, in most cases, newer parts of the city are found to have developed haphazardly around or along old areas as a result of accelerated industrialization and rapid urbanization. High densities are found in and around commercial and industrial zones offering jobs to resident and migrant population, along the transport corridors that promote easy accessibility to and from the place of work and so on and so forth. The built forms are generally mid and high rise buildings, typically designed as homogeneous, repetitive, self-referential projects that rarely respond to their adjacencies, surrounding streets or their location within the city. The haphazard mushrooming of slabs and towers represent not only the denial of a coherent urban form and public realm, but the reduction of the very idea of city-making into an unchecked, rapacious capitalism in such cases (Bharne, 2011). The urban form of the city is thus characterized by different configuration and types of built form and related population distribution across the geographical extent of the city. Alternatively, it can be stated that distribution of buildings, their typology and geometry, layout patterns, distribution/availability of open spaces, quality of infrastructure including links to the wider urban system, etc., vary from one locality to the other within the city.

So, in order to understand the relationship between urban patterns characterized by spatial structures and population distribution and urban environmental quality, it becomes quintessential to study the local environmental problems associated with different patterns of urbanization within a city. With time, it has been understood that many urban environmental problems have a local origin and should be addressed in close cooperation with local stakeholders. At the same time it has also been recognized that global environmental decay often manifests itself at a local level. It follows that, although descriptive pattern identification and mapping at the macro-scale is of value as a pointer to detailed investigation, policy relevant urban environmental quality indicators are more likely to be derived at the local area scale (Pacione, 2003). Also of importance is the fact that since urban populations are disaggregated along a large number of planes like class, caste, age, lifestyle, gender and ethnicity, to be of real value to both citizens and decision makers, urban environmental quality studies should be directed to the appropriate social groups or constituencies depicting distinct patterns of urbanization in the city.

Assessing the Urban Environment of Our Cities

Urbanization is usually viewed as a characteristic of the population, as a characteristic of particular kinds of land uses and land covers, as well as a characteristic of social and economic processes and interactions affecting both population and land (McIntyre et al., 2000). Social scientists like demographers, geographers, urban policy analysts and others generally define levels of urbanization in terms of population densities. Alternatively, regional economists, labour analysts and related researchers define urban in terms of the functional area integrated with an urban centre. For these researchers, urban is more of a sociological and functional definition rather than a structural (density-based) phenomenon. However, physical scientists like ecologists and physical planners especially approach definitions of urbanization from the standpoint of the built environment. To these researchers, density of buildings and impervious surfaces is important (McIntyre et al., 2000). However, among this group a wide variety of urban definitions are used in research, ranging from any human alteration of the landscape to more precise definitions based on density and specified land-use characteristics. Broadly speaking, the term land use is used to describe the different functions of the environment. Within the urban context, the dominant land use tends to be residential but a functional urban area requires industrial, retail, offices, infrastructure and other uses. Hence, a thorough understanding of the spatial (micro) pattern of land uses is crucial to be aware of the unregulated growth, urban sprawl and increasing land use conversions that are straining the resources and further degrading the environment of our cities.

It is also understood that density plays a significant role in determining the city's physical structure and the level of efficiency achieved by use of its land (Frenkel, 2004). Simply put, density is used as a measure of the number of people living in a given area. However, when one refers to quality of development, the configuration of the built environment and the interactions within play an important role. Density indicates the distribution of people and the urban massing. In other words, it indicates the relationship between built-up and open land. It may describe the image of a residential area or in town row house area and help in determining the physical patterns of land use and buildings (refer Figure 5).

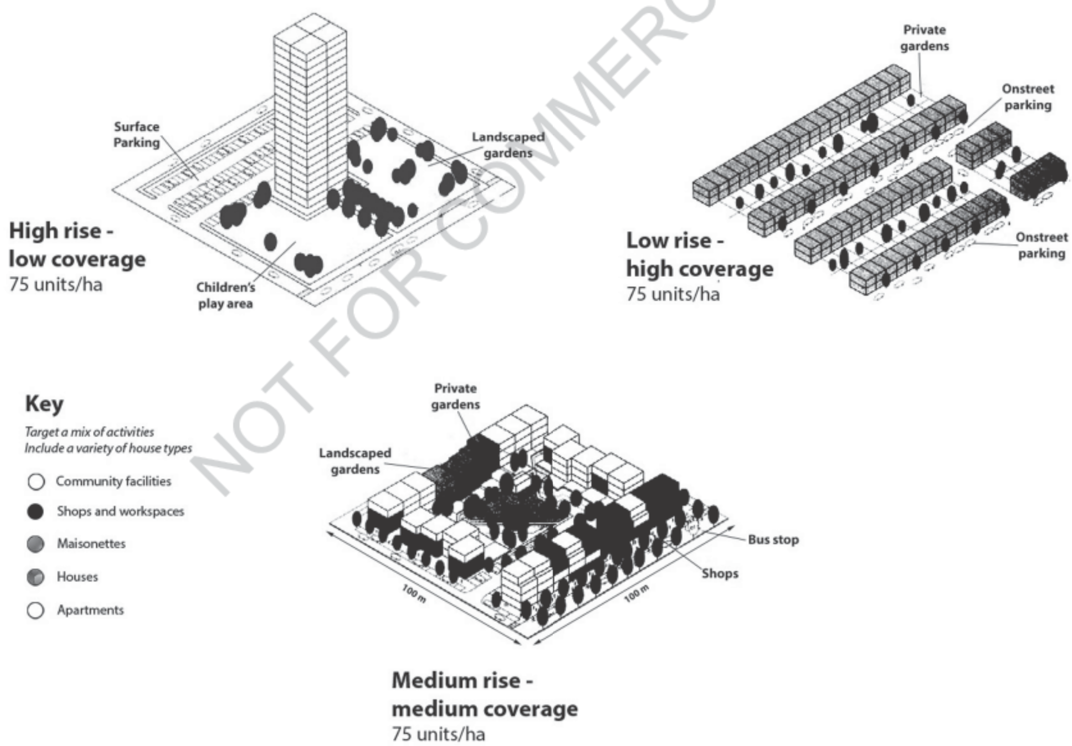

Figure 5. Relationship between Density and Urban Form

Source: Moughtin (2003).

While generally physical elements of the built fabric, such as, architectural differences and variety, the combination between the public and the private domains, the relationship between the built and open spaces, the distinction between the monumental and the ordinary, the integration between different types of land use, the harmony of the language of architecture in which every detail is a piece in an elaborate mosaic and the various means used to decorate the city (sculptures, murals and the like), help in the 'appraisal of built forms' as suggested by Kimhi (2005), it is important to note that it is not possible to define density from the outset without examining the nature of the spaces to which it is applied. In several instances it is found that localities have a specific configuration that depends on the scale of the urban space in question and the size of the open spaces contained within it. Thus, in order to assess environmental quality, it becomes imperative to examine the nature and use of spaces in the locality.

Another aspect that is important to understand is that the intra city structure is dynamic and keeps on changing with time as a result of several urban processes and mechanisms at play. However, the one common thing generally seen in the structure is that households with similar socio-economic status and similar land uses tend to cluster at various locations within the city. The locations are generally determined by a complex combination of historical, physical, socio-cultural, economical and administrative factors. These socio-economic and cultural preferences of people along with historical and political processes are found to have strong influence on the urban form patterns and hence density of development. Hence, a careful analysis of the demographic aspects also becomes a prerequisite for understanding the urban environment of the city.

Thus, it can be stated that in order to assess the urban environment based on a set of physical, social and environmental indicators, investigations pertaining to several aspects may have to be carried out to achieve certain conclusive results which can further be applied to the planning, design and maintenance of future sustainable cities. A research taking into account people's perception along with an objective analysis of the urban environment can thus really prove useful in terms of being used as a tool by residents to highlight and communicate concerns, wishes and positive aspects of their local area to fellow residents or decision makers (for example, local authorities, planners, policy makers and organizations) and as a conceptual framework for the planning and development of new areas of the city.

Conclusion

In order to gain a detailed insight into the perceived and measured components that influence environmental quality, several factors of the physical and human environment need to be evaluated from a new perspective. So far, science has not advanced a comprehensive framework to address these issues in an integrated manner and to enable an evaluation of physical, spatial, social and environmental indicators. There is no coherent system to measure and evaluate aspects of, and trends in, environmental quality though concepts of urban environmental quality and related terms, such as, liveability, quality of life and sustainability, enjoy great public popularity and form a central issue in research programmes, policy making and urban development (Leidelmijer et al., 2002). Accordingly, a study analyzing how varying urban structures and land uses in addition to distribution of people and their activities affect the urban environment can help understand current trends with respect to the urban processes taking place in and around the city. It should be understood that principally the mix of the urban built density depends on the size of the space in question, and the size of the open spaces contained within it. Hence, a number of density measures relative to the open spaces should be applied to measure the density of a given area. Employing a number of density measures can give a complete picture while accounting for the different scales of urban form (the city, neighbourhood/locality and the street). Or in other words, the above-mentioned approach can help in assessing and establishing a link between environmental quality and urban sustainability and help develop a methodology that can assess, monitor and potentially forecast developments of environmental quality of our cities.

Notes

1. United Nations Population Fund (UNFPA), Unleashing the Potential of Urban Growth, State of World Population Report 2007.
2. According to United Nations Department of Economic and Social Affairs/Population Division; World Urbanisation Prospects: The 2003 Revision Population Database: In developed countries, 75 per cent of the population already lives in cities, compared to 35 per cent in developing countries. But the rate of urbanization in developing countries is much higher—3 per cent compared to 0.5 per cent in developed countries. Estimates show that by 2030, about 84 per cent of the population of developing countries will be living in cities.
3. United Nations Population Division, World Urbanisation Prospects: The 2007 Revision Population Database.
4. Currently 30 per cent of India's total population or approximately 330 million people live in urban areas.
5. World Wide Fund for Nature (WWF), Urbanisation and Sustainability in India: An Interdependent Agenda, The Alternative Urban Futures Report 2010. http://assets.wwfindia.org/downloads/urbanisation_report.pdf

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URBAN ENVIRONMENT STUDIES FOR A SUSTAINABLE FUTURE: AN ALTERNATIVE APPROACH

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ABSTRACT

Different configuration and types of built form and related population distribution characterize the urban form of our cities. Alternatively, density given by distribution of buildings, their typology and geometry, layout patterns, distribution / availability of open spaces, quality of infrastructure including links to the wider urban system varies from one locality to the other within cities. Density gives rise to specific urban forms, land use and transit patterns in the city. In addition, urban form and land-use, and the transportation system become critical factors affecting urban environmental quality of a city. The following paper examines patterns and effects of rapid urbanization on Indian cities and the resulting deterioration of urban environmental quality in our cities. It highlights the fact that both environmental conditions and environmental quality become crucial if urban planning and management aim towards sustainable development.

Further, the paper outlines the world urbanization trends and identifies a number of cities that hold the key to future urbanization in India. Considering a naturally evolving Indian metropolitan city, the research proposes to examine the relationship between urban environmental quality and built-up density. After ascertaining several aspects for assessing urban environmental quality, a set of objective and subjective indicators are listed. The study envisages that the objective indicators shall help in diagnosing the environmental conditions whereas the subjective indicators shall help in the evaluation of the quality. The approach may be used by decision makers and physical planners, architects and urban designers to assess the effects of urbanization on the local environment of a city and help classify localities based on physical density and development patterns and corresponding environmental quality. The study also expects to assist in adopting minimal requirements of built-up density of different localities for future sustainable cities.

Keywords: *urban environmental quality, urban form, urbanization, density, configuration of built forms*

1.0 INTRODUCTION

A high concentration of population and economic activities and an urban development pattern that has so far had more negative rather than positive effects on the environmental condition of cities and their hinterland characterizes urbanization in India. Some of the visible negative effects of urbanization include – segregation and isolation, overcrowding, deficient or misallocated facilities and services, poor quality of construction, housing design and infrastructure. Other effects include – inadequate urban transport planning, inadequate treatment of solid and liquid waste, air and water pollution and risks of flooding and landslides. All these have contributed to the creation of urban space that is scarce and unacceptable for a healthy and comfortable human life. These are part of what has been called the

"Brown Agenda" which is concerned with unsustainable development in our cities, in contrast to the "Green Agenda", which concentrates on the global problems of the Earth (refer figure 1). The poor environmental quality in low-income neighborhoods has become one of the most urgent and greatest problems of Indian cities because of the risk it presents to its inhabitants' health. Despite macro-economic improvements within the cities, habitat conditions pose one of the most serious problems affecting the lives of the urban population.

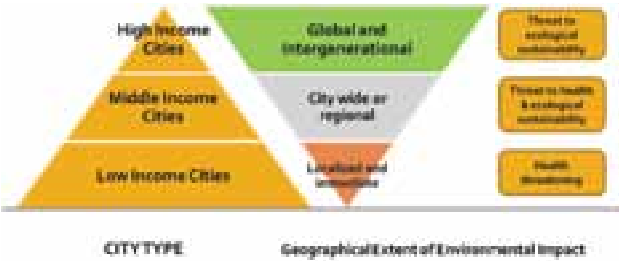


Figure 1: Brown, Gray and Green environmental issues in Cities

Source: Author's elaboration from UNU/IAS Report – Urban Ecosystem Analysis: Identifying Tools and Methods

In order to understand the urban environmental quality, it has become quintessential to study the local environmental problems associated with different patterns of urbanization within a city. Several studies show that urban environmental problems have a local origin and should be addressed in cooperation with local stakeholders. At the same time, it is recognized that global environmental decay often manifests itself at a local level. This awareness has led to the formulation of the Local Agenda 21 (1997)[1], in which a plea is made for local dedicated actions needed to combine a reduction of environmental decay with an improvement of local socio-economic conditions.

2.0 FUTURE WORLD URBANIZATION TRENDS

While much of the current sustainable cities debate focuses on the formidable problems of the world's largest urban agglomerations, it is predicted that in future majority of all urban dwellers will continue to reside in smaller urban settlements of fewer than 500,000 residents (refer figure 2). However, since no comprehensive database of cities with population below 750,000 exist in a readily available format, exact data is hard to find.

Nevertheless, according to the most recent estimates of the United Nation's Population Division, world over the lion's share of the increase in urban population over the next 15 years is predicted to continue in towns and cities with fewer than half a million inhabitants. Even by 2015, towns and cities under half a million will account for just over half of the total urban population. By comparison, less than nine percent of the world's urban population will be living in cities of 10 million or more by 2015. When added together, the combined size of the population of comparatively smaller cities and towns will make them very significant (refer figure 3).

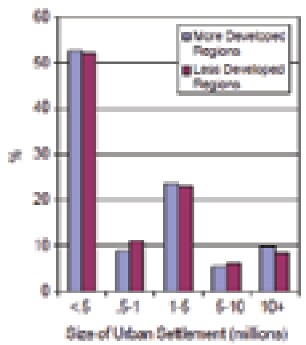


Figure 2: Distribution of urban residents by size of urban area, 2000

Source: World urbanization prospects: the 2003 revision data tables and highlights. New York, United Nations, 2004.

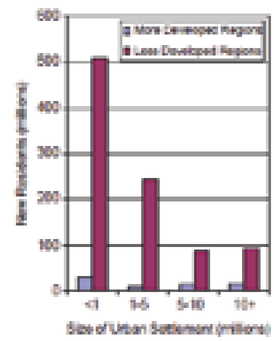


Figure 3: No. of people added to the urban milieu between 2000 and 2015 according to city size

Source: World urbanization prospects: the 2003 revision data tables and highlights. New York, United Nations, 2004.

In addition, it can be stated that since by definition these cities are starting from a comparatively smaller base, they will typically grow faster than the larger cities. Also, according to a recent study conducted by the US National Academy of Sciences, which was based on an analysis of data from more than 90 countries, it is seen that across all major geographic regions investigated, residents of smaller cities suffer a marked disadvantage in the provision of piped water, waste disposal, electricity and schools than residents of medium or large cities (refer figure 4). Also, there is some evidence to suggest that rates of poverty are higher in these cities and in many countries levels of infant and child mortality are negatively proportional to the city size[2]. Hence, in view of the role that will be played by the above mentioned class of cities in accommodating future population growth, it is clear that their need for improved basic services would have to be urgently addressed (Cohen, 2005).

3.0 URBANIZATION IN INDIA

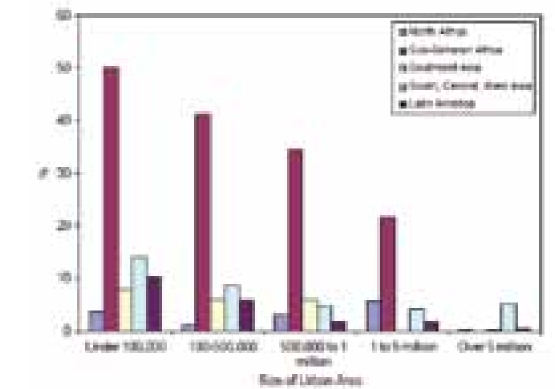
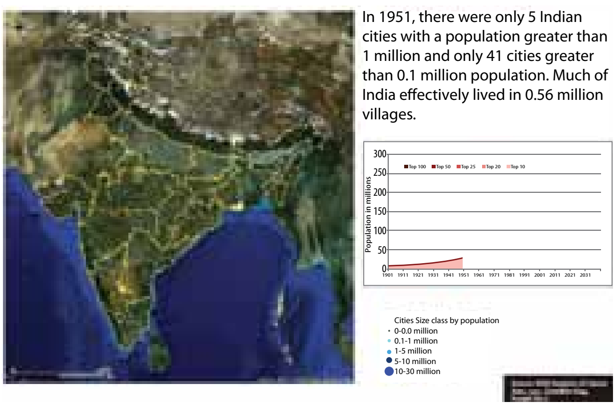


Figure 4 : Percentage of households lacking piped water, flush toilet and electricity by size of urban area and geographic region

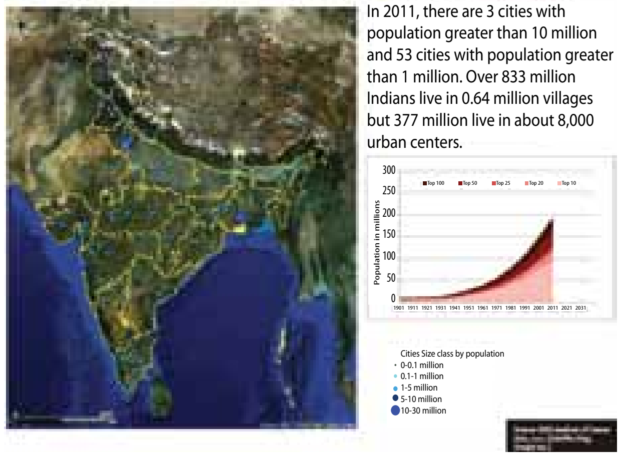
Source : National Research Council, Cities transformed: demographic change and its implications in the developing world. Washington, DC: National Academies Press; 2003.

India is well endowed with cities spread evenly across the country. Historically, cities in India have been located in areas with adequate water and on popular trade routes. Like other countries, cities have had bulk of the economic wealth and have been 24-hour market places. The high concentration of people living in the cities has brought variety of tastes, preferences, wants, resources, products and services to our cities (Bhandari, 2006). Over the years the megacities with population of tens of millions have occupied significant mind, media and policy space in terms of urbanisation in India. Post-Independence also urbanization in India has been dominated by the largest cities. However, with time, these cities have grown in size but quality of life has been severely compromised.



Map 1: Urban India - 1951

Source: IIHS Analysis[3] of Census data, 1951. (Satellite Map, Google Inc.)



Map 2: Urban India - 2011

Source : IIHS Analysis of Census data, 2011. (Satellite Map, Google Inc.)

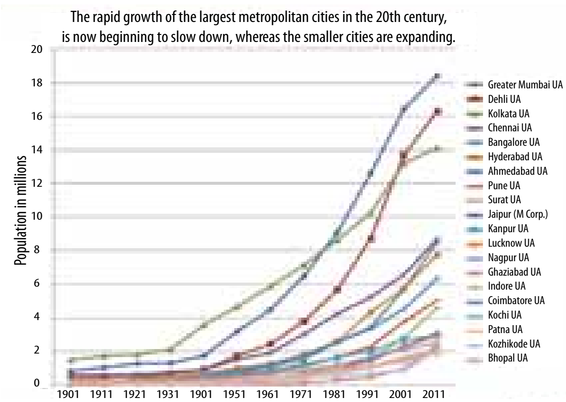


Figure 5: Largest 20 Urban Agglomerations by Population – 2011

Source: IIHS Analysis based on Census of India, 2011

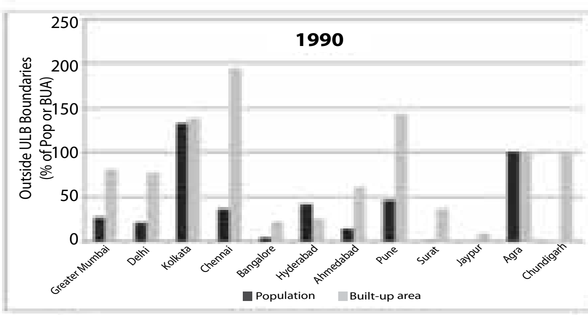
The fact, however, is that most of India's urban centres are smaller towns. The 8000 urban centres / townships identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only twenty percent live in cities of 10 million or more. Eighty percent of the urban population lives in cities and towns of population ≤ 1 million (refer map 1 and map 2). Hence, the most meaningful approach in our case would be to anticipate the rapid growth of these cities and put the Class I (0.1 – 1 million) cities centrally on the development agenda. This does not however mean that mega cities and larger metropolises would be neglected as they will continue playing a significant role in absorbing future anticipated growth, but for the near future Class I cities will hold the key to urbanization in India.

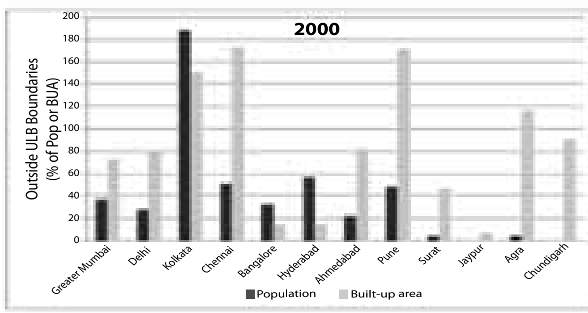
4.0 UNDERSTANDING URBAN EXPANSION AND GROWTH PATTERN OF INDIAN CITIES

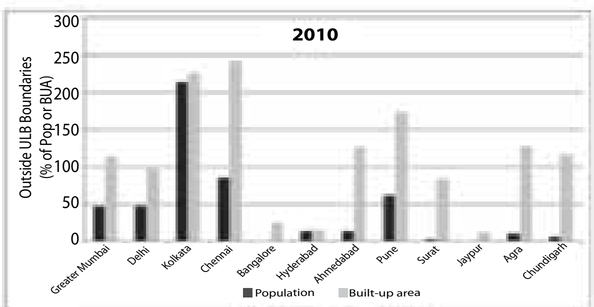
Land is one of the most contested and valuable of natural resources in urban areas. Change in land cover and modifications in land use account for one of the most significant changes in the environment due to human activity (Lambin, 1999). At first glance, the issue of land and land use might appear superfluous to urbanization as urban areas occupy less than 3% of the total land area globally (Lambin, 2001), but the issue is extremely important for a number of reasons. It is well documented that the impacts of contemporary patterns of urbanization on land and other resources far exceeds the actual extent of urban areas, as measured through ecological footprints and other tools. Moreover, there is already an indication that we may not be using land as efficiently as earlier, as the change in urban land use is faster than the rate of change in urban population (Seto, 2011). Also, in almost all developing cities, the demand for urban land gets precedence over all other uses and results in loss of fertile croplands and ecologically sensitive areas (Lambin, 2003).

While there are a few studies that measure land-use and land-cover changes for cities globally, there are only a handful of these for Indian cities. Generally, the patterns of urbanization show that cities are sprawling. As they expand past their formal administrative boundaries, city densities lower over time as population growth rates lag behind the rate of the growth of built-up areas (refer figure 6 and figure 7). This is hardly an unusual pattern when seen from a global perspective, but it does have obvious and possibly unfortunate consequences for urban governance, regional planning and the sustainability of our cities.

Most studies pertaining to causes and effects of urban expansion, nationally and internationally examine the issues at the citywide level. They however do not consider the issues at a smaller scale and understand the differences in patterns of urbanization and its effect on the environment in different localities / neighbourhoods of a city. Dowall and Monkkonen (2007) examine urban densities in Chennai. The paper suggests that the city is growing both because of increasing density in inner city areas as well as expansion of city



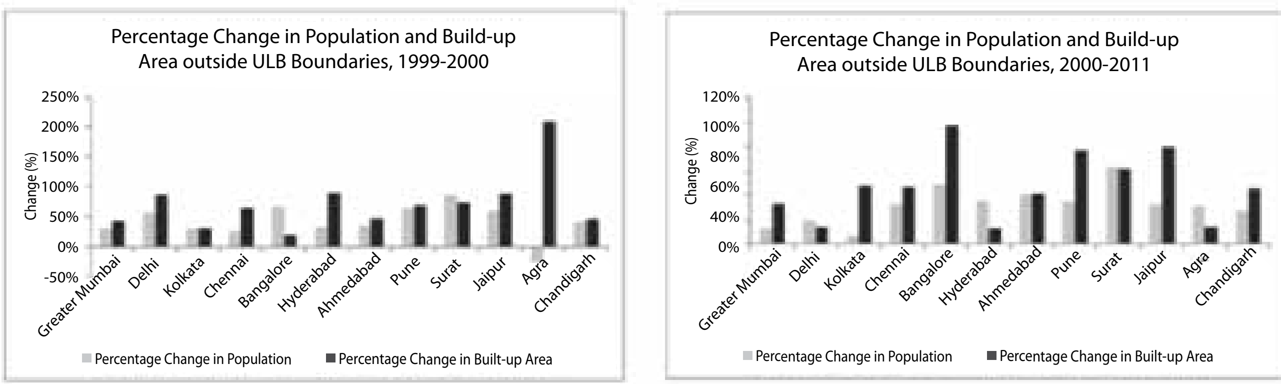




India's largest cities have a significant portion of both population and built-up areas outside ULB boundaries. In most cases, the proportion of built-up area outside ULB boundaries is greater than the proportion of population outside the administrative boundaries, implying relatively low-density sprawl. Comparison over time (highlighted in the next page) shows that this spatial expansion has accelerated between 2000 and 2010.

Figure 6: Population and Built-up Area – Inside and outside India's 10 largest cities
Source: H.S.Sudhira (2011) and IIHS Analysis.

boundaries. Densities vary drastically from as low as 13 persons per hectare to more than 1000 persons per hectare in Chennai. Studying changes between 1971 and 2001 shows that the city has grown faster than predicted and density gradient of the city has flattened over the decades. The authors illustrating the case of Chennai point out that high density in central city is not because of high-rise buildings, but because of overcrowding. The above study points out that nature of density are as significant as the measure of density. Similarly, the study by Patel (2011) is an attempt to set a framework on understanding densities and its relation to other factors that contribute to desirable urban living. The paper studies the interrelationships of six parameters: built up area per capita, public ground per capita, plot factor, floor space index, gross densities and net densities. It aims to arrive for a range of desirable values for a combination of these parameters while designing and planning an area between 20 and 200 hectares of land. The data is analyzed by plotting characteristics of select localities in Mumbai and New York. While this paper misses most sustainability aspects, it is one of the first attempts to answer the question of optimal densities in Indian cities.



Build-up area is growing faster than population in nearly all of the largest cities, especially between 2000-2011. In other words, lower-density sprawl is accelerating.

Figure 7: Urban Growth - Population versus Built-up Areas
Source: H.S.Sudhira (2011) and IIHS Analysis.

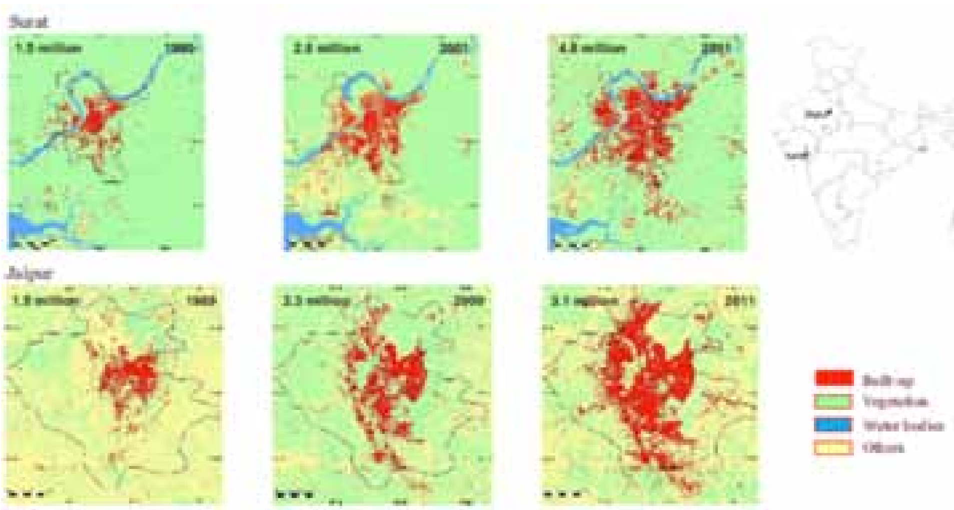


Figure 8(a): Change in Urban Built-up Area and Land Cover

Source: H.S.Sudhira (2011) and IIHS Analysis.

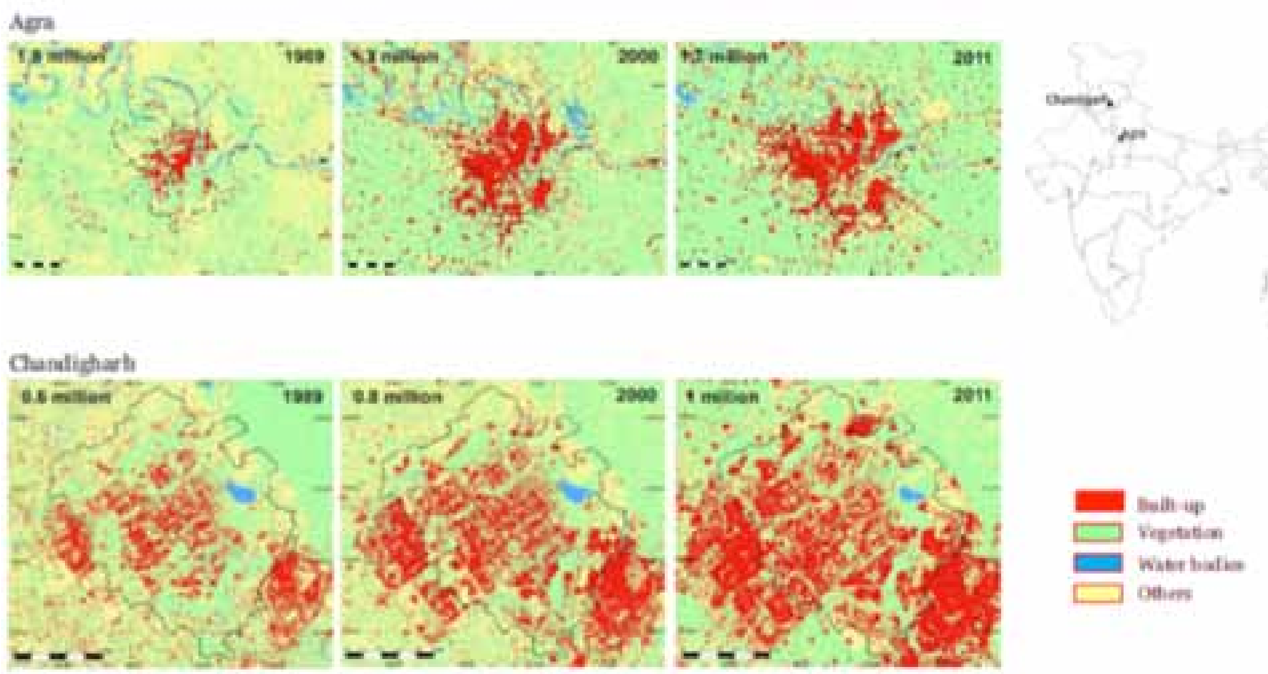


Figure 8(b): Change in Urban Built-up Area and Land Cover

Source: H.S.Sudhira (2011) and IIHS Analysis.

Thus, most studies conclude that urban areas have a tendency to expand, and then gradually fill in and become contiguous (refer figure 8a & 8b). However, since the research intends to understand the effect on the city's environmental quality with respect to the physical development and socio-economic factors, it becomes imperative to understand what is happening within a particular land use. What is the nature of built-up density? What are the type of transportation systems and resultant environmental quality? One of the reasons, as Cadenasso (2007) points out is that most land cover and land change methods are not adequate, as they do not capture urban heterogeneity well enough. These capture urban expansion, but not urban granularity at the block / neighbourhood level. Hence, a combination of tools may be required to answer the following questions:

- What are the environmental implications of specific urban densities in different localities within a city?
- What is the impact of the quality of development on the urban environment, and?
- Can urban environment studies help in designing sustainable cities?

5.0 IDENTIFYING CITIES FOR ASSESSING URBAN ENVIRONMENTAL QUALITY

In order to gain a detailed insight into the perceived and measured components that influence environmental quality and develop a methodology that can assess, monitor and potentially forecast developments of environmental quality in our cities, it is necessary to first identify some cities that hold the key to future urbanisation in India. The main criteria for selecting the cities can be as follows:

1. The cities should be emerging centres of economic activity.
2. They should be located between other urban centres and well connected.
3. In near future, these cities should create better opportunities for citizens living in and around them.
4. Some out of them should be cities that are budding and have the potential to turn into much larger centres.
5. They should be steadily gaining the necessary scales in terms of population and market size.

Based on the criteria listed and a study by an economic research firm, Indicus Analytics, all potential cities are divided into three categories as shown in Table 1.

Sibling Cities	Upcoming Cities	Budding Cities
A collection of smaller cities clustered around each other and highly dependent on the mother city.	Cities that in the recent past have come onto their own as important regional and economic centres.	Cities that have the potential to turn into much larger centres in the near future.
1. Centres that are siblings of larger cities such as Gurgaon and Noida (Delhi), Panchkula and Mohali (Chandigarh). 2. Kolkata's siblings in North 24 Parganas such as Baranagar, Barasat, Dum Dum, Kamarhati, Panihati and Salt Lake City. 3. Mumbai's siblings in Thane district such as Dombivli, Bhayandar, Navi Mumbai, Thane, Ulhasnagar and Virar. 4. Chennai's siblings in Thiruvallur district such as Ambattur, Avadi and Tiruvottiyur.	1. Goa, 2. Vijayawada and 3. Thiruvananthapuram These cities have become important regional or state centres of economic activity. As they progress, they will create opportunities for citizens living in them and their surrounding areas.	1. Capitals of states and UTs, such as Gandhinagar, Srinagar and Shillong. 2. Industrial centres such as Durg-Bhilai and Bokaro. 3. Historically important cities such as Udaipur and Mysore. 4. Religious cities such as Amritsar, Varanasi and Ajmer.

Table 1: Potential Cities that hold the key to future urbanization in India

Source: Author's elaboration from – The Diversity of top 100 cities of India by Indicus Analytics, An Economic Research Firm

All the above-mentioned cities are grouped into three population categories as shown in Table 2. However, since the literature and background studies indicate that no comprehensive database of cities with population under 750,000 exists in a readily available format, the research shall consider a city with 0.75 million-≤ population ≤ 1.5 million. It should be noted that some cities with just over 1 million population are included since they feature as potential cities according to Table 1.

Population	0.1 – 0.49 million	Shillong – 0.14 million
		Gandhinagar – 0.2 million
		Chandigarh's Siblings: Mohali – 0.15 million, Panchkula – 0.2 million
		Kolkata's Siblings: Salt Lake – 0.22 million, Baranagar – 0.25 million, Barasat – 0.3 million, Kamarhati – 0.34 million, Panihati – 0.38 million and Dumdum – 0.4 million
		Chennai's Siblings: Tiruvottiyur – 0.25 million, Avadi – 0.3 million and Ambattur – 0.47 million
		Durg – 0.27 million
		Bokaro – 0.4 million
		Udaipur – 0.45 million
	0.5 – 0.74 million	Mumbai's Siblings: Ulhasnagar – 0.5 million
		Ajmer – 0.54 million
		Bhilai – 0.6 million
		Delhi's Siblings: Noida – 0.65 million
	0.75 – 1.5 million	Thiruvananthapuram – 0.75 million
		Mysore – 0.88 million
		Vijayawada – 1.05 million
		Amritsar – 1.1 million
		Srinagar – 1.2 million
		Varanasi – 1.2 million
		Goa – 1.4 million
		Delhi's Siblings: Gurgaon – 1.5 million
		Mumbai's Siblings: Bhayandar – 0.8 million, Navi Mumbai – 1.1 million, Vasai Virar – 1.22 million, Kalyan Dombivli – 1.25 million and Thane – 1.8 million

Table 2: Population of Potential Case Study Cities

Source: List of most populous cities in India according to Census 2011 – Wikipedia

6.0 URBAN FORM OF INDIAN CITIES

Urban form deals with the physical layout and internal functional structure of an urban area. Here 'physical layout' means 'urban structure' and 'functional structure' may be interchanged with 'urban land use'. Various theories have been advanced by urban geographers to analyze the form of urban areas. Of these mention may be made of the *Concentric Zone Theory by E.W. Burgess (1923), the Sector Theory by Homer Hoyt (1939) and the Multiple Nuclei Theory by C.D. Harris and E.L. Ullman (1945).* These models have helped us in identifying various functional zones within the territorial limit of the city. These include the business area (including CBD), residential areas, industrial area, administrative area, educational areas, cultural areas, other areas and gardens and open spaces.

O.H.K. Spate and A.T.A. Learmonth (1967), John E. Brush (1962) and A.E. Smiles (1973) are the pioneers to have made significant contribution towards the study of urban form of Indian towns. According to Brush, Indian towns can be classified into two broad categories based on their physical characteristics:

1. **Indigenous:** These have fully Indian characteristics; such historic towns exist in the areas of northern plains, desert borderlands and Deccan Peninsula and exhibit impact of South-West Asian (Islamic) culture in the form of narrow winding streets.
2. **European type:** These include cantonments, civil lines, railway colonies etc. built during the British rule with regular grid pattern layout and detached bungalow type houses along straight and wide roads.

The urban form of the Indian cities was initially concentric in nature and was mostly affected by the physical characteristics of the site. During the British period with the development of new 'mohallas' (neighbourhoods), market places and suburbs it became sectored (consisting of two or three sectors). In certain port and capital cities it is multi-nuclei depicting the third stage of urban morphological development.

The study of the general urban structure and land use of the Indian cities shows that there is absence of clear separation between residential and other areas. Most of the traders, businessmen, artisans, service men and factory workers prefer to reside near their place of work. In general, upper stories, rear portions of the houses and neighbourhoods are utilized for residential purposes. The central part of the city, which is the main market place, is known as 'chowk' but its characteristics are not similar to the central business district (CBD) of the western cities. Here retail trade area extends along the main road and streets. Its commercial structure includes separate areas for food grains, clothes, ornaments, utensils, iron goods, vegetables etc. Main commercial area is surrounded by residential area that too denotes separation on basis of religion, caste, language etc. Generally, high caste and elite class residences are located nearer to the city-centre while low-income group prefers to occupy the peripheral area. In recent years, however, due to marked improvement in transport facilities, especially in road transport, people belonging to high and middle-income groups are moving away to outer parts of the city to avoid congestion and pollution. New residential colonies are also emerging in these suburban areas (see figure 10).

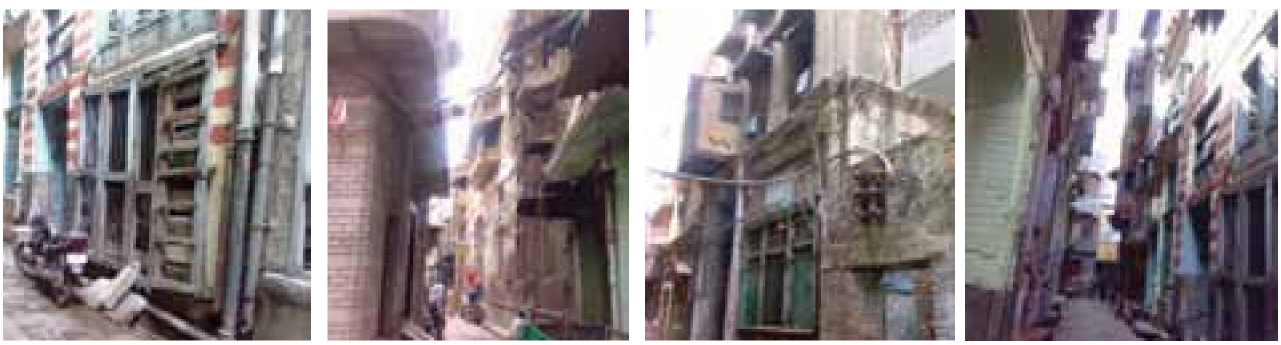


Figure 9: Poor Housing Condition, poor mass space relationship, mesh of wires and high intensity of development in the walled city (historic city) of Amritsar

Source : authors

Due to multinucleated development in the Indian cities, the CBD is not as developed as in case of Europe and America. It has emerged as a weak centre lacking mono central concentration. Excessive congestion, population density and intensity also obstruct its growth (see figure 9). The old part of the city is characterized by irregular, narrow and winding streets whose two sides are dotted with multi-storied buildings consisting of old and new houses with occasional location of temples, mosques and gurudwaras. The mixed land use further complicates the urban form and makes it difficult to identify clear functional zones in such cities.

Figure 10: View of new upcoming suburban residential projects along Bye-Pass, Amritsar

Source : authors

On the other hand, part of the city (including civil lines, military cantonment, railway colony, etc.) that developed during the British regime is very much similar to the western cities. Post-Independence many new cities have been built and old cities have been replanted on the western model. Here roads are straight and wide, well decorated with trees, parks and gardens. Along the road lie single storied bungalows without any trace of social segregation. However, with the growth of population in some cases, there is an increase in the vertical dimension of the houses.

7.0 ASSESSING THE URBAN ENVIRONMENT

In order to understand how the quality of physical development in addition to socio-economic factors has an effect on the environmental quality of our cities and assess the urban environment, an appraisal of the built forms at the neighbourhood / locality level shall be carried out as per the following stages of work.

I. Identifying 2-3 localities in the chosen city based on the following aspects:

a. Significance of the locality within the city
b. Land-use of the locality – Residential (formal or informal), Commercial or Mixed-use
c. Population and socio-economic conditions of the locality

II. Carrying out an appraisal of the built forms and quality of development by studying the following aspects of the built environment in each of the localities:

a. Urban form and built-up density (built-up versus open space relationship)
b. Grain and texture of the built forms
c. Type and quality of construction
d. Type and quality of road network serving the locality
e. Provision of urban services & utilities – electricity, drinking water supply, storm water drainage, sewage, solid waste management, etc.
f. Provision of social infrastructure – educational buildings, health services, recreational areas (shopping and community facilities), security services and green areas (parks and playgrounds)
g. Overall visual quality
h. People's perception about and aspirations for the locality

III. Identifying a set of objective and subjective indicators for assessing urban environmental quality

Both environmental conditions and environmental quality are crucial if urban planning and management aim towards sustainable development. The objective indicators shall help in diagnosing the environmental conditions whereas the subjective indicators shall help in the evaluation of the quality. The information on the subjective perception of environmental quality is as important for planners as objective information (Fadda and Jiron, 1999). In order to achieve better and more equitable living standards for especially the low and middle-income groups in our cities and give priority to the problems described in the Brown Agenda, it is most significant to assess the urban environment of low and middle-income neighbourhoods / localities. To select and evaluate meaningful environmental elements as included in the UNESCO chart, the factors pointed out by Haramoto et al., 1991 as well as the checklist proposed by Milbrath, 1978 and Rahman et al., 2011 are primarily taken into account. The parameters selected are shown in the synoptic chart in Table 3. The synoptic chart that lists down the main topics of investigation can be the first step towards the proposed methodology. The first column corresponds to the physical, social and environmental parameters selected as most significant at the locality level. Columns 2 and 3 correspond respectively to preliminary identification of the objective and / or subjective indicators out of the listed parameters.

S.No	**Parameters to assess Urban Environment Quality**	**Objective Indicators** (counting, measuring, illustrations and reports; environmental conditions and facts)	**Subjective Indicators** (observations, questionnaires and discussions)
1.	**PHYSICAL**		
1.1	***Land-use (Horizontal and Vertical)***	√	√
1.2	***Urban built form of the locality given by:***		
1.2.1	Distribution of buildings / Built-up Density	√	
1.2.2	Geometry and Typology (Height, Massing, Plot Coverage)	√	√
1.2.3	Layout Pattern (Orientation w.r.t. sun and wind)	√	√
1.2.4	Distribution of open spaces	√	√
1.3	***Population Density (Net & Gross)***	√	
1.4	***Occupancy Ratio***	√	
1.5	***Type & quality of construction***		√
1.6	***Type & quality of road network***		√
1.7	***Volume of Traffic***	√	
1.8	Provision of parking lots	√	
1.9	***Provision of Urban Utilities & Services given by:***		
1.9.1	Provision of Electricity Supply	√	√
1.9.2	Drinking Water Supply	√	√
1.9.3	Storm Water Drainage	√	√
1.9.4	Sewage	√	√
1.9.5	Solid Waste Management	√	√
1.10	Overall visual quality of the locality		√
2.	SOCIAL		
2.1	Provision of Social Infrastructure given by:		
2.1.1	Educational Buildings	√	
2.1.2	Health Services	√	
2.1.3	Religious Buildings	√	
2.1.4	Market Place / Shopping Sites	√	

S.No	Parameters to assess Urban Environment Quality	**Objective Indicators** (counting, measuring, illustrations and reports; environmental conditions and facts)	**Subjective Indicators** (observations, questionnaires and discussions)
2.1.5	Community Centre	√	
2.1.6	Security Services like police station, fire station etc.	√	
2.2	***Nature & use of Open Spaces***		√
2.3	***Availability of Public Transport***		√
2.4	***Preference of Public / Private Transport***		√
2.5	***Psychological & Social Aspects of the built form given by:***		
2.5.1	Location		√
2.5.2	Comfort (daylight, views & natural ventilation)		√
2.5.3	Privacy		√
2.5.4	Security		√
2.5.5	Spaciousness		√
2.6	Psychological & Social Aspects of the locality given by:		
2.6.1	Friendliness		√
2.6.2	Sense of identity and belongingness		√
2.6.3	Historical / religious significance		√
2.6.4	Cleanliness and maintenance		√
2.7	Monthly / Annual Expenditure on Health	√	
3.	ENVIRONMENTAL		
3.1	Air Quality (dust particles / SPM)	√	
3.2	Air Quality (% of population affected from foul smell)		√
3.3	***People suffering from specific types of diseases (allergies, water borne etc.) as a result of deteriorating environmental quality***	√	√
3.4	***Type of domestic fuel used and related emissions***	√	
3.5	***Indoor Air Quality***		√
3.6	Water Quality (physical appearance and taste)		√
3.7	% of population affected from noise given by:		
3.7.1	Noise outside (traffic / loud speaker etc.)	√	√
3.7.2	Noise inside (human noise, radio, TV, etc.)	√	√
3.8	Percentage of green areas converted to built-up areas	√	√
3.9	Temperature (summer)	√	√
3.10	Temperature (winter)	√	√
3.11	Temperature (Diurnal variations)	√	√

Table 3: Synoptic Chart of Parameters to Assess Urban Environmental Quality

Source: Synthesis of Milbrath and UNESCO, 1978; Rahman et al., 2011 and other authors mentioned in the theoretical background

It is expected that the study will demonstrate how varying urban structures and land uses given by distribution of buildings, their typology and geometry, layout patterns, distribution / availability of open spaces, quality of infrastructure including links to the wider urban system etc. in addition to distribution of people and their activities in different types of localities affect urban environmental quality.

8.0 CONCLUSION

The process suggested above may be considered as the starting point for evolving an alternative approach that can be used by decision makers and physical planners, architects and urban designers to assess the effects of urbanization on the local environment / microclimate of a city and help classify localities based on physical density and development patterns and corresponding environmental quality. It is expected to assist in adopting minimal requirements of built-up density of different localities for future cities.

Many studies have suggested that a more sustainable city is featured by green space, economic growth and continuity of open spaces (Irvine et al. 2010), which correspond well with the key factors in determining a city's environmental quality. Evidently, cities with favourable urban environmental quality hold the possibility of delivering a more sustainable future. Besides, the process can be easily adopted to conduct cross-case and cross-time comparisons at a meaningful level. This in turn shall lead to a better understanding of the relationship between urban environmental quality and urban physical and socioeconomic conditions and expedite the realization of the long term and holistic decision-making process of urban sustainability.

ENDNOTES:

1 Agenda 21 is an action plan of the United Nations (UN) related to sustainable development. It was an outcome of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the UN, governments and key groups in every area in which humans directly affect the environment. The implementation of Agenda 21 was intended to involve action at international, national, regional and local levels. Some national and state governments have legislated or advised that local authorities take steps to implement the plan locally, as recommended in Chapter 28 of the document. Such programs are often known as 'Local Agenda 21' or 'LA21'.

2 National Research Council. Cities transformed: demographic change and its implications in the developing world. Washington, DC: National Academies Press; 2003.

3 Urban India 2011: Evidence – A book produced by Indian Institute of Human Settlements (IIHS) for the India Urban Conference Evidence and Experience (IUC 2011) comprising of a series of events designed to raise the salience of urban challenges and opportunities in the on-going debate on India's development.

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Density and Neighbourhood Environmental Quality – A Comparative Study in the context of Indian Cities

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ABSTRACT: The study attempts to understand the relationship between density and neighbourhood environmental quality. A multiple case research design (Yin, 1994) is adopted by identifying different residential patterns in three case study cities. Amritsar, Chandigarh and Gurgaon are selected as the case study cities. The chosen cities are typical in nature and it is expected that through intensive analysis generalizations can be made that are applicable to other rapidly urbanizing Class I cities in the Indian context. There are important differences between the older habitations in the historic city of Amritsar with newer settlements of the city, post-independence planned interventions in Chandigarh and modern residential areas in the millennium city of Gurgaon. The assessment of Neighbourhood Environmental Quality and formulation of the Environmental Quality Index help in classifying different neighbourhoods according to the level of environmental quality. The study also helps in identifying significant relationships between different density variables and neighbourhood environmental quality. The future work envisages re-examining density measures of different residential patternsfor environmentally conducive development in our existing and future cities.

Keywords: Residential Patterns, Density, Neighbourhood Environmental Quality and its Assessment, Environmental Quality Index, Correlation Analysis

I. INTRODUCTION

Several studies indicate that majority of the Indian cities present a very similar pattern of urban development. All major towns and cities are found to be witnessing an explosive increase in urban population that strains the existing system and finally manifests into an environmental chaos. It is increasingly felt that the problems related to environmental quality in urban areas are very complex and require a systematic approach and careful analysis of all the relations between the variables that are part of the urban environment. Hence, in order to provide a cleaner and sustainable environment to the city residents, it becomes pertinent to look at the urban environment at a micro scale, specifically the habitat of a neighborhood in our Indian cities.

II. DENSITY & ENVIRONMENTAL QUALITY

The literature study outlines that Environmental Quality is an abstract concept resulting from both human and natural factors operating at different spatial scales. *In urban areas the local scale is dominated by individual buildings, streets and trees, but regional scale influences may include the whole city and beyond*(van Kamp *et al.,* 2003; Pacione, 2003; Nichol and Wong, 2005). Hence, environmental quality is both objective and subjective in nature and in other words, spatial and physical features in addition to socio-economic factors affect the environmental quality.

At the same time, a general study of the urban morphology of our cities reveals that different configuration and types of built form and related population distribution characterise the urban form across the geographical extent of the city. Alternatively, it can be stated that density given by distribution of buildings, their typology and geometry, layout patterns, distribution of open spaces, quality of infrastructure etc. varies from one locality to the other within the city. Density gives rise to particular urban forms, land use and transit patterns in the city.

Concurrently, it is also understood from various studies that urban form, land use and transport system of a city are critical factors affecting the environmental quality. Thus, it can be hypothesised that density has an impact on environmental quality.

The relationship between density and environmental quality is also found to be based on the concept of viable thresholds: at certain densities, the amount of development and number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable without putting a stress on the environmental carrying capacity. In a wider sense, as Carl, 2000 puts it; *'Sustainable Cities are a matter of Density'*.

Thus, it is seen that one of the enduring themes behind the search for more sustainable urban forms is that of the density of development. Capello and Camagni, 2000 argue that *"with the increase of residential density and the concentration of human activities within smaller built areas, it helps to exploit economies of scale for public services (e.g. schools, public buses and public utilities) and environmental resources (e.g. land, petrol and water). However, an excessive concentration of activities and proximity result in aggravated negative environmental externalities like traffic congestion, less privacy, poor access to natural agents (air, daylight, view, etc.) and overcrowding, which tend to outweigh the claimed benefits of urban compaction"*(Burgess, 2000; Rudlin and Falk, 1999; Williams *et al.,* 2000).

Hence, a research on environmental quality with an objective analysis of the built environment of a residential neighbourhood can really prove useful. It can be used as a tool by residents to highlight and communicate concerns and positive aspects of their area to fellow residents or decision makers (e.g. local authorities, planners, policy makers and organisations). It can also be used as a framework for the planning and development of new residential areas of the city.

III. OBJECTIVES OF THE STUDY

The present study is concerned with understanding the impact of density on neighborhood environmental quality. The study is limited to the objective analysis of the physical aspects of the built environment of the different neighborhoods. The investigation of people's perception to check the subjective values of an objective situation is presently kept out of the scope of the study. This is based on the argument given by Alexander (1993)that though individual cognitive factors provide a wider thinking on density as a concept, what determines density that is perceived by people is the physical density of the built environment. Also, even though people evaluate their environments as perceived, it is the physical density that provides a basis to objectively assess spatial quality of a place. Therefore, the objectives of the study are:

(i) To operationalize density and ascertain objective indicators of environmental quality at the neighborhood level.

(ii) To identify different residential patterns and find representative neighborhoods in the case-study cities.

(iii) To assess aggregated neighbourhood environmental quality and formulate the environmental quality index.

(iv) To identify significant relationships between density variables and neighbourhood environmental quality.

IV. OPERATIONALIZING DENSITY AND IDENTIFYING INDICATORS OF ENVIRONMENTAL QUALITY

'Density' is broadly disaggregated into Population Density; Built Form Characteristics like Residential Density, Height, Ground Coverage and Built to Open Ratio; Amount of Roads and Sidewalks; etc. to cover all significant physical aspects of the neighbourhood. On the other hand, the indicators of neighbourhood environmental quality are identified as: Crowding and Congestion, Nature and Use of Open Spaces, Shade and Ventilation, Temperature Variations, Average Noise Levels, Level of Cleanliness, Neighbourhood Walkability and Air Quality. A conceptual matrix showing possible correlations between Density Variables and Indicators of Environmental Quality is generated (Table 1).

V. RESIDENTIAL PATTERNS IN INDIAN CITIES

Patterns of urbanization within a city differ from one location to another. While the indigenous or traditional city is irregular in composition; the annexes (cantonment, civil lines, etc.) are found to be much more organized. These varying patterns of urban development result in differences in levels of population density, concentration and mixing of residential or commercial uses, amount of open spaces, etc. (Galster *et al.* 2001). The inner core is found to be a compact city largely designed for pedestrians and cycle rickshaws. The entire built up mass is more or less a compact monolithic volume with small punctures for the purpose of light, ventilation and movement. Old parts of Shahjahanabad (Delhi), Jaisalmer and Jaipur (Rajasthan), Ahmedabad (Gujarat), etc. exhibit these characteristics (Kapadia, 2010). The city outside is sometimes dominated by the British annexes with buildings more clearly distinguished and grouped according to their functions (Smailes, 1986).

Looking beyond, newer parts of the city are found to have developed haphazardly as a result of accelerated industrialization and rapid urbanization.

High densities are found in commercial and industrial zones offering jobs to resident and migrant population and along transport corridors promoting easy accessibility to and from the place of work. The built forms are designed asheterogeneous projects that rarely respond to their surroundings in the city (Bharne, 2011). Lastly, the residential development seen in most city outskirts are the gated communities dominated by high rise apartment blocks, community open space and shared facilities. Though these communities are usually high density enclaves but at the scale of the city, lying on the fringes they are generally part of a low-density car-orientated suburb, which is highly unsustainable and does nothing to support the traditional energy and vitality of urban life. The urban form is thus characterized by different configuration of built forms and population distributions across the city.

Table 1: Conceptual Correlation Matrix.

Density Variables	Environmental Quality Indicators							
	Crowding & Congestion	Nature and use of Open Spaces	Shade & Ventilation	Temp. Variations	Noise Levels	Level of Cleanliness	Neighbourhood Walkability	Air Quality
Population Density	●	●			○	●	○	○
Built form Characteristics	●	●	●	●	○			
Amount of Roads and Sidewalks	●				●		●	●
Amount of Open Spaces	●	●	●	●	○		●	●

● Direct Correlation ○ Indirect Correlation

VI. AREA OF STUDY

Most of India's urban centers are smaller towns. The 8000 urban centers identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only 20% live in cities of 10 million or more. Eighty percent of the urban population lives in cities and towns of population ≤1 million. Hence, the most meaningful approach is to anticipate the rapid growth of these Class I cities and devise ways for their sustainable development (Sudhira and Gururaja, 2012).

Amritsar, Chandigarh and Gurgaon with 0.75 million≤population≤1.5 million are selected as case study cities since they are from different time periods and have imprints of all types of residential patterns. There are important differences between the older habitations in the historic city of Amritsar with newer settlements outside, post-independence planned interventions in Chandigarh and modern residential areas in Gurgaon. For detailed investigation, eight neighbourhoods based on population density, residential density and height of buildings (most prominent built-form characteristic) are identified from the three case study cities (Plate 1).

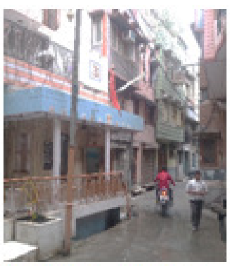
The population density is categorised as low density with <200pph, medium density with 200 to <400pph, high density with 400 to <600pph and very high as ≥600pph (refer Table 2). Similarly, the residential density is categorised as low density with <50DUs/hectare, medium density with 50-100DUs/hectare and high density with >100DUs/hectare (refer Table 4). In Table 3, G+3 storeyed structures that do not require elevators are considered low-rise. Structures with more than 8 storeys or 25m in height with mandatory provision of diesel generators in case of an electricity failure are considered high rise as per the National Building Code 2005 Fire Safety and Fire Protection Norms and buildings having 5-8 storeys are considered as medium rise structures. This is based on the population densities, residential densities and heights observed in different neighbourhoods in several Indian cities.

Table 2: Neighbourhoods grouped according to Population Density.

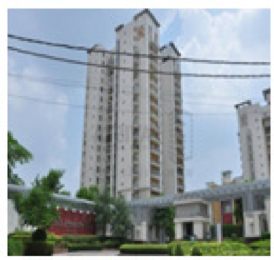
Neighbourhood	Population Density (pph)	Range	Level
Sector 8, Chandigarh	95	<200pph	**Low**
World Spa, Gurgaon	178		
Ranjit Avenue, Amritsar	256	200 to <400pph	**Medium**
Marble Arch, Chandigarh	345		
Sector 38W, Chandigarh	441	400 to <600pph	**High**
Sector 20, Pkl, Chandigarh	540		
KatraDullo, Amritsar	641	≥600pph	**Very High**
Uniworld City, Gurgaon	798		

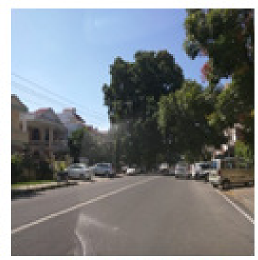
Table 3: Neighbourhoods grouped according to Height.

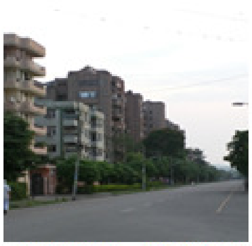
Neighbourhood	No. of Storeys	Range	Rise
Sector 8, Chandigarh	G, G+1, G+2	≤G+3 storeys	**Low**
Ranjit Avenue, Amritsar	G, G+1, G+2		
Sector 38W, Chandigarh	G+2		
KatraDullo, Amritsar	G, G+1, G+2, G+3		
Marble Arch, Chandigarh	G+4	5-8 storeys	**Medium**
Sector 20, Pkl, Chandigarh	G+5, G+6, G+7		
World Spa, Gurgaon	G+16	>8 storeys	**High**
Uniworld City, Gurgaon	G+18		


KatraDullo, Amritsar

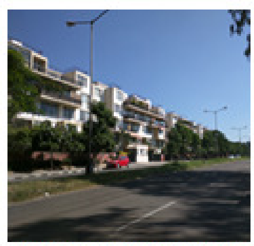

Ranjit Avenue, Amritsar


Uniworld City, Gurgaon


Sector-8, Chandigarh


Sec-20, Pkl., Chandigarh


World Spa, Gurgaon


Marble Arch, Chandigarh


Sector-38W, Chandigarh

Plate 1: Residential Neighbourhoods in Case Study Cities.

Table 4: Neighbourhoods grouped according to Residential Density.

Neighbourhood	Residential Density (DUs/hectare)	Range	Level
Sector 8, Chandigarh	17	<50DUs/hectare	**Low**
Ranjit Avenue, Amritsar	36		
World Spa, Gurgaon	44		
Marble Arch, Chandigarh	65	50-100 DUs/hectare	**Medium**
Sector 38W, Chandigarh	76		
Sector 20, Pkl, Chandigarh	98		
KatraDullo, Amritsar	149	>100DUs/hectare	**High**
Uniworld City, Gurgaon	200		

VI. METHODOLOGY

Data Collection and Organization

Data is collected from both primary and secondary sources (Fig. 1). Certain mechanical instruments like the Temperature and Humidity Data logger and Smartphone Android Applications like deciBel are used to record ambient temperatures and average noise levels in different places of the neighbourhoods.

The environmental quality indicators are measured using several variables as shown in Table 5. They are subsequently compared with threshold values given by CPCB, New Delhi; URDPFI 2014; Handbook of Service Level Benchmarking, MoUD, Govt. of India 2011; etc.

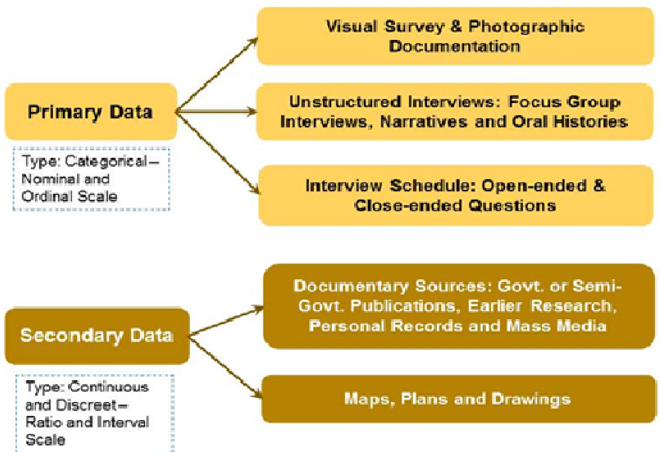


Fig. 1: Types of Data and Methods of Data Collection

Table 5: Variables to Assess Neighbourhood Environmental Quality.

<table>
<tr><th>Indicator</th><th colspan="6">Measurement Variables</th></tr>
<tr><td>Crowding and Congestion</td><td>BUA/Capita (Built-up Area per Capita)</td><td colspan="2">PGA/Capita (Public Ground Area per Capita)</td><td colspan="2">PRL/Capita (Paved Road Length per Capita)</td><td>Mobilization Factor</td></tr>
<tr><td>Nature and Use of Open Spaces</td><td>Type of Open Space</td><td colspan="2">Area of Open Space</td><td colspan="2">Percentage Tree Cover</td><td>Activity Intensity</td></tr>
<tr><td>Shade and Ventilation</td><td colspan="3">Shade Rating - No. of hours of Shade in the Neighbourhood</td><td colspan="3">Orientation of Streets w.r.t Prevailing Winds</td></tr>
<tr><td>Temperature Variations</td><td colspan="3">Temperature inside the Locality</td><td colspan="3">Temperature outside the Locality</td></tr>
<tr><td>Average Noise Levels</td><td colspan="2">At Entry Points</td><td colspan="2">Inside the Locality</td><td colspan="2">On Main Roads</td></tr>
<tr><td>Level of Cleanliness</td><td colspan="2">Cleanliness Indicator</td><td colspan="2">Sewage Indicator</td><td colspan="2">Drainage Indicator</td></tr>
<tr><td>Neighbourhood Walkability</td><td>Proximity to Daily Needs</td><td colspan="2">Type of Sidewalks</td><td colspan="2">Availability of Streetlights</td><td>Type of Open Space</td></tr>
<tr><td>Air Quality</td><td colspan="2">NO_x</td><td colspan="2">SO_2</td><td colspan="2">RSPM</td></tr>
</table>

Source: Synthesis of Milbrath and UNESCO, 1978; Rahman *et al.,* 2011 and Handbook of Service Level Benchmarking, MoUD, Govt. of India, 2011.)

Assessing Neighbourhood Environmental Quality

Each of the eight neighbourhoods are divided into smaller study units along the streets and all the parameters listed in Table 5 above are objectively ascertained using primary and secondary data for each of the neighbourhoods. Thereafter these values are merged together using Standardized Z-scores in IBM SPSS Statistics 22 (Statistical Package for Social Sciences) to get the Standardized Aggregated Environmental Quality (ZAEQ) ofall the neighbourhoods (Table 6).

The ZAEQ values are used to create an Environmental Quality Index (refer Figure 2) that can be further used to generate illustrative maps for each of the neighbourhoods showing sections with most favourable, favourable, average, less favourable and least favourable environmental quality.

Since, the aggregated environmental quality values are derived from standardized z-scores, they lie between -1 (least favourable) and +1 (most favourable).

Any number of neighbourhoods can be analysed to generate the standardized environmental quality scores and the process can be applied to entire cities thus enabling the identification of areas with good, average and poor environmental quality at the city level. It can further help in conducting cross-case comparisons and help rank cities based on the environmental quality in its residential neighbourhoods. This is partially represented by the row indicating the level of Environmental Quality in Table 6.

Table 6: Standardized Aggregated Environmental Quality of Case Study Neighbourhoods.

Study Units	AMRITSAR		CHANDIGARH				GURGAON	
	KatraDullo	Ranjit Avenue	Sec-8	Sec-38W	Marble Arch	Sec-20, Pkl	Uniworld City	World Spa
1.	0.18	0.34	-0.37	-0.35	0.37	-0.35	0.17	0.43
2.	-0.14	0.28	-0.46	-0.34	-0.16	-0.11	0.32	0.44
3.	-0.22	0.37	-0.31	-0.48	-0.06	0.01	-0.03	0.35
4.	-0.06	0.53	-0.21	-0.24		-0.45	0.23	0.36
5.	-0.21	0.41	-0.33	-0.26		-0.56	0.09	0.34
6.	-0.37	0.3	-0.27	-0.08		-0.12	0.4	0.31
7.	-0.61	0.38	0.13	-0.23		-0.36	-0.04	0.41
8.	-0.28	0.35	-0.22	-0.25		-0.27	0.23	0.49
9.	-0.24	0.64	0.05	-0.2		-0.49	0.17	0.33
10.	-0.4	0.39	0.23	-0.3		-0.51	0.4	0.3
11.	-0.19	0.46		-0.3		-0.59	-0.05	0.41
12.	-0.37	0.48		-0.2			0.21	0.34
Avg. ZAEQ	**-0.24**	**0.41**	**-0.18**	**-0.27**	**0.05**	**-0.35**	**0.18**	**0.38**
Level as per EQI	**Less Favourable**	**Favourable**	**Average**	**Less Favourable**	**Average**	**Less Favourable**	**Average**	**Favourable**

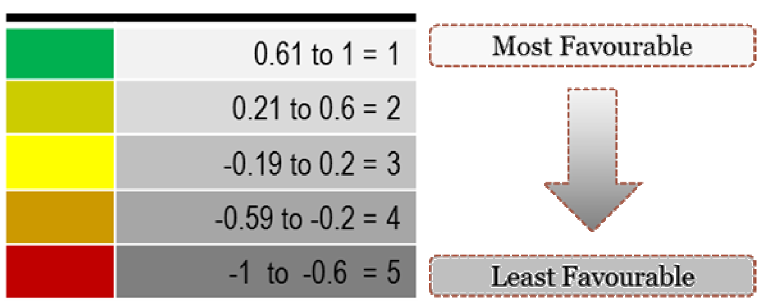


Fig. 2. Environmental Quality Index.

Preliminary Findings

It is observed from Table 6 that Ranjit Avenue, Amritsar and World Spa, Gurgaon with medium and low population density (<400pph), low residential density of 20-50DUs/hectare and low/high rise buildings have favourable environmental quality whereas neighbourhoods with high and very high population density (≥400pph), medium and high residential density (>70DUs/hectare) and low and medium rise buildings (G to G+7) have less favourable environmental quality due to crowding, congestion and lack of open spaces.

This is especially demonstrated by KatraDullo, Amritsar, Sector 38West and Sector 20, Panchkula, Chandigarh. It is also seen that rest of the three neighbourhoods have average environmental quality. The preliminary findings are summated in Table 7.

Thus, it can be said that from among the residential patterns assessed, the environmental quality is more favourable in both low and high-rise neighbourhoods with low residential density and medium and low population density respectively. This is seen in Figure 3 and Figure 4.

Figure 3 indicates that mostly areas with more favourable environmental quality have low residential density of <50DUs/hectare whereas areas with higher residential densities of ≥50DUs/hectare generally have less favourable environmental quality. Figure 4 shows that most of the areas with above average, more favourable and most favourable environmental quality have >100 and <400pph which constitute low and medium population density. Areas with ≥400pph i.e. high and very high population density fall in the category having below average, less favourable and least favourable environmental quality.

Table 7: Residential Patterns and Environmental Quality.

Built Form Characteristics	Population Density		
	Low Population Density	Medium Population Density	High / Very High Population Density
Low Rise Low Residential Density	Average	Favourable	×
Low Rise Med. Residential Density	×	×	Less Favourable
Low Rise High Residential Density	×	×	Less Favourable
Med. Rise Med. Residential Density	×	Average	Less Favourable
Med. Rise High Residential Density	×	×	×
HighRise Low Residential Density	Favourable	×	×
High Rise High Residential Density	×	×	Average

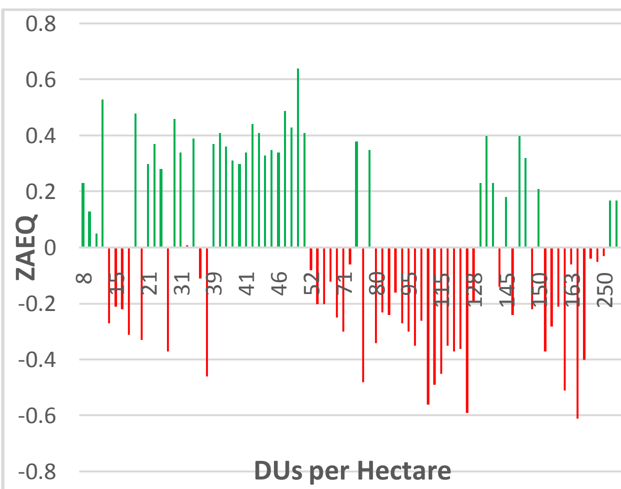


Fig. 3. Variation in Environmental Quality with Residential Density.

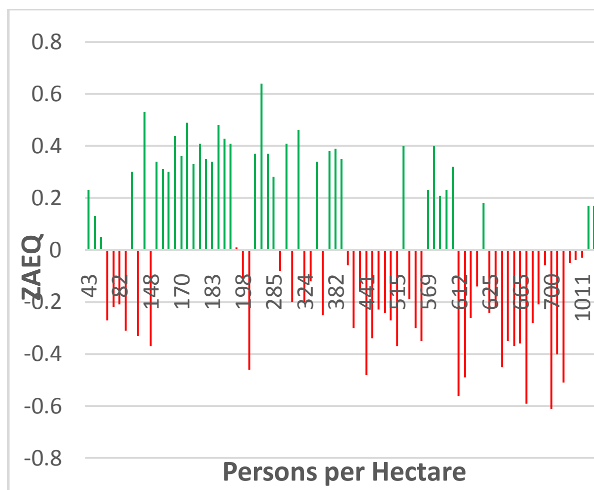


Fig. 4. Variation in Environmental Quality with Population Density.

Correlation Analysis

To statistically establish the relationship between density and neighbourhood environmental quality, a correlation analysis is carried out between density variables like persons per hectare, dwelling units per hectare, height of buildings, plot coverage, etc. and standardized aggregated environmental quality (ZAEQ) of all the residential neighbourhoods. Significant correlations at 99% confidence level are seen between many density variables and neighbourhood environmental quality. While environmental quality varies negatively with population density, residential density, plot coverage and encroachment; it shows positive correlation with height, amount of open spaces and condition of sidewalks (Table 8). In other words, this means that as population density, residential density, etc. goes on increasing the environmental quality deteriorates whereas with increase in height of buildings, amount of open spaces and good condition of sidewalks permitting walkable neighbourhoods, the environmental quality starts improving. This is also in compliance with Table 7 above.

Table 8: Correlation between Density Variables and Environmental Quality.

DENSITY VARIABLES		ZAEQ
Persons per Hectare	Pearson Correlation	-.355**
	Sig. (2-tailed)	.001
DUs per Hectare	Pearson Correlation	-.263*
	Sig. (2-tailed)	.016
Height	Pearson Correlation	.433**
	Sig. (2-tailed)	.000
Built to Open Ratio	Pearson Correlation	-.387**
	Sig. (2-tailed)	.000
Plot Coverage	Pearson Correlation	-.651**
	Sig. (2-tailed)	.000
Open Space	Pearson Correlation	.283**
	Sig. (2-tailed)	.009
Road Density	Pearson Correlation	-.097
	Sig. (2-tailed)	.382
Encroachment	Pearson Correlation	-.271*
	Sig. (2-tailed)	.013
Proximity to Daily Needs	Pearson Correlation	.107
	Sig. (2-tailed)	.331
Condition of Sidewalks	Pearson Correlation	.389**
	Sig. (2-tailed)	.000
StreetLights	Pearson Correlation	.039
	Sig. (2-tailed)	.726

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The future course of work involves carrying out hierarchical multiple regression that will help assess the extent to which the observed variance in the dependent variable (in this case Neighbourhood Environmental Quality) is explained by the variance in the independent density variables. Also the standardized 'β -coefficient' will be used to indicate the relative importance of a density variable thus helping in re-examining the density measures for achieving optimum environmental quality.

CONCLUSION

The present study helps to take up a multiple case study approach to assess and compare the environmental quality of different neighbourhoods from three rapidly urbanizing cities in the Indian context. An analytical framework devised on the basis of detailed literature review showing possible correlations between density variables and indicators of environmental quality helps in understanding the relationship between density and environmental quality. It shows that density has an impact on environmental quality.

The study further emphasizes the need for detailed empirical analyses for better planning at both micro and macro levels of existing urban structure as suggested by Radberg (1996). It envisages identifying desirable density ranges for neighbourhoods having different residential patterns so as to derive guidelines and suggest methods to achieve environmentally conducive patterns of residential development in our present and future cities.

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A Model Framework for Assessing Urban Environmental Quality

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ABSTRACT

The emergent urban problems such as unprecedented population growth, urban sprawl, disparities between city core and its periphery, urban decay in city centers, increasing traffic volume and congestion pose fresh challenges for planning environmentally sustainable (growth of our) cities. It is observed that the intra city structure is dynamic and keeps on changing with time as a result of several urban processes and mechanisms at play. The study focuses on the residential neighborhoods / localities which are the basic unit of urban planning and intends to understand the relationship between physical density patterns of residential development within a city and associated environmental quality. Based on an understanding of the various patterns of residential development found in Indian cities, physical density and urban environmental quality are defined and the various parameters to assess the same in residential localities are identified.Subsequently an analytical framework is developed to understand the causal relationship between the density variables and indicators of urban environmental quality. On the basis of the analytical framework, a bottom-up theoretical model is proposed to understand the effect of physical density on urban environmental quality. The model envisages finding correlations between the density / urban structure variables and indicators of environmental quality and hence prove/disprove the hypothesis – Density affects Urban Environmental Quality. It also proposes to identify the desirable density ranges for neighborhoods in light of the findings of the study so as to arrive at guidelines to achieve environmentally conducive patterns of residential development in our cities

Key words: Residential Neighborhoods, Physical Density Patterns, Urban Environmental Quality

1.0 INTRODUCTION

Several studies indicate that majority of the Indian cities present a very similar pattern of urban development. All major towns and cities are found to be witnessing an explosive increase in urban population that strains the existing system and finally manifests into an environmental chaos. It is increasingly felt that the problems related to environmental quality in urban areas are very complex and require a systematic approach and careful analysis of all the relations between

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PR19

Multi-criteria Approach for Assessing Neighbourhood Environmental Quality

A way towards Future Sustainable Development of Indian Cities

Swati Dutta, Dr. Suchandra Bardhan and Dr. Sanjukkta Bhaduri

Abstract

India is well endowed with cities spread evenly across the country. These cities are the centers of commercial, political, educational and cultural activities with millions of people residing and many more migrating in and out of them constantly. The high concentration of people brings variety of preferences, resources, products and services to our cities **(Bhandari, 2006)**. Over the years, the megacities with population of tens of millions have occupied significant mind, media and policy space in terms of urbanization in India. With time, these cities have grown in size but quality of life has deteriorated[1].

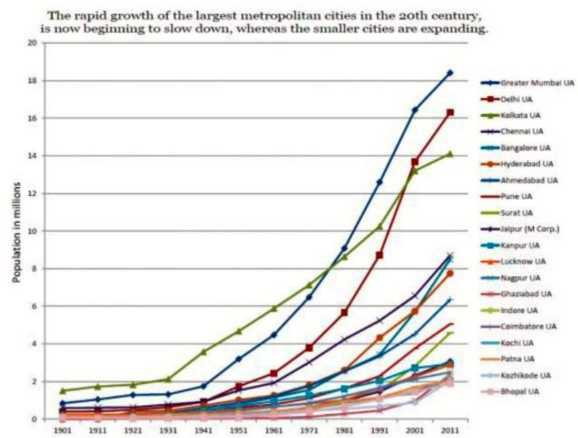

Fig 1: Largest 20 Urban Agglomerations by Population – 2011 (Source: IIHS Analysis based on Census of India, 2011)

On the other side, most of India's urban centers are smaller towns. The 8000 urban centers identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only 20% live in cities of 10 million or more. Eighty percent of the urban population lives in cities and towns of population ≤ 1 million[2]. Figure 1 shows that from 20th century onwards the rapid growth of the largest metropolitan cities has slowed down, whereas the smaller cities are expanding. Hence, the most meaningful approach is to anticipate the rapid growth of these cities and devise ways for their future sustainable development **(Sudhira and Gururaja, 2012)**.

Objectives of Study - The objectives of the study are to Assess the Environmental Quality at the Neighbourhood Level and Understand the relationship between Residential Density and Environmental Quality and suggest measures for environmentally conducive future development.

Scope of Work - The present study identifies typical residential patterns based on physical density variables in a case study city and assesses environmental quality at the micro-level – the level of the residential neighbourhood. Two neighbourhoods are analyzed for the pilot study. The preliminary findings show that significant correlations exist between residential density and neighbourhood environmental quality. The study is limited to the organized sector and socio-economic factors and qualitative perceptions of people are kept out of the scope of the study.

Area of Study - For the first phase, Amritsar - a major pilgrimage/tourist destination and one of the youngest metropolitan cities of India is selected for the study (Sandhu and Teotia, 2013). As no comprehensive database of cities with population under 750,000 exists in a readily available format **(Barney, 2005),** the research is based on cities with 0.75 million≤ population ≤ 1.5 million.

Methodology - Several tools are applied to carry out the analyses. They are: Multi-criteria Approach to assess the neighbourhood environmental quality. It helps to consider several physical density variables that can be controlled and modified during the planning and design phase to achieve better spatial quality of the designed space. Correlation Coefficient Analysis to understand the relationship between density variables and neighbourhood environmental quality. Generating an "Environmental Quality Index" as a tool to classify different localities of the city according to the level of environmental quality (refer figure 2). The approach identifies the problem areas and creates the possibility of taking up local actions at the micro-level (street/cluster level) by the residents and urban local bodies to improve the environmental quality.

Outcome of Study - The research provides a useful basis for further study of environmental quality by combining socio-economic characteristics with the physical characteristics. Presently, it helps in better understanding of the relationship between residential density and neighbourhood environmental quality and envisages expediting the realization of the long term and holistic process of achieving urban environmental sustainability.

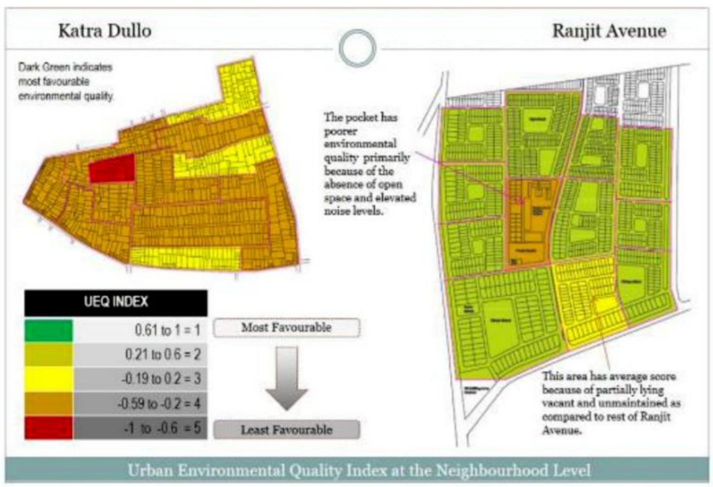

Fig 2: Study Neighbourhoods of Amritsar Classified according to the Level of Environmental Quality (Source: Authors, 2015)

Keywords

Patterns of Urbanization, Residential Density, Neighbourhood Environmental Quality, Multi-criteria Approach, Environmental Quality Index

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Density and Neighbourhood Environmental Quality – A Comparative Study in the Context of Indian Cities

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ABSTRACT

The study attempts to understand the relationship between density and neighbourhood environmental quality. A multiple case research design (Yin, 1994) is adopted by identifying different residential patterns in three case study cities. Amritsar, Chandigarh and Gurgaon are selected as the case study cities. The chosen cities are typical in nature and it is expected that through intensive analysis generalizations can be made that are applicable to other rapidly urbanizing Class I cities in the Indian context. There are important differences between the older habitations in the historic city of Amritsar with newer settlements of the city, post-independence planned interventions in Chandigarh and modern residential areas in the millennium city of Gurgaon. The assessment of Neighbourhood Environmental Quality and formulation of the Environmental Quality Index help in classifying different neighbourhoods according to the level of environmental quality. The study also helps in identifying significant relationships between different density variables and neighbourhood environmental quality. The future work envisages re-examining density measures of different residential patterns for environmentally conducive development in our existing and future cities.

Ms. Swati Dutta is an architect and urban planner from India born in Chandigarh in 1979. She has done Bachelors in Architecture (B.Arch) from Chandigarh College of Architecture (CCA), Panjab University, Chandigarh and Master of City Planning (MCP) from Department of Architecture and Planning, IIT Kharagpur, West Bengal. She has been the recipient of many awards throughout her academic career. Some of her achievements being:

1. Institute Silver Medal for First Position, Master of City Planning from IIT Kharagpur
2. Certificate of Merit for Best Thesis at Post Graduate Level by ITPI, New Delhi
3. Award for Best Thesis at Post Graduate Level by West Bengal Regional Chapter of ITPI, India
4. University Medal for Standing First in B.Arch Final Exam (May 2002)
5. Government Gold Medal for the year 2001 – 2002
6. Le Corbusier Gold medal for the Best All – Rounder of the 1997 – 2002 Batch

Ms. Swati has been working in the field of academics in various institutions since 2004 and has been felicitated for her teaching skills. She is presently working as an Associate Professor in School of Architecture and Design, Manipal University Jaipur. She has attended many National and International conferences and workshops and has authored many technical papers in the field of Architecture and Planning. She has also contributed in organizing special lectures and workshops. Her areas of interest include – Architectural Design Pedagogy, Environmental Planning and Sustainable Urban Design Strategies. She is a registered Architect with the Council of Architecture-India.

She is married to Dr. Siddhartha Koduru and is blessed with a daughter, Sukanya.