ENVIRONMENTALLY SUSTAINABLE IMPERATIVES FOR URBAN SETTLEMENTS IN INDIA

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by

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CERTIFICATE FROM THE SUPERVISORS

This is to certify that thesis entitled **'Environmentally Sustainable Imperatives for Urban Settlements in India'** submitted by Shri. Shuvojit Sarkar who got his name registered on 24/01/2008 for the award of Ph.D. (Engg.) degree of Jadavpur University is absolutely based upon his own work under the Supervision of Prof. Tapas Kumar Bhattacharyya and Dr. (Prof.) Shovan Kumar Saha and that neither his thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.

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CREATED BY AN ACT OF PARLIAMENT)

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PREFACE

Urban centers are constantly growing as universal phenomena and increasingly gaining attention of development planners.

A review of the IISD Compendium (2007) reveals that none of the Indian cities even featured in it.

This very fact inspired me to sudy the possibilities of formulating a set of indicators addressing the need for environmentally sustainable settlements in India.

The environmental performance index used as a tool will enable planners, politicians, national agencies, international organizations to assess the current ‘environmental’ status, to identify areas of weakness and strength, comparing one settlement with other and introducing suitable measures after an evaluation of the situation, possibility of introduction of reward or incentive system to different city administrators and managers.

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ABBREVIATIONS

ADB	Asian Development Bank
BMC	Brihanmumbai Municipal Corporation
BOD	Biochemical Oxygen Demand
CDI	Composite Domain Index
CDP	City Development Plan
CGWB	Central Ground Water Board
CIV	Comparative Indicator Values
CNEMC	Creating National Environmental Model Cities
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
CPCB	Central pollution control board
CPHEEO	Central Public Health and Environmental Engineering Organization
CPWD	Central Public Work Department
CSD	Compendium of Sustainable Development
CSO	Central Statistical Organization
DCB	Delhi Cantonment Board
DDA	Delhi Development Authority
DEAT	Department of Environment and Spatial Planning
DG	Diesel Generator
DJB	Delhi Jal Board
DO	Dissolved Oxygen

DPSIR	Driving Force-Pressure-State-Impact-Response
DSD	Division for Sustainable Development
DSR	Driving Force State and Response
DUAC	Delhi Urban Arts Commission
DUSIB	Delhi Urban Shelter Improvement Board
EEA	European Environment Agency
EPI	Environmental Performance Index
ESI	Environmental Sustainability Index
EU	European Union
EUMM	Environmental Indicators Human Settlement
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GIS	Geographical Information System
GoI	Government of India
GSDP	Gross State Domestic Product
HDI	Human Development Index
IISD	International Institute of Sustainable Development
IT	Information Technology
ITES	Information Technology Enabled Services
JPOI	Johannesburg Plan of Implementation
LPG	Liquefied Petroleum Gas
MCD	Municipal Corporation of Delhi
MCGM	Municipal Corporation of Greater Mumbai

MDGs	Millennium Development Goals
MoE	Ministry of Environment
MoEF	Ministry of Environment & Forest
MLD	Million Liters Per Day
MPD	Master Plan Of Delhi
MPN	Most Probable Number
MSW	Municipal Solid Waste
NAAQMP	National Ambient Air Quality Monitoring Program
NAAQS	National Ambient Air Quality Standards
NCR	National Capital Region
NCT	National Capital Territory
NCTD	National Capital Territory of Delhi
NDMC	New Delhi Municipal Corporation
NEPA	National Environmental Protection Agency
NGOs	Non-Government Organisations
NSSO	National Samples Survey Organisation
OECD	Organisation for Economic Co-operation and Development
PSR	Pressure-State-Response
R.C.C	Reinforced Cement Concrete
RSPM	Respirable Suspended Particulate Matter
SDI	Sustainable Development Indicators
SEPA	State Environmental Protection Administration
SGNP	Sanjay Gandhi National Park

SPM	Suspended Particulate Matter
TPD	Tons Per Day
UDPFI	Urban Development Plans Formulation And Implementation
UECIQES	Urban Environment Comprehensive Improvement Quantitative Examination System
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCHS	United Nations Commission on Human Settlements
UNCSD	United Nations Commission for Sustainable Development
UN-DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNFPA	United Nation Fund for Population Activities
UN - HABITAT	United Nations HABITAT
UNSD	United Nations Statistics Division
WCED	World Commission on Environment and Development
WCSD	World Council for Sustainable Development
WEF	World Economic Forum
WHO	World Health Organisation
WSSD	World Summit on Sustainable Development
YAP	Yamuna Action Plan

NOTATIONS

NH_4	Ammonium
CH_4	Methane
PM_{10}	Particulate Matter 10 micron
$PM_{2.5}$	Particulate Matter 2.5 micron
SO_2	Sulphur dioxide
NO_X	Nitrogen Oxide
CO	Carbon monoxide
O_3	Ozone
NO_2	Nitrogen dioxide

NOMENCLATURE

µg/m^3	Nanogram per cubic meter
mg/l	Miligram per litre
ml.	Mililitre
sq.km.	Square kilometer
m	Meter
mld	Million litre per day
sq.m.	Square meter
m^2	Square meter
sq.mi.	Square mile
lpcd	Litres per Capita per Day

Map No.1

N
INDIA
AFGHANISTAN
JAMMU & KASHMIR
Srinagar
Jammu
CHINA
HIMACHAL PRADESH
Amritsar
Jalandhar
Shimla
Ludhiana
Chandigarh
PUNJAB
Patiala
UTTARAKHAND
PAKISTAN
Ganganagar
Hardwar
Karnal
Sirsa
HARYANA
Muzaffarnagar
Sonipat
Meerut
Moradabad
NEW DELHI
Ghaziabad
Bareilly
Bikaner
Gurgaon
Faridabad
NEPAL
Aligarh
Shahjahanpur
Sikar
Alwar
Mathura
Bahraich
Bharatpur
Farrukhabad
RAJASTHAN
Jaipur
Agra
Etawah
Lucknow
Gorakhpur
Ajmer
Kanpur
Rae Bareli
Jodhpur
Gwalior
UTTAR PRADESH
Mau
Pali
Jhansi
Allahabad
Varanasi
Bhilwara
Kota
Mirzapur
Udaipur
Satna
Rewa
SIKKIM
Gangtok
Siliguri
BHUTAN
ARUNACHAL PRADESH
Itanagar
ASSAM
Guwahati
NAGALAND
Kohima
Darbhanga
Chapra
Purnia
Raiganj
Patna
BIHAR
Bhagalpur
Gaya
MEGHALAYA
Shillong
Imphal
Ingraj Bazar
BANGLADESH
MANIPUR
Baharampur
JHARKHAND
Dhanbad
Asansol
Durgapur
Agartala
TRIPURA
Aizawl
MIZORAM
Ranchi
WEST BENGAL
Barddhaman
Kolkata
Jamshedpur
Kharagpur
Haldia
MYANMAR
Murwara
Jabalpur
Bhopal
Ujjain
Dewas
Indore
MADHYA PRADESH
Ratlam
Gandhinagar
GUJARAT
Ahmedabad
Jamnagar
Rajkot
Vadodara
Sagar
Bilaspur
Korba
Raurkela
ODISHA
Bhavnagar
Khandwa
Junagadh
Burhanpur
Surat
Jalgaon
Nagpur
Raipur
Dhule
Daman & Diu
Bhilai
DADRA & NAGAR HAVELI
Akola
Amravati
Cuttack
Malegaon
Bhubaneswar
MAHARASHTRA
Chandrapur
Jalna
CHHATTISGARH
Brahmapur
Ahmednagar
Mumbai
Nanded
Pune
Nizamabad
Karimnagar
Latur
Warangal
Bidar
Vizianagaram
Solapur
Visakhapatnam
Hyderabad
Arabian Sea
Bay of Bengal
Sangli
Kalaburagi
TELANGANA
Rajahmundry
Kakinada
Kolhapur
Vijayapura
Vijayawada
Eluru
Raichur
Guntur
Belagavi
Machilipatnam
Kurnool
Panaji
GOA
Hospete
Bellary
ANDHRA PRADESH
Anantapur
Nellore
KARNATAKA
Shivamogga
Tirupati
Tumkuru
Chennai
Mangaluru
Bengaluru
Vellore
Mysuru
Puducherry
Puducherry
Salem
Kozhikode
TAMIL NADU
Tiruchirappalli
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Port Blair
International Boundary
State Boundary
Rivers
Country Capital
Major Cities
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INDIAN OCEAN
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CHAPTER 1
INTRODUCTION

1.1 EMERGING SCENARIO

The 21st Century is the ‘Century of the City’ with more than half of the world population now living in cities of different sizes and within the next two decades, nearly 60 percent of the world’s population will reside in urban areas and it is in the developing countries that this growth will take place most rapidly. Cities are the creators of a nation’s wealth, employment opportunities, enhance social development, host infrastructural facilities and symbolise the dreams, hopes and aspirations of societies. However they are also the breeding grounds for slums, poverty, inequality and environmental degradation (UN-HABITAT, 2008). Today, urban areas account for 50 percent of all waste, generate 60-80 percent of all greenhouse gas emissions and consume 75 percent of natural resources, yet occupy only 3 percent of the Earth's surface (UNEP, 2012).

With the rapid pace of urbanisation worldwide, urban sustainability has become a very pertinent issue today. The decision makers are well aware of the contradictions and dilemmas associated with urban development and the resulting resource consumption, environmental damages, and its consequences. The course adopted in urban development over the next few decades will play a crucial role in the trajectory of fundamental health and wellbeing of the human species and other forms of life on this earth.

The need of the hour is environmentally sustainable urban development for the protection of the natural environment and liveable pollution free built environment. There is a pressing need that the city planners and policy makers focus on to what extent the urbanisation could be permitted, so that either the impact on the environment stays within sustainable limits or there is a possibility of replenishing resources and recovering from impact on environment within a reasonable time frame.

1.1.1 Urbanisation in the World Scenario

The world urban population is expected to increase by 72 per cent by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050. By mid of this century the world urban population will likely be the same size as the world's total population was in 2002. Urban growth rates are highest in the developing world and it is responsible for 95 percent of the world's urban population growth. The urban population of the developed world is expected to remain largely unchanged rising slightly from over 900 million in 2011 to 1100 million in 2050, whereas the urban population of the developing world is projected to increase from 2700 million in 2011 to roughly around 5300 million by 2050; where Asia alone will accommodate 63 percent of the world's urban population (UN-DESA, 2011; UN-HABITAT, 2008).

The world urban population grew at an average rate of 2.6 percent per year between 1950-2011and is expected to grow at an average annual rate of 1.7 percent during 2011-2030. Then it is expected to decline at a rate 1.1 per cent per year during 2030-2050. However, the sustained increase of the urban population combined with the pronounced reduction in the rural population growth will result in continued urbanisation. Globally, the level of urbanisation is expected to increase from 52 per cent in 2011 to 67 percent in 2050. The level of urbanisation is expected to increase from 78 per cent to 86 per cent in the developed world and from 47 per cent to 64 per cent in the developing or less developed world over the same period. (UN- DESA, 2011).

The world urban population is not distributed evenly among cities of different sizes. While three in every five people living in urban areas reside in cities smaller than one million inhabitants in 2011, this proportion is expected to decline in the future. By 2025, only one person out of two will live in cities of this size. In contrast, cities of one million and more inhabitants, accounting for about 40 per cent of the world urban population in 2011, are expected to account for 47 per cent of the world urban population by 2025. Indeed, the future urban population will increasingly be concentrated in large cities of one million or more inhabitants. In fact, among the million plus cities, the megacities of at least ten million inhabitants will experience the largest percentage increase. This increasing urban concentration in very large cities is a new trend, which contradicts previous observations (UN-DESA, 2011).

The tremendous growth in urban population, in developing countries particularly, is a consequence of both demographic changes, i.e., the declining mortality rates (have not been matched by a corresponding decline in fertility) and substantial continued migration from rural to urban areas.

World over; big cities tend to attract a lot of migrants in search of employment and better living conditions. With the progress of time, the big cities get crowded with people and city infrastructure is often not able to support the population. Increased stress on infrastructure often leads to unhygienic living conditions, water shortage, inefficient waste collection and disposal, shortage of power supply, traffic congestion and environmental pollution. Inadequate systems and inefficient facilities lead to urban and environmental problems causing deterioration in the quality of urban environment and thereby affecting the quality of life.

1.1.2 Urbanisation in India

India is the second most populous country in the world after China and together they constitute 37 per cent of the world's population. In India, as per census 2011, out of the total population of 1210.2 million about 377.1 million are residing in urban areas accounting for 31.16 percent of the total population. The net addition of population in urban areas over the last decade is 91.0 million that accounts for around 31.8 per cent increase from the urban population at 286 million in 2001.

As per the population projections by Registrar General, Census of India, 2001, the population of India is expected to increase from 1029 million to 1400 million during the period 2001-2026, an increase of 36 percent in twenty five years at the rate of 1.2 percent annually. The urban population is expected to increase to 38 percent by 2026 from 28 percent in 2001.The urban growth would account for over two-thirds (around 67 percent) of total population increase by 2026. Out of total population increase of

371 million during 2001-2026 in the country, the share of increase in urban population is expected to 249 million.

Census of India has classified the urban areas as Class-I to Class-VI towns on the basis of population. As per Census 2011, India has 7935 urban centres comprising of 4041 Statutory Towns and 3894 Census Towns. There is a net increase of 2774 towns over a decade from 5161 towns in 2001. Out of 7935 urban centres in 2011, 475 qualify as Class-I towns or cities having at least one hundred thousand population each and accommodates in total 264.9 million persons accounting for around 70 percent of the total urban population. The corresponding number in Census 2001 was 384 class I towns or cities. Out of 475 cities in 2011, 53 cities qualify as million plus cities having a population of one million or above each. These 53 million plus cities are the major urban centres in the country accommodating 160.7 million persons accounting for 42.6 percent of the total urban population. The number of million-plus cities is expected to increase significantly in the next decade. The trend of urbanization in India over the period 1981-2011 is given in the table below:

Table1.1 Trend of Urbanisation in India (1981-2011)

	Total Population (million)	Total Urban Population (million)	No. of Million Plus Cities	Urban Population in Million Plus Cities (million)	Percentage of Population in Million Plus Cities to Total Urban Population
1981	683.3	161.5	12	42	26
1991	846.3	218.75	23	70	32
2001	1028.6	286	35	108	37.8
2011	1210.2	377.1	53	160.7	42.6

Source: Census Data, 1981-2011

As evident from the above table, the Indian urbanisation scenario in recent decades is characterised by two significant features. First, there has been a massive growth in the absolute number of people living in urban areas. During 1981-2011, there is an increase of around 133.4 percent in the country's urban population from 161.5 million in 1981 to 377.1 million in 2011.

Secondly, there has been an increasing concentration of urban population in the Class I towns or 'cities' with one million or more population. During 1981-2011, there is an increase of around 282.6 percent in the urban population living in million plus cities from 42 million in 1981 to 160.7 million in 2011. The concentration of urban population in million plus cities increased from around one fourth of the total urban population in 1981 to more than two-third of the total urban population in 2011. Also it has been noted that the distribution of population in India is highly skewed since the four megacities accommodate about a quarter of total urban population, thus creating a situation, which is reasonably complex, and pose sustainable planning problems. Thus though the urbanisation rate has reduced from 46.1 percent during 1971-81 to 31.3 percent during 1991-2001, there is fast pace of urbanisation in absolute terms and a continued concentration of urban population in million plus cities and existing city agglomerations (Planning Commission, Government of India).

Large cities are the engines of national economic growth and development. The pattern of population concentration in large cities reflects the spatial polarisation of employment opportunities. This skewed spatial distribution of population has led to deterioration in the quality of natural environment, built environment, infrastructure and hence the overall quality of life in urban areas.

1.1.3 Environmental Concerns & Global Initiatives

Cities of a million or more population were uncomprehendable before 1800 when London achieved this level of population. With new technological advances such as the motorcar, the railroad, elevators, modern plumbing and electric lights, people moved away from the countryside/rural areas to urban environment. With over bulging population, non-existent or inadequate infrastructure, deforestation of the countryside, the late nineteenth and early twentieth century megacities experienced enormous problems related to public health, services, sanitation, air and water pollution at an ever increasing magnitude. The major planning themes that emerged at that time with the deterioration of urban conditions were the balance between city and nature, need of equitable society and economic growth compatible with limited resources of our planet. Various debates around these three concerns - environment, equity and economy, frequently referred to as the "three e's" of sustainable development have thus been gestating for a century or more. The term "sustainable development" apparently was used first time in the 1972 book 'Limits to Growth' which focused on the issue whether growing human population and resource consumption were sustainable (Sustainable Urban Development Reader, 2004).

UN General Assembly convened a conference on the "human environment" at Stockholm in June 1972, which came out with guiding principles on "human environment". It emphasised that man has the fundamental right to environment of quality and also that he has a responsibility towards protecting the environment for present and future generations. It also maintained that natural resources of the earth must be safeguarded for the benefit of present and future generations (UN Stockholm Conference, 1972).

About a decade later, to address the issues concerning continuing depletion of natural resources and unsustainable development, the World Commission on Environment and Development was created in 1983, popularly known as '*Brundtland Commission*'. The global focus on the notion of the sustainability got a major impetus after the Brundtland Commission's report, 'Our Common Future' in 1987. The Brundtland Commission defined 'Sustainability' as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". This definition is perhaps the simplest and most acceptable one as it addresses the inter-generation and intra-generation equity (WCED, 1987).

After twenty years of Stockholm Declaration, the United Nations Conference on Environment and Development was held at Rio de Janeiro, Brazil in 1992 (also known as '*Earth Summit*'), which was convened to address urgent problems of environmental protection and socio-economic development and was attended by governments of 178 countries. *'Agenda 21'*, Programme of action, adopted at the Conference promised to reduce poverty, provide clean water and health care, protect the natural resources and emphasised on development of sustainability indicators by the participant countries for environmentally sustainable decision making (UNCED,1992).

Subsequently, the second conference of United Nations on Cities- *'Habitat II'* with the key theme of "Sustainable Human Settlements in an Urbanizing World" was held in 1996 in Istanbul, Turkey, two decades later of the first international UN conference- Habitat I was held in 1976 in Vancouver, Canada to address the urbanisation issues. The outcome of the summit, the 'Habitat Agenda', a global call for action at levels, offers within a framework of goals and principles and commitments, a positive vision of sustainable human settlements where all have adequate shelter, a healthy and safe environment, basic services and productive and freely chosen employment (UN Habitat, 1996).

The World Summit on Sustainable Development at Johannesburg in 2002– also known as the 'Earth Summit 2002' – further focused the world's attention on environmental problems and importance of sustainability and direct action of Governments of various participating Nations towards meeting difficult challenges, including improving people's lives and conserving natural resources in a world that is growing in population, with ever-increasing demands for food, water, shelter, sanitation, energy, health services and economic security. Commitment to effective implementation of 'Agenda 21' and improving governance at all levels were also the key issues of the discussion (WSSD, 2002).

Thus all the major world conferences and global initiatives taken so far on environment and development have stressed on sustainable development that recognises the interdependence of environmental, social and economic systems and stresses on achieving a balance between the development of the urban areas and protection of the environment along with fulfilment of basic human needs for clean air and water, food, shelter, education, safety and satisfying employment opportunities.

1.2 THE NEED OF SUSTAINABLE IMPERATIVES

With rapid expansion of urban population around the world there has arisen a wide awareness and concern about minimising the environmental costs of urbanisation. Population growth and environmental degradation are engaged in a complex, multi-factor relationship, where one serves to exacerbate the adverse impacts of the other (UNEP, 1995). The concentration of population in particular areas can have a particularly damaging effect on environment once critical pollution thresholds are exceeded. Unless properly planned and managed, this alarming growth is increasingly resulting in urban sprawl, mounting stress on infrastructure, creation of slums, a widening rich-poor divide, deteriorating quality of urban services, depletion of non-renewable resources and increased environmental pollution and energy use. Developing countries, including India, have become more aware of their role and contribution in environmental improvement due to various international conferences and global initiatives addressing the challenges of urbanisation and environmental degradation.

Although India is one of the less urbanised countries of the world with only 31.16 per cent of the population living in urban agglomerations/towns (Census, 2011), the country is at present under a lot of developmental pressure and accompanying environmental crisis. Though urbanisation has been an instrument of economic and social progress, it has led to serious environmental and socio-economic problems. The sheer magnitude of the urban population, haphazard and unplanned growth of urban areas, and a desperate lack of infrastructure are the main causes of such a situation. Most of the million plus cities in India are characterised by high density of population, shortage of housing, mushrooming of squatter settlements, water scarcity, inadequate sewerage and drainage facilities especially in slums, improper solid waste management, lack of open green spaces, inefficient public transport and infrastructure, shortage of power and poor quality of life.

As per Census 2011, in urban India 32.1 percent of total urban households are having only one room for accommodation and 17.36 percent of total urban population is living in slums and another 0.25 percent of total urban population is homeless and live as pavement dwellers. 62 percent of the total urban households have potable water supply service, 81.4 percent of total urban households have access to proper toilet facilities within premises and only 32.7 percent of the total urban households have proper sewage facilities. Though 92.67 percent of total urban households have electricity connection, only 0.4 percent of the total urban households use solar energy and biogas, the renewable sources of energy (Census 2011). This further reinforces the point that problems related to air and water environmental pollution, public health, traffic congestion, poverty, slums and crime are assuming distressing magnitude and hence requires immediate attention and action.

Sustainable city planning in India, a geographically vast, culturally diverse and second most populated country in the world presents an encompassing challenge. A good, practical and much-needed starting point in the direction of attaining urban environmental sustainability is improving the delivery of basic urban services like supply of clean drinking water, sanitation; management of municipal solid waste, efficient transport system, adequate supply of power and energy along with minimisation of pollution levels to improve the quality of lives of the people. The cities should be able to produce and distribute the services in an economic, environment friendly and equitable way. Most basic indicators and the values from which they flow are common to all human beings - everyone wants better health, livelihood security, safe communities, reasonable level of educational attainment, clean air and water, etc. Hence, the fundamentals transcend circumstance and culture.

Ensuring environmental sustainability is one of the eight international Millennium Development Goals (MDGs) that were established following the Millennium Summit of the United Nations in 2000. At the global level the various initiatives associated with urban environmental planning have taken a formal shape in last few decades. However in the developing countries especially India these efforts have helped mostly in raising awareness about the future urban development challenges and environmental crisis. India has been a regular participant in various international environmental conferences and is committed to follow many global commitments towards solving the urban development and environmental issues. Though the tackling of these issues on the local ground requires a different perspective as the urbanisation and environmental problems are different in scale and focus in the developing countries.

So the major question that arises is how to incorporate urban environmental sustainability concept in the physical planning of urban settlements in India. The physical planning of cities and towns in India is dominated by ‘Master Plan Approach’, which is focused on land use and often ignores many important socio-economic and environmental aspects (Devas, 1993). There is inadequacy of research relating to the spatial planning of the cities and towns in India as the first few Five Year Plans after independence focused on country level macro-economic planning and development (Kundu, 2001). Moreover, in India after independence planning has been dominated by top-down approach. However, an effective plan or policy should be an outcome of dynamic interaction of ground reality, expert’s opinion and people’s perception. In reality, both the top-down approach and bottom-up approach are important for effective planning at macro level and implementation at micro level (Banerjee et al., 1982; Richardson, 1982; Mathur 1984).

The city planners and policy makers need a set of tools to arrive at a sequence of logical actions which could help them in making judicious resource allocation and informed decisions for continual improvement of human settlements.

The ‘Agenda 21’adopted at Earth Summit in 1992 recognized the importance of development of sustainability indicators by countries to make informed decisions at all levels concerning sustainable urban development.

1.2.1 Development of Sustainability Indicators

In the post-industrial era, industrialised nations interpreted development in terms of material wealth and hence Gross Domestic Product and per capita income are popularly used as development indicators.

In the early 90s, concept of human development was introduced by the United Nations through ‘Human Development Index’ (UNCHS 2001). Today, there are additional social indicators which are included to measure human development apart from the usual measures of development. In some of the instances countries or cities are ranked on the basis of Liveability index, Environmental Quality Index, Quality of Life Index, Financial wellbeing index etc. City Development Index (CDI) introduced by the United Nations is one of the most popular policy based indicator system for cities and settlements (UNCHS, 2001).

A lot of efforts have been made in the past two decades around the world not only by developed countries and international bodies but by many developing countries like Brazil, Mexico, Malaysia and Colombia that have also initiated efforts in developing sustainable development indicators to achieve the goal of sustainability across one or all of its various dimensions (social, economic & environmental).

However, most of these studies have primarily focused on country level data with just a few major indicators. As a result micro level or settlement level variations and details are not captured, measured and interpreted in an adequate manner.

In the Indian scenario, none of the Indian cities figures in the IISD Compendium, the most comprehensive database to date to keep track of Indicators efforts all over the world (IISD, 2007). Irrespective of the various initiatives at global level, it is a matter of deep concern that none of the Indian cities, regions, or India as a whole has so far registered a similar initiative to tackle the urban environmental sustainability.

Thus to incorporate urban environmental sustainability concept in the physical planning of urban settlements in India there is a dire need to develop a set of simple and effective sustainable development indicators at various levels. Apart from broader indicator sets at national / city level, there is also a need of developing comprehensive micro-level urban ecosystem sustainability assessment indicators to overcome the hindrance of data availability and to ensure community participation, education and awareness. The indicators at the micro level could be qualitative in nature but the initiative at micro level as stated earlier increases the probability of better community participation thereby increasing the chances of awareness in the community as the cause and effect are easily comprehendible. This ensures better accountability of the service provider, more responsive governance and better delivery of public goods and services, better maintained community assets, and a more informed and involved citizenry that is capable of undertaking self-initiated development activity (Mansuri and Rao 2003). Sustainable development should be defined by people themselves, to represent an ongoing process of self-realisation and empowerment. The community is supposed to be brought into focus through participation. Without the community becoming both the architects and engineers of the concept, sustainability of the settlement may not be achieved since the community is unlikely to take responsibility for something they think that they do not own themselves. (Redclift 1992).

The careful framing, monitoring and interpreting of the indicators would help the urban areas to assess the present state of the sustainability, highlight critical aspect of the socio-economic-environmental status of the system and to devise future action plans or policies to ensure inter-generation and intra-generation equity.

1.3 THE RESEARCH GROUND

1.3.1 Hypothesis

Environmental sustainability of an urban settlement in India requires fulfilment of basic needs of its inhabitants through judicious use of natural resources and minimisation of waste outputs so as not to exceed ecological carrying and renewal capacity of the ecosystems. It entails regular monitoring to generate exhaustive baseline data and effective enforcement of controls and measures, along with awareness and education of the community; to improve the accountability and delivery of services for sustainability of the settlements.

1.3.2 Research Objectives

- To develop a set of indicators and indices to assess the current state of complex and dynamic urban environment of settlements of different scales.
- To demonstrate the use of the indices for measuring environment performance and sustainability of the urban settlements at both macro (city) and micro (local area) level.
- To find the inter-relations and impacts of the selected indicators on each other.
- To provide a tool to the planners and policy makers for an objective assessment of the current status, keeping a track of the changes in the state of the environment and benchmarking of the environmental performance of the settlements for

enabling them to take an informed decision before preparation of any proposal for future development.

1.3.3 Research Questions

The above mentioned areas could be addressed through a set of following research questions:

1. What is an indicator? What are the various major sustainability indicator initiatives at the global level and in India?
2. How to develop a framework to choose a set of domains and indicators and to further develop indices (both quantitative and qualitative) to assess the current state of the environment of an urban settlement?
3. How to apply the indices (both quantitative and qualitative) and measure the environmental performance of a settlement both at city (macro) and neighbourhood (micro) level through their overall benchmarking (ranking)?

1.3.4 Scope of Work

The concept of sustainable development and its interpretations could make the scope of research work very vast, because it brings together various disciplines- sociology, economics, public health, environment, development and planning.

The study focuses primarily on urban environmental sustainability and issues of economic and social sustainability have been carefully selected and touched upon. Since the three pillars of sustainability cannot be compartmentalised and considered in isolation, in the physical environment there are areas where social and economic factors exert an environmental effect hence they may be considered suitably wherever necessary and considered under the domain of environment, infrastructure, energy and the remaining ones considered under the domains of population and finance.

1.3.5 Limitations of Work

Measuring the environmental performance of urban settlements poses many challenges. It includes the process of identification and collection of data which is valid, reliable and comprehensive. At times the data is not readily available or it is not in a ready to use format. Also there exists a multiplicity in available data from various sources which makes the activity of identifying and collecting it a tedious task. The collection and organisation of information in a way that is valid, efficient, comparable across cities to address the sustainability issues are the major challenges.

As for few parameters the latest data is not available for the selected case study cities for same base year, the data from the period 2001 to 2011 has been used to present the larger picture of the past decade. Planning norms and national standards have been used as benchmark wherever available. At the micro level because of the non-availability of detailed and reliable data on many parameters, data collection has been done by the author primarily through field surveys, people's feedback and information from various local offices and community based organisations.

1.3.6 Methodology

The study investigates if the present pattern of urban development in India in the creation of major urban centres or metropolitan cities is sustainable from the environmental perspective. The research study is focussed on developing domain wise Environmental Performance Index (EPI) for the urban settlements in India at macro or city level which can be Environmental Performance Index Macro (EPI Macro) and at the micro level or neighbourhood level which can be Environmental Performance Index Micro(EPI Micro), based on natural and built resource dynamics.

Hence, based on natural, built and human resource dynamics, the domains chosen are air, water, land, energy, housing, infrastructure, population and finance. The indicators represent a primary tool to provide guidance for policy makers and to potentially assist them in decision-making and monitoring local strategies and action plans. The outcome of the study will contribute to the design of approaches, tools, and policies essential for planning in order to attain the goal of environmentally sustainable development of the urban settlements.

METHODOLOGY CHART

BACKGROUND STUDY

Urbanisation in the World, Urbanisation in India,
Environmental Concerns & Global Initiatives, Need of Sustainable Imperatives

RESEARCH GROUND

Formulation of Hypothesis, Research Questions, Scope of Work,
Limitation of Work

RESEARCH OBJECTIVES

- To develop a set of indicators & indices to assess the current state of environment of urban settlements.
- To demonstrate the use of the indices for measuring environment performance of the urban settlements at both macro (city) and micro (local area) level.
- To provide a tool to the planners and policy makers for an assessment of the current status, keeping a track of the changes in the state of the environment and benchmarking of the environmental performance of the settlements to take an informed decision before preparation of any proposal for future development.
- To involve the community in monitoring and thereby improving the state of the environment of their neighbourhood/colony/locality, raise awareness by sharing the results, improve the accountability of the stakeholders and ensure efficient delivery from the service providers.

LITERATURE REVIEW

- Sustainability Approach, Concepts of developing human settlements incorporating methods of sustainable development,
- Environmental concerns and sustainability initiatives by Indian Organisations
- Environmental legislation in India: History and present
- Indicators of Sustainable Development, Various SDI initiatives in the World & India, Different Frameworks for development of SDIs, Lessons from various global initiatives and way forward in India.

FRAMEWORK FOR SELECTION OF SUSTAINABILITY INDICATORS AND DEVELOPING AN ENVIRONMENTAL PERFORMANCE INDEX FOR URBAN SETTLEMENTS IN INDIA

- Conceptual Approach, Selection of the Structural Framework
- Identifications of Domains, Formulation of Indicators,
- Recommended Set of Urban Environmental Sustainability Indicators at Macro level and Micro level,
- Development of Environmental Performance Index: EPI-Macro, EPI-Micro
- Correlation Analysis

APPLICATION OF ENVIRONMENTAL PERFORMANCE INDEX- FINALISATION OF CASE STUDIES

MACRO LEVEL

- Mumbai
- Delhi
- Kolkata
- Chennai
- Bangalore
- Hyderabad
- Ahmedabad
- Pune

MICRO LEVEL

- Settlements in Delhi (South)
- A Planned Colony
- An Urban Village
- A Cluster of Slums

DATA COLLECTION

Present Environmental Profile of the Selected Settlements under the resource based domains (Natural, Built and Human Resource)

Air, Water, Land, Energy, Housing, Infrastructure, Population, Finance

- Macro Level- Secondary Sources- Census of India, Statistical Handbooks, Development Plans, CPCB Reports, Municipalities etc.
- Micro level- Primary & Secondary Sources- Field Surveys, Stakeholders Survey, Local Offices, Master Plans, Zonal plans, Electoral List etc.

DATA ANALYSIS

EPI-Macro

- Conversion of all indicator values into positive indicator values
- Data normalisation using mean (average) equal to zero and standard deviation equal to one to eliminate the impact of different ‘size’ of values of indicators.
- Assigning of Weights to various Indicators and Domains by expert opinion
- Calculation of Domain wise Environmental Performance Index (EPI)
- Calculation of EPI Macro for each city
- Ranking of the Cities based on EPI-Macro score

EPI-Micro

- Assigning a Score, a ‘Comparative Indicator Value’ (CIV) to each indicator through Likert Scale, to ascribe a quantitative value to a qualitative data, in statistical analysis to make it amenable.
- Assigning of Weights to various Indicators and Domains by expert opinion
- Calculation of Domain wise Environmental Performance Index (EPI) by averaging the CIV values computed for each of the indicators in the domain and multiplying it with the weightages given by experts
- Calculation of EPI Micro for each settlement
- Ranking of the Settlements based on EPI-Micro score.

CORRELATION ANALYSIS

- Correlation analysis was carried out for 32 indicators for 8 cities.
- Coefficient of correlation was computed for different pairs of indicators and a correlation matrix was prepared to study the related indicators and their relationship.

CONCLUSIONS & RECOMMENDATIONS

- Generic and Specific Concerns
- Generic Conclusions and Findings
- Macro level Findings and Way ahead
- Micro level Findings
- A framework for Action agenda and Policy guidelines
- Action Agenda
- Final word

CHAPTER 2

SUSTAINABILITY APPROACH AND INDICATORS FOR MEASUREMENT OF SUSTAINABILITY OF AN URBAN SETTLEMENT

2.1 ENVIRONMENT AND URBAN DEVELOPMENT: SUSTAINABILITY APPROACH

‘Designing with Nature’ or ‘Sustainable Design’ are not entirely new concepts. In the history of settlements, the approaches which were suggested from time to time had inherent sensitivity and consideration for sustainability and ecology. However, some of the approaches were too theoretical and far away from the reality and expectedly they were termed ‘utopian’.

Ebenezer Howard, Tony Garnier, Frank Lloyd Wright and Le Corbusier also had radical ideas for improving city life. But all of them, in their own way, gave special importance to the nature (Spreiregen, 1965).

Jane Jacobs, in the 1960s, criticised utopians and argued against segregation and uniformity and supported variety and diversity to enable cities to retain natural and organic vitality.

Mumford was, one amongst the first, to ask ecological questions about cities and their sustainability. His article “The Natural History of Urbanisation” (1965) is on the ecology of urbanisation. He noted the dependencies of cities on their hinterlands and the steady extension of their influences aided by the growing power of transportation technology. He pointed out that in the cities everywhere, increasingly, natural is being substituted by artificial leading to loss of connection with the Earth within a city (Mumford, 1961 and 1965; Rowe, 2000).

The history of settlement planning reveals that the planning of cities and towns over the world has been influenced by various concepts relating to physical, social and economic aspects. The fundamental principles behind some of these aspects are closely linked to sensitivity towards environment. However, the present day practice and approach to development do not give explicit importance to natural resource conservation and environment. In past few decades, in India and in the developing countries, ‘economic development’ has dominated the process of planning. Development with industrial growth has brought new challenges to urban life. Environmental pollution and depletion of natural resources has affected the cities and the towns.

A large variety of concepts have emerged as a result of an urge to improve urban environmental conditions in urban settings. The following section discusses the various concepts of developing human settlements incorporating methods of sustainable development focusing on judicious use and consumption of natural resources:

- **Sustainable Development-** The global focus on the notion of the sustainability got a major impetus after the Brundtland Commission’s report, ‘Our Common Future’ in 1987. The Brundtland Commission defined ‘Sustainability’ as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*”. This definition is perhaps the simplest and most acceptable one as it addresses the inter-generation and intra-generation equity (WCED, 1987).

  The Rio Earth Summit, in 1992 brought this idea more to the forefront. Today there are more than seventy definitions of sustainable development in circulation. A definition proposed by the World Conservation Union (IUCN) highlights the constraints of the biosphere. The IUCN defines sustainable development as “improving the quality of human life while living within the carrying capacity of supporting ecosystem”. (IUCN: UNEP: WWF, 1991)

  Some notable contributions were made by Mitlin and Satterthwaite (1996), Pugh (1996) and Baron and Tsourou (2000) by extending the concept to include ‘social sustainability’, ‘economic sustainability’, ‘community sustainability’ and even ‘cultural sustainability’.

- **Quality of Life-** It is a concept that encompasses a huge agenda ranging from the state of environment, personal growth, health, economic rewards, satisfaction in life, to psychological well being. It is about the quality of our society as a whole and not only about quality of an individual life. (Cahill,2002)
- **Environmental Space-** It is a set of resource consumption indicators- first proposed by Jaohan Opschoor and then developed by 'Friends of Earth' (Mc Laren, 2001). While showing current status these indicators are also linked to a sustainable benchmark value for each indicator. In other words, it is one of the few indicator based approaches which not only documents the amount of ecological capacity used by people, but also the amount that could be used in the sustainable world (Chambers et. Al,2000).
- **Ecological Footprint-** William Rees developed this concept to evaluate the impact of a city on its surrounding area. This is based on the old concept of the 'carrying capacity' of an ecological region- the maximum rate of resource consumption and waste discharge that can be sustained over an indefinite period without impairing the integrity of the system itself. In the calculation of 'Ecological Footprints' Wachernagel and Rees (1996) suggested resource consumption pattern for sustaining a settlement, which led to a popular belief that bigger the city bigger the footprint (Rees, 1992; Wachernagel and Rees, 1996).

  The 'footprint' intentionally says nothing about people's quality of life (Chambers et.al, 2000). Clearly the cities reach beyond their immediate area and draw upon the resources of a wide and variable set of hinterlands, thus setting up situations of regional deficit and surplus as resources (and waste) are shifted between regions. This concept was criticised for being too simplistic in its calculations (Pacione, 2001).

The following section discusses some of the approaches that are being considered as alternative ways of shaping the cities considering the environmental dimension:

- **Ecopolis-** Girardet (2004) has used it as a generic term for sustainable cities of the future. Ecopolis or ecological cities are ecologically sound cities in their structure and operations. They work with natural processes; do minimal harm to the environment and uses resources efficiently. According to Rowe (2000), it is difficult to identify any city as ecological city today. Paul Downton of Urban Ecology, Australia has stated "An ecological city is a as much about balance between humans and society as it is about balance between humans and nature" (Downton, 1997).

- **Green Cities-** The principles of Green City are influenced by philosophies of Howard's Garden City and Geddes's belief that urban planning should be based on knowledge of natural regions and their resources. The approach of designing with nature was developed subsequently by Ian McHarg, who advocated detailed examination of the environmental condition of an area prior to urban development in order to identify those areas where urbanisation would least damage natural ecosystems. (Geddes, 1949; Howard, 1967; McHarg 1969, Pacione, 2001).

- **Sustainable Neighbourhood and Sustainable Cities-** The concept of 'neighbourhood' (conceived by Clarence Perry and applied for New York Plan in 1920) is closely connected to social and environmental sustainability. The size and physical expanse of neighbourhood depend on certain principles related to community. 'Sustainable' refers to the ability of the neighbourhood and wider urban systems to be sustained and to minimise their environmental impact. 'Urban' refers both to the location of the area and to its physical character whilst neighbourhood relates to the social and economic sustainability of the area, the community ties which holds it together and its relationship to surrounding areas. Rudlin and Falk (1999) stress incorporation of reduced inputs from energy consuming systems, use of local resources, minimisation of waste, making use of urban economics, etc.

  The concept of 'sustainable cities' is also discussed by a number of thinkers, ecologist and environmentalists under various names like 'Green Cities', 'Eco cities', 'Sustainable Cities' etc. but the fundamental principle which binds all of them together is designing with nature and designing in environmentally responsive way.

2.2 ENVIRONMENTAL CONCERNS AND SUSTAINABILITY INITIATIVES

The realisation of the issue of phenomenal urbanisation and associated environmental degradation in the past few decades at the global level has led to participation of various countries in the initiatives for protection of environment and conservation of natural resources. It has led to numerous actions in the form of creation of action groups, commitments and guidelines for future development etc.

The urban environmental issues and resource consumption patterns are different in the countries of the developed and the developing world. It is thus also recognised that the issues pertaining to the developed and the developing countries need different and specific approach. In the developing countries, including India, the situation is more complex, as issues of poverty eradication, women and child health, unemployment and population control tend to get higher priority as compared to environmental issues.

A number of programmes and projects are initiated by different agencies to tackle the issues depending on the countries (regions) and their priorities. At the global level United Nations has initiated various programmes about environment, public health and cities. United Nations agencies like UNCRD, UNCHS, UNDP, etc. are focusing on conducting research studies and preparing programmes on urban development. At regional level various organisations and groups like EU, ESCAPE, OECD etc. are conducting studies and initiating proposals to tackle the urban environmental problems.

To implement such initiatives and projects, especially in the developing countries, funding agencies like World Bank and Asian Development Bank are contributing towards the projects and building infrastructure.

2.2.1 Indian Organisations and Their Actions

The Government of India is well aware of global concerns and is committed to meet international standards .It has taken several steps in various Five year plans to handle the problem arising out of urban and environmental issues. In India, over the last few decades, environmental laws have been enacted and concerted efforts are being made through several conservation and protection projects being implemented by various Government Departments. The action on urban environmental issues can be broadly divided into three groups- the first dealing with natural resources and environment, the second dealing with human and built environment and the third dealing with impact of built on the natural environment.

Several development programmes are initiated by GoI which are centrally funded and supported by State Governments. Some non-government organisations that are contributing to implementation of the programmes.

There are several projects and programmes for protection of natural resources i.e. forest, wild life, water bodies, hill areas etc. There are programmes which deal with urban problems of pollution and solid waste management. A few programmes also include study of impact of human activities and actions on settlements and environment.

Pollution of water bodies is a major issue arising out of development and establishment of industrial estates in various underdeveloped and developed regions in India. One of the most discussed and talked about initiative to curb pollution of the rivers was the 'Ganga Action Plan' (GAP) initiated in 1980s by GoI in response to damage to water resources due to domestic sewage and industrial effluent being disposed off in the rivers. Other than pollution of water bodies, scarcity of water, over exploitation of underground water resources, its contamination, scarcity of potable water etc. are becoming prominent issues in India.

In India, Ministry of Environment and Forest (MoEF) is supporting a number of projects, research initiatives etc. on general as well as specific environmental issues. Town and Country Planning (TCPO), Housing and Urban Development Corporation (HUDCO), Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) are supporting several such initiatives, Non-Government Organisations (NGOs) are contributing in awareness building programmes. Organisations like Environmental Planning Coordination Organisation (EPCO) whose primary focus is on activities related to environmental planning and development are also active in this regard. Environmental Information System (ENVIS) centres are also functioning in different regions of India (website-CPCB-ENVIS)

The programmes for improvement of living environment in the cities are undertaken primarily for areas with poor living conditions and slums by addressing issues of basic services- water supply, solid waste management and urban sanitation. In the tenth Five year Plan, initiatives under the title of 'Eco-City' were started in selected cities.

Another initiative worth mentioning is the Sustainable Land and Ecosystem Management (SLEM) Programme is a joint initiative of the Government of India and the Global Environmental Facility (GEF) under the latter's Country Partnership Programme (CPP).The objective of the SLEM programmatic approach is to promote sustainable land management and use of biodiversity as well as to maintain the capacity of ecosystems to deliver goods and services while taking into account climate change. One of the recent initiatives of the GoI is the Smart Cities Mission which is a bold new initiative. It is meant to improve infrastructure and ensure sustainable environment through good governance and citizen participation while addressing safety, health, education and security of citizens, particularly women, children and the elderly.

2.2.2 Environmental Legislations in India

The concept of environmental protection is an age old idea imbibed in the Indian cultural ethos since time immemorial. 'Paryavaranam' is a Sanskrit word for environment that was prevalent in ancient India. Indian Ethos since Vedic period till the modern era depicts Indian's awareness about importance of environmental protection and conservation of natural resources. To understand the present day legislations for environment protection and conservation of natural resources, it is important to look into the past Indian traditions and practices of protecting the environment.

2.2.2.1 Law and Policy Relating to Environmental Protection in Ancient India

Environmental awareness can be said to have existed even in the Pre-Vedic Indian valley Civilizations which flourished in northern India about 5,000 years ago. This is evident from the archaeological evidences gathered from Harappa and Mohenjo-Daro which were the prominent cities of the civilisation. Their awareness about hygiene and sanitation is evident from their constructions of ventilated houses, orderly streets, numerous wells, bath rooms, public baths, covered underground drains and sewerage treatment mechanisms.

2.2.2.2 Vedic Approach to Environment

The idea of environmental protection and conservation of natural resources can be traced to Vedic Civilization where worship of nature appears to have originated and the Vedic views revolve around the concept of nature and life. The ancient Vedic literature encompasses a holistic attitude of the cosmic vision in a poetic way. Veda appears to impose obligations on the society and individuals to worship nature through worshipping trees. The worshipping of Vanaspati, tree having thousand branches is akin to worshipping the entire creation. Atharva Veda examines the importance of forest conservation and preservation and protecting of three particular trees namely, “Parijath, banyan and peepal”. Ancient Indian seers and scholars advocated wise use of water even though India is blessed with perennial rivers and heavy rainfall. Several Vedic hymns are prayers maintaining balance in the functioning of all aspects of nature and it is argued that some of those ideas expressed in them resemble modern principles relating to conservation of resources. Ancient Indians believed that ecological balance is dependent on actions, good or bad, of individuals and society. Accordingly Rigveda says: “Environment provides bliss to people leading their life perfectly. River blesses us with the sacred water, and plants provide us health, morning sun blesses us with peaceful life. Our cows provide us sweet milk”. The Vedic culture emphasised conservation of trees. It was also insisted that every village must have a small jungle where trees are grown and protected, and this obligation can be compared to modern concept of social forestry.

2.2.2.3 Buddhism and Environmental Protection

It has been argued that while many human centric western religions, Buddhism is eco-centric. Gautam Buddha admired trees stating that trees provide shade and shelter to the humans and animals. He preached in Vanaropa Sutra in Sanyukta Nikaya that gardening and afforestation are acts which increase doers' merit every day. Environment and natural resources are considered as things not inherited from the past generation but things borrowed from the future generations. If we destroy natural resources base or pollute environment, future generation will find it difficult to survive. Environmental pollution has reached such an alarming rate that world is increasingly becoming unsuitable for human habitation. Buddhism is one of the religions which has greatly emphasised to think of future generations. In Kariya metts Sutra, Buddha while insisting on compassionate to all living beings said "whatever breathing creatures here may be no matter whether they are frail or firm, or middle sized or be they short or small or whether they are dwelling far or near existing or yet seeking to exist may beings all be of a blissful heart". Buddhism while specifying certain virtues of rulers insists that an ideal king is expected to protect not only the people but also forests, animals and birds. Buddhist king Asoka's 5th Pillar Edict prohibits killing of certain species of animals and birds. Firstly, birds and animals such as *Cakravaka* (geese), swans, *nandi mukhas* (duck), pigeons, bats, ants shall not be killed. Secondly, fishing was prohibited on certain days in a month. Thirdly, on certain days cattle and horses are not to be branded. Buddhism further taught the need for environmental education and therefore it is asserted that foundations for modern environmental protection were firmly laid in Buddhism.

2.2.2.4 Jainism and Respect for Nature

Reverence for all forms of life is deeply ingrained in the Jain Ethos. It is strongly asserted that every living being wants to live. Sorrow and killing are not liked by any living being. All beings have the right to live. Non-violence is for the welfare of all beings. Lord Mahavira has said "To kill or to hurt any living being amounts to killing or hurting oneself. Compassion of others is compassion to one's own self." Man should live in harmony with all beings and nature. Hence, the relevance of Jain concept of nonviolence which can bring in adaptability in modern life style and makes it more relevant in today's world.

2.2.2.5 Mauryan Administration and Resource conservation

The regulation of human activities in the interest of protecting environment and conserving natural resources were developed during Mauryan period. Several offices were created for enforcement of norms relating to environmental protection. Firstly, *Suvarnadhyaksha* was responsible for exploring minerals, mining, processing, producing trading and conserving resources. He was primarily required to set up factories for processing gold and not to allow unauthorized persons to produce gold and other metals. Secondly, *Kuppyadhyaksha* was required to procure forest product and convert them into useful products. *Seetadhyksha* was involved in collecting seeds of all kinds, flowers, fruits, vegetable, roots and other products. He was in charge of regulating agriculture. For Mauryas most important forest animal resource was elephants and Kautilya unambiguously specifies the responsibilities of officials in respect of protecting and preserving Elephant forests. Kautilya in Arthashatra laid down certain norms relating to conservation of forests. Firstly, state to maintain forests and said "Rulers shall not only protect forest produce, elephant forest but also set up new ones. Forests shall be grown, one for each forest produce and factories for goods made from forest produce shall be erected, and foresters working in the produce forests shall be settled there". Secondly, selling, certain trees and plants without approval of authorities was made punishable and penalties were levied for cutting branches, destroying trunks and uprooting trees. Thirdly, the Superintendent of forests shall fix adequate fines and compensations to be levied on those who cause any damage to productive forests except in calamities. Fourthly, for the purpose of protection of wild life the Superintendent of slaughter house was empowered to punish those persons killing certain types of wild animals, deer, lions, birds, or fish which are declared to be under state protection. It can be said that seeds of certain modern wild life conservation originated during Mauryans administration. Lastly, the Superintendent of slaughter house was empowered to levy fee for hunting those wild animals not prohibited from hunting.

2.2.2.6 Evolution of Environmental Law and Policies during British rule

The overexploitation of natural resources and plundering of nature started in India during early British rule. The abundant natural resources such as forest products and minerals became a chief source of raw material for industries. During the days of East

India Company rule ruthless exploitation of timber from Indian forests and trade in natural resources transferred natural wealth to Britain and Indians were pushed to misery and poverty. For the purpose of legitimising ruthless exploitation of timber forests and natural wealth Britishers introduced forest policy to prohibit private exploitation of forest resources and public regulations authorising the government to exploit forest resources. Thus forest department was setup during British rule in provinces and in some princely states. The first show of interest towards the conservation of forest resource found the reservation of teak forests in Malabar in 1806, and it was dictated by strategic imperial needs. This was the result of depletion of the Oak Forest in England and other western countries and the increasing demand for timber for ship building industry and increasing demand from railways. Devoid of good forests in Britain, Britishers realised the commercial value of Indian forests and tried to establish a rigid system of control over them. One can trace the beginning of the systematic forest policy to 1855, where the Governor General, Lord Dalhousie, issued a memorandum on forest conservation called the 'Charter of Indian Forests'. He suggested that teak timber should be retained as state property and its trade strictly regulated. The first step towards the organised forest management was taken in 1864 with the appointment of First Inspector General of Forests. The Forest Policy statement of 1894 classified forests into four categories. They are (i) forests, preservation of which was essential on climate and physical grounds, (ii) Forests, which supplied valuable timber for commercial purposes, (iii) minor forest which produced only inferior sorts of timber and (iv) pastures which were forest only for namesake. The policy was opposed by many on the ground of lack of recognition of rights of forest dwellers; it allowed unchecked exploitation by the Government and diversion of forest land to agriculture and plantation and no provision for wild life protection and private forests. During British rule forest management laws and several other legislations were enacted for the purpose of environmental protection and conservation of natural resources.

2.2.2.7 Development of Law and Policy in India (Post- Independence)

Environmental Protection and improvement were explicitly incorporated into the Constitution by the Constitution (Forty Second Amendment) Act of 1976. Article 48A was added to the directive principles of state policy. It declares: 'The State shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country.' Article 51A (g) in a new chapter entitled 'Fundamental Duties' imposes a similar responsibility on every citizen 'to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures…' Although the language in the two articles differs, the difference appears to relate to form rather than to substance. Together, the provisions highlight the national consensus on the importance of environmental protection and improvement and lay the foundation for jurisprudence of environmental protection.

A review of environmental protection laws by Suresh et al. (1992) mentions that till the year 1974 'environmental pollution' as a subject matter of legislation did not find a place in the Indian law books. Prior to this year, only recourse available to a citizen against pollution of any kind was through Indian Penal Code. The Indian Penal Code, passed in 1860, penalises persons responsible for causing defilement of water of a public spring or reservoir with imprisonment or fines.

The watershed event in the environmental movement was the Stockholm Conference on Human Environment in June 1972. The conference made it apparent to all attendees that each nation needed to adopt comprehensive legislation addressing health and safety issues for people, flora and fauna. The United Nations, organisers of the conference, requested each participant to provide a country report. Stockholm, thus, served as the genesis for the series of environmental measures India passed in the years to come.

Water Act was enacted in 1974 to provide for the prevention and control of water pollution and for water maintenance in the country. The Water Cess Act was enacted in 1977, to provide for the levy and collection of a cess on water consumed by persons operating and carrying on certain types of industrial activities. Forest Conservation Act was enacted in 1980 to protect and conserve country's forest. Air Act was introduced in 1981 to provide for prevention and control of air pollution in India.

In India environmental problems and hazards are being viewed very seriously after the 'Bhopal Gas Tragedy' which took place in December 1984. Any presence of hazardous industries in urban neighbourhood can cause unmitigated damage to the generations to come was experienced in this tragic event.

Environment Protection Act (1986) which came into existence in India after 14 years of UN conference was the first comprehensive legislation with regard to environmental pollution. It evoked encouraging response and support from all environmental groups. It was widely acclaimed as the first Act to address the problem of pollution. But the Act itself was a major disappointment as it was neither comprehensive enough in its scope nor sufficient powers were provided to effectively bring the offenders to the book and control environmental problems.

The Man and Biosphere (MAB) programme of UNESCO was launched in 1971; India joined it in 1988 after formation of bio-reserve committee. Purpose of this is to develop a base for rational use or conservation of natural resources while improving the relationship between the man and environment.

In 1989 Hazardous Waste Rules were framed in which hazardous chemicals list was finalised.

The outbreak of plague, in Surat, Gujarat (1994) was another major landmark incident which brought the role of municipal bodies under scrutiny and highlighted the importance of public health, cleanliness and safe disposal of urban waste. The Municipal Solid Waste (Management & Handling) Rules, 2000 (MSW Rules) were implemented which made every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solids. In the past decade, Surat is always quoted as one of the best examples of municipal management; ironically this has happened subsequently after the plague.

In the Noise Pollution Rules (2000) the state government categorised industrial, commercial and residential or silence zones to implement noise standards. The Biodiversity Act (2002) was born out of India's attempt to realise the objectives mentioned in the United Nations Convention on Biological Diversity (CBD) enacted in 1992 states that country should use their own biological resources.

The issues of development along the sea coast, Coastal Regulations and Coastal Regulatory Zones (CRZ) were in attention after a Tsunami hit the Indian coast in December 2005 causing severe damage to the coastal areas and urban floods of Mumbai in 2006.

National Green Tribunal Act, 2010 in an Act of the Parliament of India which enables creation of a special tribunal to handle the expeditious disposal of the cases pertaining to environmental issues. It draws inspiration from the India's constitutional provision of Article 21, which assures the citizens of India the right to a healthy environment. During the Rio de Janeiro summit of 'United Nations Conference on Environment and Development' in June 1992, India vowed the participating states to provide judicial and administrative remedies for the victims of the pollutants and other environmental damage. This is the first body of its kind that is required by its parent statute to apply the "polluter pays" principle and the principle of sustainable development. This court can rightly be called 'special' because India is the third country following Australia and New Zealand to have such a system.

The National Green Tribunal, a specialized body established under the National Green Tribunal Act 2010, is equipped with the necessary expertise to handle environmental disputes involving multi-disciplinary issues. Tribunal is competent to hear cases for several acts such as Forest (Conservation) Act, Biological Diversity Act, Environment (Protection) Act, Water & Air (Prevention & Control of Pollution) Acts etc. and also have appellate jurisdiction related to above acts after establishment of Tribunal within a period of 30 days of award or order received by aggrieved party. The Tribunal is not bound by the procedure laid down under the Code of Civil Procedure, 1908, but shall be guided by principles of natural justice. The Tribunal's dedicated jurisdiction in environmental matters shall provide speedy environmental justice and help reduce the burden of litigation in the higher courts. The Tribunal is mandated to make an endeavour for disposal of applications or appeals finally within 6 months of filing of the same. Initially, the NGT is proposed to be set up at five places of sittings and will follow circuit procedure for making itself more accessible. New Delhi is the Principal Place of Sitting of the Tribunal and Bhopal, Pune, Kolkata and Chennai are the other four place of sitting of the Tribunal.

In one of its most notable orders, on 25th April 2014, the NGT recommended the Government to declare a 52 km stretch of the Yamuna in Delhi and Uttar Pradesh as a conservation zone and opposed the recreational facilities as it affects the health of the River.

Enforcement of environmental legislations from time to time, has led to a rethinking on the present approach to city planning and importance of eco-sensitive planning and design has gained more importance.

2.3 INDICATORS OF SUSTAINABLE DEVELOPMENT

The work carried out by international agencies in the last few decades tells that urbanisation and environmental concerns could be addressed by translating global commitments through appropriate planning to local level actions. In order to incorporate urban environmental sustainability concept in the physical planning of urban settlements, the city planners and policy makers need a set of tools to arrive at a sequence of logical actions which could help them in making judicious resource allocation and informed decisions for continual improvement of human settlements. Also, an effective plan or policy should be an outcome of dynamic interaction of ground reality, expert's opinion and people's perception.

The 'Agenda 21'adopted at Earth Summit in 1992 recognised the importance of development of sustainability indicators to make informed decisions concerning sustainable urban development. A global call was made for harmonisation of efforts by the countries, as well as international, governmental and non-governmental organisations to develop indicators of sustainable development that can provide a support for decision-making at all levels (UNCED, 1992).

Global concern of rapid urbanisation and environmental degradation has led to a lot of initiatives in the past two decades around the world by various international organisations and countries of both the developed world and the developing world in developing sustainability indicators at various scales to achieve the goal of sustainable urban development.

2.3.1 What is an Indicator?

In Arabic the word ‘indicator’ means pointer which describes how an indicator is intended to point towards some desirable state or course of action. Each indicator is usually a kind of small model in its own right, implying elements of cause and effect, of social norms that constitute progress and of policy actions and outcomes (ADB, 2001).

The United Nations defines indicators as not datasets, rather models which simplify a complex subject to a few numbers that are easy to understand and to grasp by the policy makers. Indicators can translate physical and social science knowledge into manageable units of information that can facilitate the decision-making process (UNCSD, 1996; UNCHS, 1997).

OECD (2003) outlines two major functions of indicators. Firstly, they reduce the number of measurements and parameters, which normally would be required to give an exact presentation of a situation. Secondly, they simplify the communication process.

Also, an indicator not necessarily has to be statistical or quantitative, it could be of qualitative nature too (Dhakal, 2002). In case of urban resource dynamics, sustainable development indicators guide the resource allocation and use pattern. Indicator development is an ever-evolving process. No set of indicators can be final or definitive. Indicators are adjusted over time to fit the specific conditions, priorities and capabilities (UNCSD, 1996).

Thus indicators are like early warning systems, which when carefully designed, closely monitored and judiciously interpreted, not only show the critical aspect of the socio-economic-environmental status of the settlement but also influence the planning and policy decisions, monitor their effectiveness and facilitate community action (DEAT, 2001)

2.4 SUSTAINABLE DEVELOPMENT INDICATORS INITIATIVES

The various sustainable indicator initiatives are not limited to only macro scale at global, country or city level but there are efforts too at local or neighbourhood level. Few of the initiatives encompass all the three social-economic & environmental dimensions of sustainability, whereas few focus only on any one of its dimension.

Many major cities like Kitakyushu (Japan), London (UK), Seattle (US) and countries of the developed world like Canada, South Africa, New Zealand, Argentina and Australia have developed their own set of sustainable development indicators on the basis of their priorities and goals, which help these urban areas to assess the present state of the sustainability, highlight critical issues and to devise future action plans or policies to ensure inter-generation and intra-generation equity. A comprehensive designing of the indicators require inputs and dynamic interaction between citizens, technical experts and government agencies.

Many developing countries like Brazil, Mexico, Malaysia, and Colombia have also initiated development of sustainable development indicators at various levels and are making efforts to be at par with the developed world.

Sustainable development indicators initiatives are not limited to local bodies, cities or countries. Sustainable development indicators have also been developed by different international bodies like the United Nations (UN), European Union (EU), African Union, OECD, World Bank (WB) and Asian Development Bank (ADB). International Institute of Sustainable Development (IISD) has developed a Compendium of Sustainable Development (CSD) Indicator Initiatives that contains links to various such indicator initiatives. A review of the IISD Compendium, the most comprehensive database to date to keep track of Indicators efforts shows 836 entries worldwide out of which are 250 metropolitan initiatives and 193 local or community-level initiatives

(IISD, 2007). However, none of the Indian cities figures in the list which deserves an attention from all concerned.

The following section reviews few major existing sustainable development indicator initiatives at global and regional (Asia) level in terms of their conceptual framework, salient approach, methodology, output in form of policy response or action plans to recommend an approach for measurement of urban sustainability in India at various levels. Care has been taken to select and review the initiatives which are varied in their structural framework, coverage of aspect of sustainability and area of study and implementation.

2.4.1 International Efforts on Sustainability Indicators

The major international efforts on the development of sustainable development indicators which are widely accepted have been appraised here in order to give an insight into the trends and future needs.

The international initiatives examined here are:

- **United Nations Commission for Sustainable Development (UNCSD) Indicators**
- **The Organisation for Economic Co-operation and Development (OECD) Indicators**
- **United Nations Commission on Human Settlements (UNCHS) Indicators**
- **European Union (EU) Local Sustainability Indicator**
- **The Environmental Indicators Human Settlement, Australia**

2.4.1.1 UNCSD Indicators (1996, 2001, 2006)

The United Nations Conference on Environment and Development held at Rio de Janeiro, Brazil in 1992 recognised the importance of indicators in helping countries make informed decisions concerning sustainable development. Following up this recommendation, the first draft set of indicators of sustainable development was developed in 1995 by the Division for Sustainable Development (DSD) and the Statistics Division, both within the United Nations Department of Economic and

Social Affairs. The result was an initial set of 134 indicators, published in 1996, organised as a driving force, state and response (DSR) framework, a variation of the pressure-state-response framework. The first CSD indicators were also grouped according to the dimensions of sustainable development—social, economic, environmental as well as institutional, and matched to the relevant chapters of Agenda 21.

From 1996 to 1999, 22 countries from across the world voluntarily pilot-tested the indicator set and during 1999 to 2000, the results of the national testing were evaluated, and the indicator set was revised. Most countries found that the initial CSD indicator set was too large to be easily managed. Consequently, the revised set of CSD indicators was reduced to 58 indicators in 2001, organised along the four dimensions of sustainable development and embedded in a more flexible policy oriented framework of themes and sub-themes.

The revision of the CSD indicators in 2001 discontinued the DSR framework mainly because it was not suited to addressing the complex interlinkages among issues; the classification of indictors into driving force, state or response was often ambiguous; there were uncertainties over causal linkages; and it did not adequately highlight the relationship between the indicators and policy issues.

The new revised set of the CSD indicators has been developed in 2006 in response to decisions by the CSD and the World Summit on Sustainable Development in 2002 in Johannesburg, South Africa (Johannesburg Plan of Implementation), which encouraged further work on indicators at the country level in line with national conditions and priorities and invited the international community to support efforts of developing countries in this regard.

Subsequent to the publication of the previous set, knowledge of and experience with sustainable development indicators of countries and organisations has increased significantly, as has the emphasis on measuring progress on achieving sustainable development, including the Millennium Development Goals (MDG), at the national and the international levels. By incorporating these developments, the revision of the

CSD indicators gives vital support to countries in their efforts to develop and implement national indicators for sustainable development.

The newly revised CSD indicators contain a core set of 50 indicators. These core indicators are part of a larger set of 96 indicators of sustainable development. The introduction of a core set helps to keep the indicator set manageable, whereas the larger set allows the inclusion of additional indicators that enable countries to do a more comprehensive and differentiated assessment of sustainable development.

The indicator set retains the thematic/sub-thematic framework that was adopted in 2001. In doing so, it remains consistent with the practice of most countries applying national sustainable development indicator sets and it is directly relevant to the monitoring of national sustainable development strategies. The division of indicators under four 'pillars' of sustainability i.e. social, economic, environmental and institutional is no longer explicit in the newly revised set. This change emphasises the multi-dimensional nature of sustainable development and reflects the importance of integrating its pillars.

The major themes on which CSD indicators are based are the following:

- Poverty
- Governance
- Health
- Education
- Demographics
- Natural Hazards
- Atmosphere
- Land
- Oceans, Seas & Coasts
- Freshwater
- Biodiversity
- Economic development
- Global economic partnership
- Consumption & production patterns

Since almost all CSD indicators directly or indirectly correlate to Agenda 21 and the Johannesburg Plan of Implementation (JPOI), using the CSD indicators as basis for national indicators of sustainable development can assist countries in monitoring national implementation of their international commitments too. In this regard, the CSD indicators are useful for measuring the outcome of policies towards achieving sustainable development goals.

2.4.1.2 OECD Indicators (1993)

The Organisation for Economic Co-operation and Development (OECD) has pioneered the development of international environmental indicators and has long supported the efforts of its member countries in this field. The OECD member countries are 30 developed countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States of America. The Commission of the European Communities takes part in the work of the OECD.

OECD's work in the field of environmental indicators initiated in 1989 when the OECD Council called for further work to integrate environment and economic decision-making. This was echoed in consecutive G-7 summits and led to the approval of an OECD Council Recommendation on Environmental Indicators and Information by OECD Governments in 1991. In 1993, the "OECD Core Set of Indicators for Environmental Performance Reviews" was published.

The OECD work on environmental indicators is designed to:

a) contribute to the harmonisation of individual initiatives of OECD Member countries in the field of environmental indicators by developing a common approach and conceptual framework- the pressure-state-response (PSR) model
b) assist in further development and use of environmental indicators in OECD Member countries;
c) promote the exchange of related experience with non-members and other international organisations; and
d) support the OECD's policy analysis and evaluation work by developing core sets of reliable, measurable and policy-relevant environmental indicators to measure environmental progress and performance, monitor policy integration, and allow effective international comparisons;

The OECD work focuses mainly on indicators to be used in national, international and global decision making with a top-down approach, yet it may also be used to develop indicators at sub-national or ecosystem level adapting it to national or micro level circumstances. The actual measurement of indicators at these levels is encouraged and lies within the responsibility of individual countries.

The OECD development of environmental indicators uses a pragmatic approach, recognising that there is no universal set of indicators; rather, several sets exist, serving several purposes and stakeholders. Also OECD development of environmental indicators is a dynamic process, where none of the OECD indicator sets is necessarily final or exhaustive in character; they are regularly refined and may change as scientific knowledge, policy concerns and data availability progress.

Those indicators for which internationally comparable data exist are regularly published and used in OECD work, particularly in environmental performance reviews. They are a way to monitor the integration of economic and environmental decision making, to analyse environmental policies and to gauge the results.
OECD work on environmental indicators includes several categories of indicators, each corresponding to a specific purpose and framework:

a) **Core Environmental Indicators -** A core set of about 50 indicators, classified following the PSR model and covering issues that reflect the main environmental concerns in OECD countries. They are designed to help in tracking the environmental progress and performance and analyse environmental policies.
b) **Key Environmental Indicators -** A set of core indicators, selected from the OECD Core Set that serve wider communication purposes. They inform the general public and provide key signals to policy makers.
c) Sectoral Environmental Indicators- A set of indicators focussing on a specific sector such as transport, energy, household consumption, tourism, agriculture etc,; classified following an adjusted PSR model reflecting sectoral trends of environmental significance. They are designed to help integrate environmental concerns into sectoral policies.

d) **Indicators derived from Environmental Accounting-** They are designed to help integrate environmental concerns into economic and resource management policies. Focus is on: environmental expenditure accounts; physical natural resource accounts, related to sustainable management of natural resources; and physical material flow accounts, related to the efficiency and productivity of material resource use.

e) Decoupling Environmental Indicators- They are derived from other indicator sets and measure the decoupling of environmental pressure from economic growth. In conjunction with other indicators used in OECD country reviews, they are valuable tools for monitoring progress towards sustainable development.

OECD Indicator's Themes based on Environmental Issues are:

- Climate change
- Ozone layer depletion
- Eutrophication
- Acidification
- Toxic contamination
- Urban environmental quality
- Biodiversity
- Cultural landscapes
- Waste
- Water resources
- Forest resources
- Socio-economic, sectoral & general indicators
- Soil degradation (desertification, erosion)
- Material resources
- Fish resources

Results of OECD work, and in particular its conceptual framework- The *Pressure-State-Response Model* based on a concept of 'causality', have in turn influenced similar activities by a number of countries and international organisations. Continued cooperation is taking place in particular with: the United Nations Statistics Division (UNSD), the UN Commission for Sustainable Development (UNCSD) and UN regional offices; the United Nations Environment programme (UNEP); the World Bank, the European Union (Commission of the European Communities, Eurostat, the European Environment Agency-EEA) and with a number of international institutes. Such co-operation is essential to achieve synergies, to help identifying commonalities and to clarify the specific purposes of the various initiatives. Cooperation and exchange of experience is also taking place with various non OECD countries.

2.4.1.3 UNCHS Indicators (1996)

The first international UN conference, *Habitat I*, to comprehensively address the urbanisation issues was held in 1976 in Vancouver, Canada.

UN-HABITAT has been one of the leading organisations in the formulation of indicators for urban development. The '*Housing Indicators Programme',* a joint Habitat and World Bank initiative was introduced in 1988 to monitor various shelter performances and it collected housing indicators in major cities across 53 countries during the period 1991-1992. This ultimately became Urban Indicators Programme in 1993 focusing on a larger range of urban issues and helped countries in formulating, collecting and applying indicators data.

The second conference of United Nations on cities (*Habitat II*) with the key theme of "Sustainable Human Settlements in an Urbanizing World" was held in 1996 in Istanbul, Turkey to do an assessment of the progress in the past two decades and to set further goals. The outcome of the summit, *the Habitat Agenda,* was espoused by 171 countries and put forth over 100 commitments and 600 recommending guidelines. It was decided in the conference that UN Habitat will continue monitoring the urban conditions over the world and the Member States of Habitat Agenda will keep updating about the trends by reporting their urban conditions from time to time.

The Urban Indicators Programme helped in establishing key trends in urban issues by creating Global Urban Indicators Database I in 1996 and Global Urban Indicators Database II in 2001, which were presented in Habitat II summit and the Istanbul +5. The Global Urban Indicators Database produced in 2003 and updated annually addresses the Habitat Agenda key issues, with a specific focus on the MDG , particularly, its Target 7D on the improvement of slum dwellers.

The Major theme of the Habitat Agenda Indicators is based on the following Goals as targets:

- Shelter
- Environmental Management
- Social Development & Eradication of Poverty
- Economic Development
- Governance
- The Millennium Development Goal-Slum Target

2.4.1.4 EU Local Sustainability Indicator (Ambiente Italia, 2003)

The European Common Indicators initiative is focused on monitoring environmental sustainability at the local level. A set of ten environmental sustainability indicators have been developed based on thematic framework and with bottom up approach.

The European Common Indicators are a ready to use, self-contained set of indicators with methodologies also defined for collection of data that can help a local authority interested in the quality of its urban environment to begin to monitor progress. Towns and cities can adapt or add to the 10 indicators to suit local circumstances. The focus of the initiative is on helping local authorities monitor their own progress.

The Ten European Common Indicators are:

- Citizen satisfaction with the local community
- Quality of local ambient air
- Noise pollution
- Local contribution to global climatic change
- Children's journeys' to and from school
- Products promoting sustainability
- Local mobility and passenger transportation
- Sustainable management of the local authority and local business
- Availability of local public open areas and services
- Sustainable land use

2.4.1.5 The Environmental Indicators Human Settlement, Australia (1998)

The Government of Australia published its first and comprehensive assessment of Australia’s state of the environment through the environmental indicator report in 1996 and a revised one 'The Environmental Indicators for National State of the Environment Reporting, Human Settlement, Australia' in 1998 to meet its international obligations under Agenda 21 and OECD environmental performance reviews. The report suggests indicators, developed by an expert panel supported by a large group of stakeholders, to be used both to measure the impact of urban systems on the environment and to measure their success in providing an adequate environment for their inhabitants.

The Environmental Indicators Human Settlement (1998), Australia is based on systems approach which uses Extended Urban Metabolism Model (EUMM) in state of the environment reporting on human settlements at the national level. EUMM considers the quantity of materials in human settlements from raw input to waste outputs and the transformation of these through the dynamics of urban settlements processes into desirable livability outputs. This model is also normative, having explicit goals of reducing resource inputs, reducing waste outputs and improving livability for future generation. It follows a domain based approach where indicators have been developed under the ten identified domain areas of the human settlements.

The Environmental Indicators Human Settlement, Australia have been identified under the following domain areas:

- Energy
- Water
- Urban Design
- Transport & Accessibility
- Population
- Housing
- Indoor Air
- Environmental Health
- Noise
- Waste

2.4.2 Asian Efforts on Sustainability Indicators

The Asian sustainability indicators initiatives examined here are:

- **Urban Environment Comprehensive Improvement Quantitative Examination System (UECIQES), China**
- **Kitakyushu Initiative, Japan**

2.4.2.1 UECIQES, China

UECIQES is an important target-based framework program for environmental protection in urban areas implemented by SEPA (State Environmental Protection Administration) in China since 1989. The system involves urban environmental planning with a set of scientifically designed indicators with the objective of unifying the social, economic and environmental benefits through quantifiable improvement made in environmental protection, urban infrastructure development and economic progress.

The programme is being supervised by the respective mayors of the cities (around 46 key cities and 560 other cities) and implementation is done by the various sectoral agencies according to their assigned responsibilities taking into consideration the community feedback (Bottom up planning approach). The assessment of environmental performance of the cities through a reward based incentive mechanism to cities and being included in the Government's top priority work outline has generated a sense of accountability at all levels of implementation and supervision for environmental protection.

The series of indicators being currently implemented includes 24 individual indicators grouped under four broad categories: environmental quality, pollution control, environmental infrastructure and environmental management, scoring a total of 100 points.

The seven indicators for ambient environmental quality (scoring 30 points) include the annual average value per day of TSP, SO_2 and NO_x, drinking water, surface water quality, average value of noise and traffic noise.

The six indicators for pollution control (scoring 31 points) include smog control coverage, noise control coverage, industrial wastewater treatment, vehicle emission control, industrial solid waste disposal and reutilisation and hazardous waste disposal.

The six indicators for environmental infrastructure (scoring 20 points) include the municipal waste treatment, central heat supply, gas use proportion, municipal waste disposal, urban green area coverage and nature reserve coverage.

The five indicators for environmental management (scoring 16 points) include environmental institutional capacity, environmental investment, implementation of the rule of simultaneous design, construction and operation of new project and its associated environmental facility, collection of pollutant discharging fees and operation of pollution abatement facilities. The working quality of examination scores the remaining 3 points.

This is a very successful initiative, which has led to the rise of a more integrated approach to urban environmental management. The urban environmental improvement has been set as an important responsibility of the municipal governments of the cities. The environmental monitoring data of the key cities in China shows considerable improvement in the atmospheric environmental quality since 1989.

Another major program of urban improvement - creating national environmental model cities (CNEMC) initiated in 1997 by National Environmental Protection Agency (NEPA is former SEPA) all over the country has also helped in integrating the national strategy of sustainable development into local actions and practices at city level and supports national strategy of sustainable development.

2.4.2.2 Kitakyushu Initiative, Japan

Kitakyushu, located in the Fukuoka Prefecture in Kyushu, Japan is an international, industrial and trade city established in 1963. The city aims to become "an International and Technological City with Waterfront, Green Environment and Human Contact". Their achievement in recovering from environmental damage due to rapid development has been noted internationally.

Kitakyushu has been the host city for the Kitakyushu Initiative started in September 2000. The Kitakyushu Initiative aimed to conduct research on urban environmental sustainability and bring together practices and experiences of Kitakyushu city and other cities in the Asia Pacific region to provide an effective guideline for this region. The second cycle of the Kitakyushu Initiative lasted from 2005 - 2010. As of 2010, 61 cities in 18 countries around the Asia Pacific region participated in the Initiative.

The system adopted for Kitakyushu initiative has its roots in the DPSIR (Driving forces, Pressures, State of the Environment, Impacts, Response) system. Several limitations have been identified from past practices of the DPSIR system. The system does not capture the complexity and dynamics of causes and effects of the problem. The interdependency between isolated chains of indicators cannot be accounted for by the system.

However, their approach added new elements which reflect the vulnerability of human systems to cope with the changes in the environmental systems (Dhakal 2002). It is similar to the Environmental Sustainability Index (ESI) of the World Economic Forum in this aspect, but they have adjusted the model to make it relevant for Kitakyushu and other cities. The system does not isolate causes and effects as in DPSIR; instead, it includes four elements: State of environmental system, Stress of activities on the System, Vulnerability of Socioeconomic Systems and Responses and Capacity to Cope.

Traditionally, top-down approaches have been readily received in Kitakyushu. However, after the emergence of Local Agenda 21, and the grass-root organisations gaining popularity and importance, studies and practices of "bottom-up" approaches are becoming popular.

The distinguishing features of the reviewed sustainable development indicator initiatives are given in the table:

Table 2.1 Summary of Major Sustainable Development Indicator Initiatives

Indicator Initiative	Structural Framework	Key Features	Aspect of Sustainability

UNCSD (1996)	Thematic/ Sub-Thematic framework	- Monitoring & implementation of AGENDA 21 - Integrated the four pillars of sustainability - Top-down approach - *Scope-(International)Country (22 countries comprising developed and developing ones)*	social, economic, environmental and institutional
OECD (1993)	Pressure-State-Response framework	- Several categories of measurable indicators each corresponding to a specific purpose - Top-down approach - *Scope-(International)Country (30 OECD member countries)*	Only environmental
UNCHS (1996)	Policy based framework	- Implementation of HABITAT AGENDA - Specific focus on Millennium Development Goals(improvement of slum dwellers) - Top-down approach - *Scope-(International)City (cities from developed, developing and under developed countries)*	social, economic and environmental
Indicator Initiative	**Structural Framework**	**Key Features**	**Aspect of Sustainability**

EU Common Indicators, Ambiente Italia (2003)	Thematic framework	- Ready to use, self-contained set of indicators with methodologies for collection of data - Bottom-up approach - Scope-(International)City, Local level (cities of member countries under EU)	social, economic and environmental
UECIQES, China (1989)	Target based framework	- Assessment of environmental performance of the cities through a reward based incentive mechanism - Bottom-up approach - Scope-City (cities of Peoples Republic of China)	Only environmental
Kitakyushu, Japan (2000)	Causal Framework (a variation of PSR framework)	- Unlike PSR the framework does not isolate cause and effect relationship - Include the vulnerability of the human systems to cope with changes in the environment - Top-down approach - Scope-City (Kitakyushu, Japan)	Only environmental
Environmental Indicators Human Settlement, Australia (1998)	Systems Framework (Extended Urban Metabolism Model)	- State of the environment reporting on human settlements - Domain based classification of indicators - Goals of reducing resource input and waste output and improving livability - Top-down approach - Scope-Country (Australia)	Only environmental

Source: Compiled by Author from IISD Compendium and respective websites

2.5 EFFORTS ON DEVELOPMENT OF INDICATORS IN INDIA

The nature of Indicator systems being in practice in India were elaborated in detail in a paper by the then Comptroller and Auditor General of India, at the 'OECD World Forum of Key Indicators' held in Palermo, 2004. The paper highlighted that there are various centralised agencies in India such as the 'Central Statistical Organisation (CSO)' and the 'Programme Evaluation Organisation' which collect and analyse information about many parameters which have importance at national level for formulation of planning and development policies.

The 'Census of India', the population surveys since 1881 done on a decadal basis, has been one of the most trusted demographic indicators information source at national level.

The Department of Health and Family Welfare provides information on vital statistics such as mortality rates, data on communicable diseases, various family welfare programmes etc. through an 'Annual Health Information Index'. The various surveys conducted by 'National Samples Survey Organisation (NSSO)' of CSO such as consumption expenditure survey of households, employment survey etc. provide useful data for study on levels of living, analysis of consumer behaviour, incidence of poverty, number of employed people according to the activity status and their demographic and economic characteristics etc. The 'Below Poverty Line surveys' conducted by Department of Rural Development help in poverty alleviation programmes of the Government.

The paper also considered the 'Human Development Report, 2001' a key initiative in formulation of indicators by the Planning Commission of India at national level, wherein an effort was made to evaluate the development process through a set of seventy indicators and three composite indices- a Human Development Index, a Human Poverty Index and a Gender Equality Index. An exhaustive state level data base was made across the seventy indicators using the data of past two decades (1980&1990). The indicators mainly focussed on three aspects of wellbeing, health, education and standard of living. Human Development Index (HDI) combined information on inflation and inequality in per capita consumption expenditure and Human Poverty Index covered information on longevity, educational and economic deprivation. The data presented through 'development radars', gives a snapshot view of the achievements of goals in different aspects of quality of life and the areas of gaps for formulation of State level development policies. However, the Human Development Report was not able to integrate all the aspects of sustainability and did not focus on the environmental issues.

In addition to the above two broad groups of social and economic indicators, the state of Environment Report for India (2009) has been compiled by the Ministry of Environment and Forests (MoEF) which gives an overview of the environmental scenario of the country and assist government agencies in decision making and serves as a useful reference document for NGOs and civil society. The key identified environmental issues are: climate change, food security, water security, energy security and urban management.

However, irrespective of the work by various data collection, information and statistical organisations in India, it is lagging behind in coordinated development of comprehensive urban environmental sustainability indicators at various levels that can provide a solid base to the policy and decision making process especially the spatial planning process.

2.6 SUSTAINABLE DEVELOPMENT INDICATORS FRAMEWORKS

Frameworks are the logical structures over which the indicators are developed. They help clarify and focus what to measure, what to expect from measurement and which derived data to use (IISD, 2005). Without a framework, indicators always remain ad-hoc, biased, incomplete, overly dense in some areas, and sparse or even missing in other important areas (IISD, 1999).

Different indicator initiatives across the globe have developed various framework methods over the time which mainly differ in the way the different aspects of sustainable development are being focussed, the inter-connection between the various aspects, the way they highlight the major issues to be monitored and the criteria for selection of indicators for assessment of the state of sustainability and providing necessary inputs for decision making (IISD, 2005).

The few commonly used frameworks for developing sustainability indicators, as seen as the core distinguishing factor in the major indicator initiatives discussed in the previous section, have been examined here in brief to provide the necessary input in selection of the structural framework for the present research work.

2.6.1 Policy Based Framework

A policy based framework is based on developing a comprehensive inventory of major social goals and devising indicators to measure progress towards these goals. Such indicators originate from a nation or a community concern in a particular area and aim at establishing urban strategies and policies. The UNCHS indicators programme and the subsequent Global Urban Observatory have been developed based on this framework (ADB, 2001)

2.6.2 Theme and Index Driven Framework

A thematic and index driven framework works by establishing broad themes and sub themes such as livability, sustainability, compact city, ecological city or good governance which are not directly observable, but are either multidimensional, involving different aspects which have different indicators, or may be expressed as indices such as Human Development Index, City Development Index or linear combinations of indicators. They do not target at specific policy goals and not necessarily associated with a strategy. Thematic framework has been in development of UNCSD and EU Common Indicators (ADB, 2001)

2.6.3 Causal Framework (Pressure- State-Response Framework)

The Pressure-State-Response framework developed and popularised by OECD (2004) for State of Environment reporting has emerged as the most widely used indicator framework for environmental reporting. The PSR framework represented an advance in environmental indicators development by introducing the concept of cause and effect relationship amongst indicators covering human pressure on the environment, actual state of the environment, and the responses which may be undertaken to alleviate environmental damage (ADB, 2001). For example emission of CO_2 due to human activities is an Environmental pressure indicator, rise in global temperature is a State of Environment indicator and various actions like carbon tax, planting of trees etc. at global, national or local level are Response indicators. One of the advantages of PSR framework is its attention to responses to environmental problems which are often neglected in the area in indicator studies (Australia, 1998).

Driving force-pressure-state-impact-response (DPSIR) framework is an extended version of PSR framework, adopted by the European Environmental Agency (EEA) and the European Statistical Office (Eurostat, 1997). Driving forces are the underline causes of pressure such as demography, urbanisation, lifestyle, economic situation, poverty etc.

There are two major limitations in the underlying foundation on which the PSR framework is based. Firstly, it is difficult to categorise an indicator as a pressure or a state or a response, because the focus of the observer may change depending on the underlying objective. The indicator, which is a pressure in one perspective, may be a state in another and a response in a third (Australia, 1998). For example, housing, which is a pressure indicator for land use, is a state indicator for construction domain and is a response for the homelessness. Similarly, CO_2 emission is a pressure to the environment, CO_2 concentration is a state, global temperature increase attributed to emissions is an impact, whereas carbon tax imposed on the basis of CO_2 emissions is a response.

Secondly, the pressure, state and response/ impact mechanisms are complex and cannot be isolated into single cause and effect. There can be relationships between causes themselves and effects themselves.

The causal framework (DSR model) initially adopted for development of UNCSD indicators was later abandoned realising its above limitations and especially it was found to be inappropriate for economic and social indicators as it lacks focus on policy (UNCSD, 1996).

In order to overcome the above limitations, a modified version of PSR has been used in Environment Sustainability Index (ESI), developed by the World Economic Forum (WEF) where apart from PSR two additional components were added, human vulnerability and global stewardship (WEF, 2005). Kitakyushu initiative is another such example where the modified PSR framework does not isolate cause and effect relationship and include the vulnerability of the human system to cope with changes in the environment (Dhakal, 2002).

2.6.4 Systems Framework- The Extended Urban Metabolism Model

The systems approach differs from the policy based approach in beginning with a simple but explicit physical model or systems diagram of the city or the environmental system, within which the various actors operate and in which linkages and causality between various sectors are delineated (ADB,2001)

The Extended Urban Metabolism Model (EUMM) developed by Newman et al. (1996) for State of the Environment reporting in Australia (Australian Environmental Indicators Human Settlements, 1998) is based on systems approach and explicit the notion of livability and reinforces the normative concept of improved environmental outcomes over time (ADB,2001).

EUMM interpret cities as dynamic urban system (population dynamics, economy, industry, infrastructure, transport, institution, linkages) which require inputs of key resources (Land, Water, Energy, Population, Finance) which are drawn into the urban processes and transform them into desirable livability outputs or Services (Employment, Income, Health, Education, Housing, Accessibility to services, Community life) and waste (Solid waste, Sewage, Air pollutants, Noise). The desirable change for the system is improvement of livability and reduction of waste. EUMM is closely aligned with the paradigm of sustainable development where future orientation, sustainability goals and targets and linkages among different dimensions are made explicit (Australia, 1998; Newton, 2001).

2.6.5 Performance / Target Based Framework

This framework is based on outcome oriented indicators system capable of providing data for establishing and assessing public sector goals and targets in the context of agency management and accountability, strategic planning, economic development program evaluation, customer satisfaction and city competitiveness (ADB, 2001)

In local government, performance measurement indicators have been employed across departments such as police, fire, solid waste , public transport, health and social services to assess areas such as workload, outputs and efficiencies and sometimes across a whole sector such as a single sector indicators report conducted by ADB on the water sector. City governments have also developed performance indicators to assist with assessing the rate of success of major projects, such as urban revitalisation programs (ADB, 2001)

The UECIQES China (1989) is structured on target based framework for assessment of environmental performance of the cities through a reward based incentive mechanism and enhances the sense of responsibility of government authorities at all levels.

2.7 LESSONS LEARNT FROM VARIOUS GLOBAL INITIATIVES

The UNCSD indicators are based on monitoring and implementation of AGENDA 21 and are broad in their coverage, focussing on all the dimensions of sustainability at national level. The revision of the indicators over time from 1996-2006 after testing in various countries focussed on reducing the initial large CSD indicator set to a manageable one through a core set and an additional set of indicators; discontinuing the use of DSR framework to a more flexible policy oriented framework of themes and sub-themes as the DSR framework was not found to be very suitable to address the complex interlinkages among issues and; emphasising the multi-dimensional nature of sustainable development by integrating the four pillars of sustainability (social, economic, environmental and institutional). CSD indicators can provide a good base for formulation of Sustainable Development Indicators at national level in India by modulating according to Indian urban context. By doing so India can monitor national implementation of the various international commitments of AGENDA 21(Earth Summit), JPOI and Millennium Development Goals (MDG).

The OECD indicators focus on environmental issues of sustainability at the national scale and are structured on Pressure-State-Response framework which is based on the concept of 'causality' and has emerged as the most widely used indicator framework for environmental reporting. The forte of this indicator system lies in well-defined set of measurable and policy-relevant environmental indicators, a pragmatic approach that recognises that there is no universal set of indicators; a dynamic process where none of the indicator sets are final or exhaustive and need regular refinement. OECD work on environmental indicators includes several categories of indicators, each corresponding to a specific purpose: track environmental progress and performance, communication with the public and policy makers, integrate environmental concerns into sectoral, economic and resource management policies and together they are valuable tools for monitoring progress towards sustainable development. The OECD work focuses mainly on indicators to be used in national and global decision making, yet it may also be used to develop indicators at sub-national or micro level in India, as it might be possible to get such data at local levels too.

The UNCHS indicators focussed on attaining objectives of Habitat Agenda that initially put greater emphasis on housing and shelter issues of urban settlement and later moved on to the broader issue of sustainable development encompassing all the three dimensions with specific focus on Millennium Development Goals (particularly on improvement of slum dwellers). UNCHS indicators are based on policy based framework and the strength lies in action oriented indicator system. Based on this framework policy based goals and actions could be identified for urban issues in India and quantitative and qualitative indicators can be constructed for the specific action areas

The European Common Indicators are ready to use set of indicators based on thematic framework and bottom up approach which can help local authorities in monitoring their progress in environmental sustainability at the local level. However the urban issues addressed in these indicators are very specific to the cities of the developed world. Hence certain sectors need to be included in the indicator set to address the urban issues at local level in India or the other Asian cities of developing nations.

The UECIQES, China is a very successful initiative structured on target based framework for environmental protection in urban areas at local level. Similar system of assessment of environmental performance of the cities through a reward based incentive mechanism in India can enhance the sense of responsibility of government authorities at all levels for urban environmental protection. However the set of indicators designed will have to pay adequate attention to the public participation and the inputs of the local community at large apart from the inputs of the local authorities.

The Kitakyushu Initiative, Japan is focused on urban environmental sustainability and brings together practices and experiences of Kitakyushu and other cities in the Asia Pacific region to provide an effective guideline for this region. Their achievement lies in recovering from environmental damage due to rapid development. The strength of this initiative lies in using a variation of PSR framework realising its limitations and focus on not isolating causes and effect and adopts the systems approach. Similar approach can be followed in India for formulating urban environmental sustainability indicators at local or micro level.

On a concluding remark, most of the reviewed indicator initiatives address global or national issues and only few such as 'UECIQES programme of China' and 'European Common Indicators' address urban sustainability issues at local level. Also from the various indicator initiatives studied only few of them have an integral approach taking into account environmental, economic and social aspects. In most cases the focus is on one of the three aspects. Few of the indicator initiatives such as UNCSD and UNCHS are agenda based implementation programmes.

Though several agencies and countries across the world have already worked towards formulating indicators of sustainable development at various levels and provide relevant guidance; the final framework needs to address the urban sustainability issues in the Indian context.

2.8 WAY FORWARD FOR INDIA

Each nation or city is unique in its geographic location, cultural and social values, economic condition, national goals and policies and thus a universal set of indicators which can be applied globally may not be a wise idea.

If we take the specific case of India, the design of a complete set of sustainable development indicators involves a great complexity. The first major problem lies in identifying a group of indicators which can be applied throughout the country in varied urban areas irrespective of the diverse socio-economic, regional and environmental issues. The other major issue is the availability of data at the local level.

One of the ways forward in this direction could be to formulate indicators at various levels in India: the core/main indicators based on common global/national issues at the broader level with minimum data and additional or comprehensive indicators based on local issues specific to individuality of the place with short term and long term priorities. Inferences can be drawn from the OEDC indicator initiatives to design a clear and logical set of multi-level indicators.

Secondly as IISD (2000) has pointed, there is a demand for simple and effective indicators without compromising the underlying complexity. Sustainability is more than an aggregation of the important issues, it is also about their interlinkages and the dynamics developed in a system. An indicator should be scientifically, analytically sound and at the same time simple to understand by stakeholders at all levels. It could be qualitative and quantitative in nature depending on availability of data. Another important point is to translate the information from indicators into policies at national level and actions into local level. Participation of grass root level into any of such national indicator making and policy setting process is important and is the very essence of the decentralised democratic governance (Dhakal, 2002).

In order to address the challenge of data availability for indicator system at local level, there is a pressing need for developing an efficient, simple, workable and ready to use indicators set for assessing micro-level urban ecosystem sustainability. The data collection can be done at small neighbourhood or community level and threshold values could be assigned to the collected data to perform a relative sustainability assessment at that level and the results can be aggregated to the local level. Adopting this approach it might be possible to generate sufficient and reliable data bank to make comparison at the local level feasible and provide implementable inputs to the local area environmental and developmental action plans. The collated data at the local level may further be aggregated at the regional /state or national level in a meaningful manner ,wherever possible, and can be used to translate the information in national level planning and development policies. This method would ensure sustainable ecosystems and a bottom-up approach in formulation of national level policies.

CHAPTER 3
A FRAMEWORK FOR SELECTION OF SUSTAINABILITY INDICATORS AND DEVELOPING AN ENVIRONMENTAL PERFORMANCE INDEX FOR URBAN SETTLEMENTS IN INDIA

3.1 CONCEPTUAL APPROACH

Sustainable Development is a broad and multidimensional concept. The most popular definition of Sustainable Development as given by Brundtland Commission (WCSD, 1987) is "Sustainable development is the development that meets the needs of the present without comprising the ability of the future generations to meet their own needs". A modified version of this definition to make it applicable to the urban context is "the path of urban environmental sustainability is the one in which urban development meets the environmental needs of the present urban dwellers without compromising the ability of non-urban dwellers and the future generations to meet their own needs which are affected by the environment" (MoE Japan, 2002).

Consequently for environmental sustainability of an urban settlement it requires monitoring of the internal environment of the settlement and its success in fulfilment of basic needs of its inhabitants while minimising undesirable effects; as well as the impact that the settlement has on the wider natural environment through resource use and waste outputs. The success of the environmental sustainability of an urban settlement is achieved by collating the results and making the general public aware about the state of the environment and to raise awareness thereby ensuring improved accountability and efficient delivery from the service providers and in the process ensure greater sustainability. Therefore, to achieve the aim of environmentally sustainable urban development following three major goals have been identified:

a) Ecological resilience of the Natural environment- To preserve balance of the natural resources and the restoration and renewal capacity of the natural ecosystem.

b) Sustainable development of the Built Environment - Energy efficient settlements with adequate and secure housing and efficient infrastructure.
c) Improved Quality of Life – Socially and economically strong settlements with adequate opportunities for personal growth, health, psychological well-being, economic rewards and overall satisfaction in life.

In order to achieve the above goals, the research work focuses on formulating an indicator system (qualitative and quantitative) which performs the following tasks:

- To assess the present state of the environment
- To keep track of the changes in the environment and to do a performance review of the state of the environment and environmental policies from time to time.
- To inform the general public about the state of the environment and to raise awareness thereby ensuring improved accountability and efficient delivery from the service providers to ensure sustainability.
- To provide necessary inputs to the planners and policy makers to facilitate decision making for them for the overall environmental improvement of urban settlements to make them more sustainable.

The study focusses on formulating an indicator set which can satisfy the following characteristics to the extent feasible:

- Multilevel indicators
  - Core indicators-common set of indicators with available data at broader level and with opinion of experts; and
  - Additional indicators- specific set of indicators relevant to a local area and with public participation
- Simple and easy to understand by policy makers and the general public
- Bottom up approach and multi stakeholders participation
- Policy responsive and action plan oriented
- Analytically sound
- Mix of quantitative and qualitative indicators
- Quantifiable with available reliable data

Thus to develop a set of indicators at macro and micro level for environmentally sustainable development of the urban settlements in India, following broad objectives/tasks have been identified:

- To recommend a structural framework for developing the multilevel indicators set focusing on resource dynamics of urban settlements.
- To develop a set of core indicators for urban settlements in India for state of the environment reporting at the national/city level.
- To develop a set of additional indicators for assessing the urban ecosystem at micro level (neighbourhood level) and to overcome the challenge of data availability at local level.
- To ensure that the indicators adequately cover all the major urban environmental issues in the Indian context.
- To assign weightages to the domains through experts opinion, input and feedback.
- To form an index at macro and micro level and benchmark/rank (the cities at macro level and settlements at micro level).
- To inform the general public about the state of the environment and to raise awareness and involvement thereby ensuring improved accountability and efficient delivery from the service providers and in the process ensure sustainability.
- To identify relevant data sources for each indicator, wherever available.
- To define the baseline information that is needed to properly interpret the results of the indicators and successfully translate them in the form of policies at national level and action plans at local level.

3.2 SELECTION OF THE STRUCTURAL FRAMEWORK

A review of the major structural frameworks in use in development of sustainability indicators brings to the notice that irrespective of systems framework advantage over the causal and thematic ones, especially in development of environmental indicators, it has not been much explored. Australian Environmental Indicators Human

Settlements is the sole literature in indicator research found using EUMM model based on systems framework (Australia, 1998).

The systems approach contrasts from the policy based approach in beginning with a simple but explicit physical model or systems diagram of the city or the environmental system, within which the various actors operate and in which linkages and causality between various sectors are delineated. The limitations of the PSR framework for urban indicator development have also been addressed via the Extended Urban Metabolism Model which makes explicit the notion of livability and reinforces the normative concept of improved environmental outcomes over time. EUMM is closely aligned with the paradigm of sustainable development where future orientation, sustainability goals and targets and linkages among different dimensions are made explicit (Australia, 1998; Newton, 2001).

Thus for the present study *Extended Urban Metabolism Model* (EUMM), based on systems framework, developed by Newman et al. (1996) has been adopted with modifications relevant to context of the study. The EUMM has been discussed in detail in the section below.

3.2.1 Systems Framework (Extended Urban Metabolism Model)

EUMM observes cities as systems which require raw inputs of resources which are transformed through the various forces at work in the urban process into livability outputs and waste outputs. The desirable change for the system is reduced resource use, enhanced livability and reduced waste. The various components of the EUMM are discussed below:

a) Resource Inputs - The raw inputs required for functioning of an urban settlement are generally derived from natural resources- Land, Air, Water and Energy (from both renewable and non-renewable sources). Food, drinking water, materials for building and industries, oil for transport etc. are derived from the said natural resources.

b) Dynamics of Urban Settlement - Population growth and spatial distribution are major determinants of urban activity, intensity of resource usage and environmental impact. The various economic and industrial activities, provision of infrastructure, transport facilities and linkages, institutional and cultural facilities are all various driving forces which are required to sustain a population in an urban settlement and hence consume resources and generate desired outputs and waste by-products.

c) Livability - It is a measure of quality of life of an urban settlement which is governed by the parameters such as clean and healthy natural environment (air quality, water quality, urban green) and sustainable physical built environment (access to proper housing and efficient infrastructure) along with various economic and social factors such as employment opportunities, affordability, better health and educational facilities and interactive and safe community life.

d) Waste Outputs - The consumption of resources by various human activities lead to various undesirable by-products such as air pollutants, greenhouse gases, liquid waste, sewage, solid waste, toxins, heat and noise.

The relationship between the various components of EUMM has been explicated in Figure 3.1 below. For sustainable living conditions it is required to have judicious use of input resources so that they can replenish over time and a reduction in waste production through various measures such as end-of-pipe technologies, systematic redesign etc. to minimise the environmental impacts and increase the quality of life.

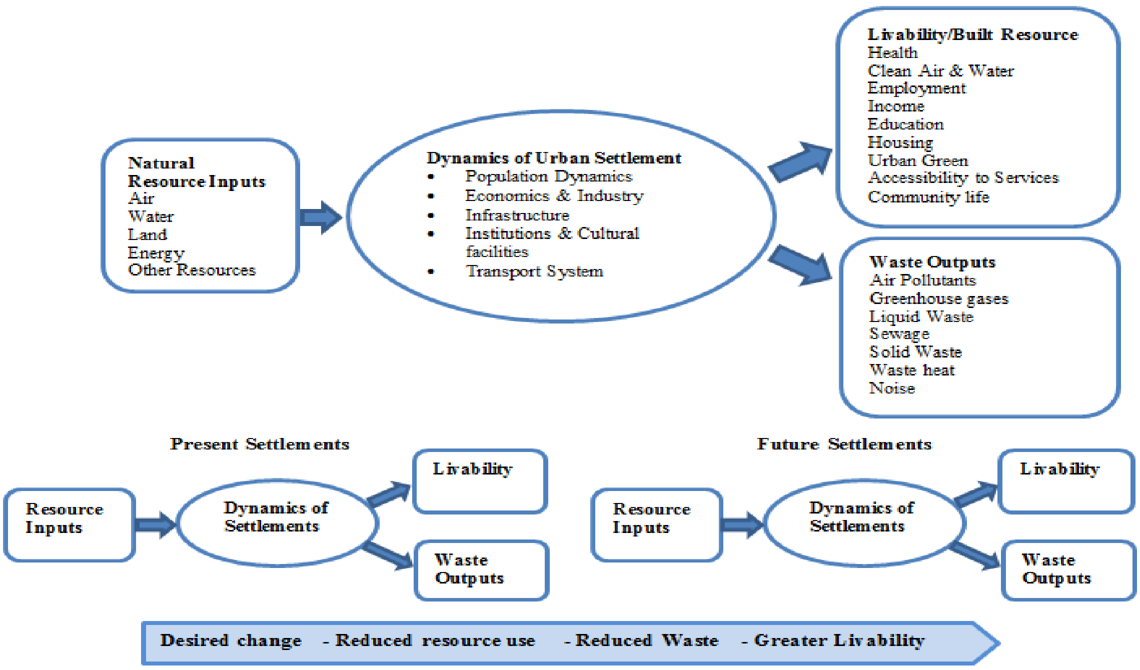


Figure 3.1: Extended Urban Metabolism Model of Human Settlements
Source: Adapted from Newman et al. (1996)

3.3 IDENTIFICATION OF DOMAINS

The objective of the study is to develop set of indicators for greater livability in urban areas with focus on environmental dimension. For this, as seen in Australian Environmental Indicators Human Settlements (1998), domain-based classification becomes appropriate as this ensures experts participation for the development of sound indicators with the required scientific or disciplinary backing.

For the present study, eight domains have been identified based on the essential natural resources: air, water, land, energy which are required for the sustenance of urban system; built in resources: housing, infrastructure, the adequacy and efficiency of these services determines smooth running of the urban system; human resource: population (labour) and; capital resource: finance (capital), both labour and capital are required to transform natural resources to desirable services or outputs. The population growth and density affects the natural and built in resources apart from the quality of life by exerting consumption pressure and by generation of waste.

The above identified domains areas are not standalone in them and often their effects are beyond the respective domains blurring the boundaries. Each domain has overlapping zones which contributes to ecological health, social well-being and economic efficiency, all the pillars of sustainability required for healthy functioning of urban environment.

For greater livability of the settlements following urban environmental sustainability determinants have been elucidated for the above identified domains with the goal of achieving resilient natural environment, sustainable built environment and healthy quality of life.

a) Air- Maintaining air quality and reducing pressure on the atmosphere
b) Water- Maintaining water quality and reducing pressure on the water systems
c) Land- Balanced built land use and urban green and reducing demographic pressure for development.
d) Energy- Efficient energy use by sensible use of resources and minimisation of waste.

e) Housing- Access to proper and durable housing for satisfaction of basic need of shelter
f) Infrastructure- Access to infrastructure for satisfaction of basic needs of clean and adequate potable water and sanitation.
g) Population- Access to provisions and infrastructure for satisfaction of basic needs of proper health and education for a better quality of life.
h) Finance- Access to facilities like land, labour, capital and entrepreneurship for ease of doing business for creating employment opportunities, financial wellbeing and security.

3.4 FORMULATION OF INDICATORS

Formulation of indictors should reflect a thorough understanding of the systems they are going to monitor. A set of domain models have been developed for the above identified resource based eight domains: air, water, land, energy, housing, infrastructure, population and finance structured on EUMM model for providing the framework within which the core indicators at the macro level and additional indicators at micro level could be developed. Population growth and various human activities have been considered as the major underlying forces determining the intensity of resources usage and environmental impact through various urban activities.

In developing the models for the identified domains the focus is on explicating the observable parameters i.e. the resource input, livability and waste output and the unobservable complex parameters i.e. various forces at work in urban settlement for conversion of resources to the various outputs have not been enumerated. This approach satisfies the property of an indicator. For example health of a human body is tested through various indicators like temperature, blood sugar etc. without going in to the complexities of what happens inside the human body.

The following sections give an insight into the resource dynamics of each identified domain and the basis of selection of indicators under each domain for assessing urban environmental sustainability.

3.4.1 Air

The quality of air in an urban area depends upon the geography of the place, meteorological conditions and the various economic activities and type of energy use. Air pollution in India is quite a serious issue with the major sources being vehicle emissions, industries, generators, fuel wood and biomass burning (domestic combustion), fuel adulteration, roadside dust, construction activities etc. An approach for improving the air quality in urban areas require identification of emission sources, an assessment of the extent of contribution by these sources to ambient air quality, prioritisation of sources that needs to be addressed and accordingly formulation of an action plan. The various air pollutants generally found in urban areas are SPM, PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO, O_3, and Benzene etc. as per the various studies by government monitoring authorities. Amongst the above mentioned pollutants the major parameters for assessment of air pollution in the urban areas in India as being monitored under the National Ambient Air Quality Monitoring Program (NAAQMP) conducted by CPCB are SO_2, NO_2 and RSPM (i.e., PM_{10}). Respirable Suspended Particulate Matter in particular pose a serious immediate health hazard for the urban dwellers. CO_2 and other greenhouse gases concentration is a global phenomenon and is responsible for global warming.

3.4.1.1 Selection of Indicators under the 'Air' Domain

Figure 3.2 illustrates the EUMM model applied to the Air domain. From the environmental perspective stress is on reducing down the quantum of air pollutants and greenhouse gases for clean air and health of urban dwellers.

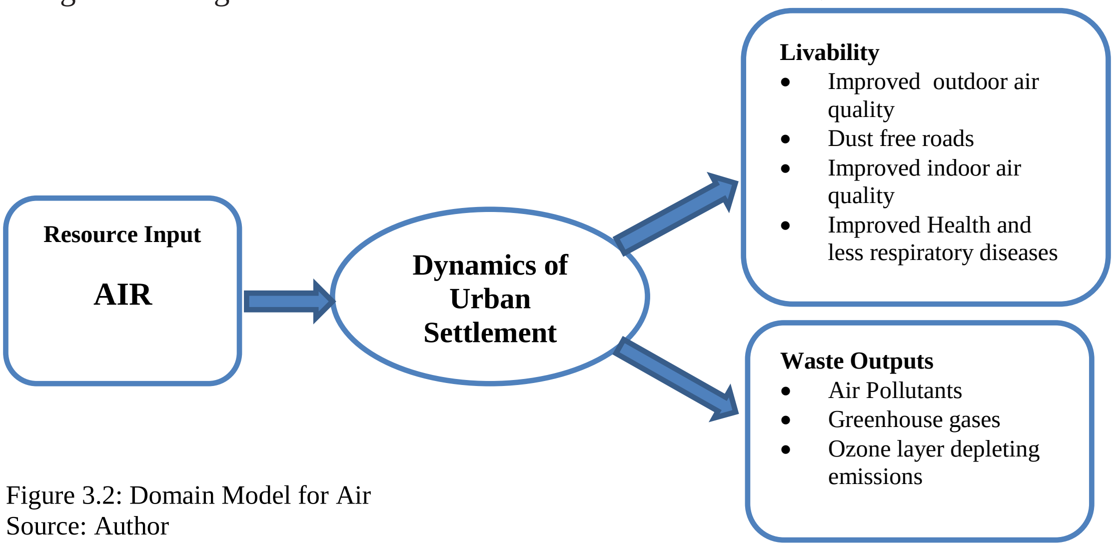


Figure 3.2: Domain Model for Air
Source: Author

SO_2, NO_2 and PM_{10} concentrations have been chosen as indicators of air quality assessment at macro level as these as the air pollutants generally found in urban areas in India and their concentration within permissible limits indicate that there is manageable stress on the atmosphere due to various human activities. CO_2 concentration being a global phenomenon has not been taken as one of the indicator for the present study.

At the micro level a qualitative assessment is done specific to the characteristic of the local area through reconnaissance survey and stakeholders feedback to identify the major sources of emission and to prioritise and to address the problem areas. Hence the chosen indicators are emissions from residential energy use such as use of biomass for cooking or some other domestic purposes, emissions from commercial energy use such as use of DG sets, emissions from small scale industrial energy use such as use of chemicals, paints etc. and emissions from burning of solid waste/dry leaves etc. Since SPM/RSPM concentration pose a serious immediate health hazard for the urban dwellers, an assessment is done at the local level through the indicators- percentage of paved (black topped) road length to total area under roads and percentage of road with roadside green and plantation.

3.4.2 Water

Water is one of the basic resources for sustenance of life on this earth. In an urban settlement water is required for carrying out essential activities of various sectors and even for various recreational purposes.

In the urban areas, water is tapped for domestic and industrial use from rivers, lakes, streams and wells. Around eighty per cent of the water supplied for domestic use comes out as waste water. Waste water in the form of treated, partially treated and untreated sewage, effluents from industries, storm water runoff from improper solid waste dump areas, landfills, agricultural fields, roads etc. when discharged in water bodies or allowed to sink in the ground are the major causes of surface and ground water pollution in the urban areas. Water pollution is responsible for the various public health problems and the loss of aquatic/marine life.

Municipal Sewage is defined as "waste (mostly liquid) originating from a community, may be composed of domestic wastewaters and /or industrial discharges" (CPCB, 2009). As per the various monitoring studies conducted by CPCB, Municipal Sewage is the major source of water pollution in India, particularly in and around large urban centres. Drinking water increasingly fails to meet standards due to pollution, poor operation of sewage treatment facilities, lack of disinfection and the poor condition of supply systems and sewerage systems. Supplying safe drinking water is therefore an important environmental sustainability issue which requires explicit emphasis on quality.

3.4.2.1 Selection of Indicators under the 'Water' domain

Figure 3.3 illustrates the EUMM model applied to the Water domain. From the environmental perspective stress is on maintaining water quality by reducing down the quantum of water pollutants for availability of clean and safe drinking water for urban dwellers.

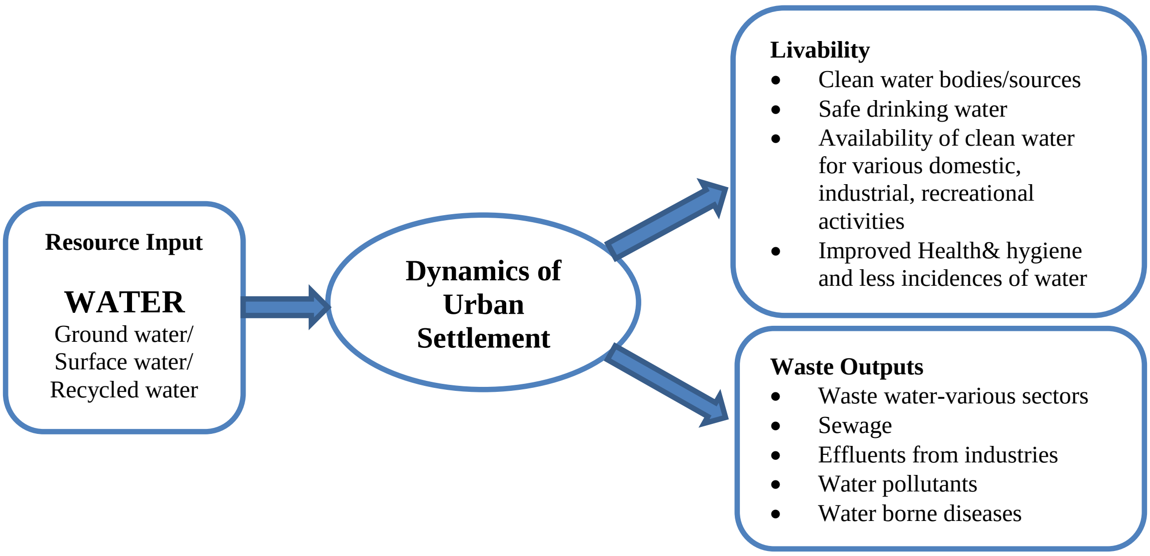


Figure 3.3: Domain Model for Water
Source: Author

For assessment of the health of the water sources at macro level average DO, BOD and Total Coliform concentration of the major water bodies have been considered for water quality assessment. In the coastal urban areas average COD concentration of the coastal water may be considered, if required, for assessment of water pollution and hence the water quality.

At the micro level both surface and ground water pollution and quality of the drinking water supply are assessed by doing a reconnaissance survey of the local area and from stakeholder's/ community feedback. The chosen indicators are the mode of sewage disposal (municipal connection/ pit/ septic tanks/ open defecation/storm water drains), solid waste disposal(open dumping /dumping in storm water drains) , contamination of storm water runoff (agricultural fields/ landfills/ chemical working sites/ others)and incidences of water borne diseases if any.

3.4.3 Land

Land, being a limited resource, needs to be utilised in a sustainable manner. There is a tremendous pressure on land to satisfy the residential, commercial, industrial and public facilities requirements of the growing population. The various human activities driven land usage pattern in urban areas leads to various environmental problems of complex nature.

The large scale urbanisation of land to satisfy the demands of the growing population encourages felling of trees, destruction of green cover and a rise in hard paved areas/concrete surfaces. Population growth is responsible for 80 percent of deforestation worldwide and about three quarter of arable land expansion (UNFPA, 1992).This leads to soil erosion, loss of nutrient rich top soil i.e. soil fertility, loss of agricultural produce and loss of biodiversity.

An increase in impervious surfaces alters the natural water cycle by less evapotranspiration, less percolation of storm water in the ground and an increase in surface runoff leading to declining ground water table and increased rain fed urban floods. There is also loss of dissipation spaces like wetlands and mangrove lands leading to increased events of urban floods. Moreover, the urban heat island effect due to the increase in built and paved surfaces leads to increased temperatures that are linked to global warming and climate change.

Also the use of chemicals in agricultural fields and the generation of hazardous waste from various industrial and building construction activities pose a serious threat to human health and natural environment. The dumping of these wastes on land leads to contamination of land and ground water and surface runoff from these areas leads to surface water pollution.

3.4.3.1 Selection of Indicators under the 'Land' Domain

Figure 3.4 illustrates the EUMM model applied to the Land domain. From the environmental perspective stress is on balance between the land under built use and urban green and reducing various environmental impacts due to the demographic pressure for development activities on the land.

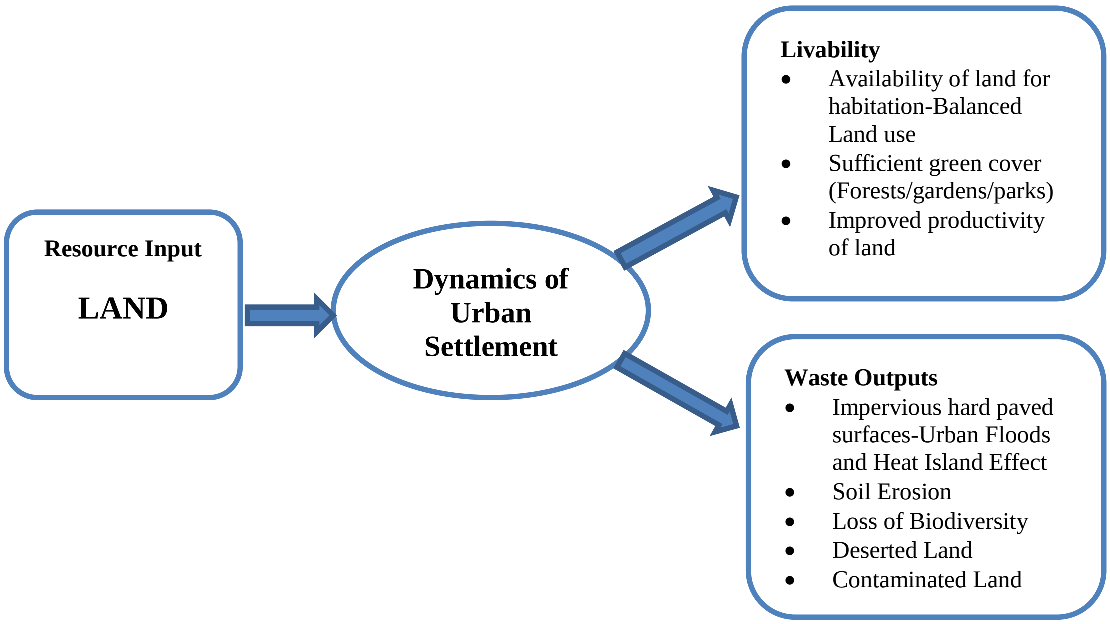


Figure 3.4: Domain Model for Land
Source: Author

Unprecedented population growth and concentration of population is the root cause of demographic pressure on the land and the resulting urban sustainability and environment problems. Hence population density i.e. number of persons occupying per sq.km of land has been chosen as one of the indicators at macro level as it outline the carrying capacity of an area and the ability of the environment to regenerate and cope with human intrusion.

Urban green spaces help in local habitat and biodiversity conservation, enhance micro climate by reducing albedo and solar radiation load, prevents soil erosion and aids in better air quality by trapping particulate pollutants. The role of green space in urban system is very crucial and thus for assessing the sufficiency of the green space at macro level the chosen indicator is the per capita availability of green space.
In order to assess the unproductive land at the macro level the chosen indicator is the percentage of land under sanitary landfills, hazardous dumping or percentage of deserted land if any.

At the micro level apart from the population density of the area, depending upon the characteristic of the area whether it is completely residential or mixed land use, floating population may also be one of the indicators to assess the pressure of the population coming to the cites for various jobs during the day time.

The measurement of green area with respect to the total population has been chosen as an indicator for assessment of urban habitat and micro climate. The surface run off rates of different land cover types at the neighbourhood level will be another indicator to assess the risk of rain fed urban flooding and erosion.

Another indicator at the micro/neighbourhood level is the impervious surface ratio with respect to the total area of the land to assess the changes in evapotranspiration rates due to increase in built and paved areas. Evapotranspiration is a collective term for the transfer of water into the atmosphere from both vegetated and non-vegetated surfaces (Wang et al.,2013)

For assessment of urban heat island effect due to impervious surfaces on the microclimate, measurement of albedo of different surfaces is required. Albedo is the ability of a surface to reflect incoming solar radiation. Surfaces with low albedo absorb most of the solar radiation whereas surfaces with high albedo reflect most of the solar radiation (Akbari et al., 1992).Impervious surfaces cause increased land surface temperature and results in an air temperature difference in the urban and the countryside which is called the urban heat island effect. Urban green spaces reduce surface temperature by releasing water vapour in the air through evapotranspiration, providing shade to the built forms and dark surfaces and reducing the energy use. Thus urban vegetation reduces the urban heat island effect and improves the urban microclimate.

Another indicator is for assessment of contamination of land, if any, by dumping of hazardous waste or chemicals etc. which may be ascertained by a reconnaissance survey and stakeholders feedback.

3.4.4 ENERGY

Energy is essential for social and economic wellbeing and plays an important role in the prosperity of a nation. It is fundamental for functioning of domestic sector, commercial sector, delivery of goods and services like water supply, sewerage network, manufacturing in industries, building construction, transportation etc. Energy in the form of non-renewable energies as oil, coal, gas for electricity is an inevitable necessity to enable the functioning of urban environment and ensuring quality of life. A gradual shift towards renewable energy sources is evident.

However, there is nexus between energy use and severe impacts on the environment and health of the human beings. Energy is produced from a range of raw inputs and during the process there are inherent inefficiencies which results in the waste by-products such as emissions of particulates, noxious gases, greenhouse gases, residues, noise etc. along with depletion of resources over time.

Also, there are large disparities in the level of energy consumption, not only among different regions (urban and rural), but also among various sections of the society in the same locality due to economic disparity. Thus the need of the hour for sustainable development is provision of adequate energy services at affordable prices minimising environmental impacts and without affecting the long term availability of the resources to avoid future energy crisis. This can be achieved by appropriate fuel choice, replacing inefficient technologies for efficient ones and use of renewable energy in place of non-renewable resources.

As per U.S. Energy Information Administration, 2013, India is the fourth-largest energy consumer in the world, following the United States, China, and Russia. Coal is India's primary source of energy; the power sector accounts for more than 70 percent of coal consumption. India has the world's fifth-largest coal reserves. As per the same report India was the fourth largest consumer of oil and petroleum products in the world in 2011 and relies heavily on imported crude oil, mostly from the Middle East. India became the world's sixth-largest liquefied natural gas importer in 2011.Since the electricity demand of the country is growing; India plans to increase its nuclear share of generation to 25 percent, up from 4 percent in 2011.

However, rural areas in India do rely heavily on traditional biomass, as they lack access to other energy supplies. According to the 2011 India census, more than 80 percent of rural households and 22 percent of urban households use traditional biomass (including firewood and crop residue) as the primary fuel for cooking which is responsible for air pollution and health problems and needs to be replaced by cleaner fuel like LPG. In the urban areas in India, in particular the metropolitan cities like Delhi, the tremendous increase in the number of private vehicles primarily as a result of dearth of efficient public transport, is not only putting excessive pressure on the energy consumption, but also one of the major cause of air pollution and congestion on the roads.

3.4.4.1 Selection of Indicators under the 'Energy' domain

Figure 3.5 illustrates the EUMM model applied to the Energy domain. From the environmental perspective stress is on efficient energy use by sensible use of resources and minimisation of waste and pollutants.

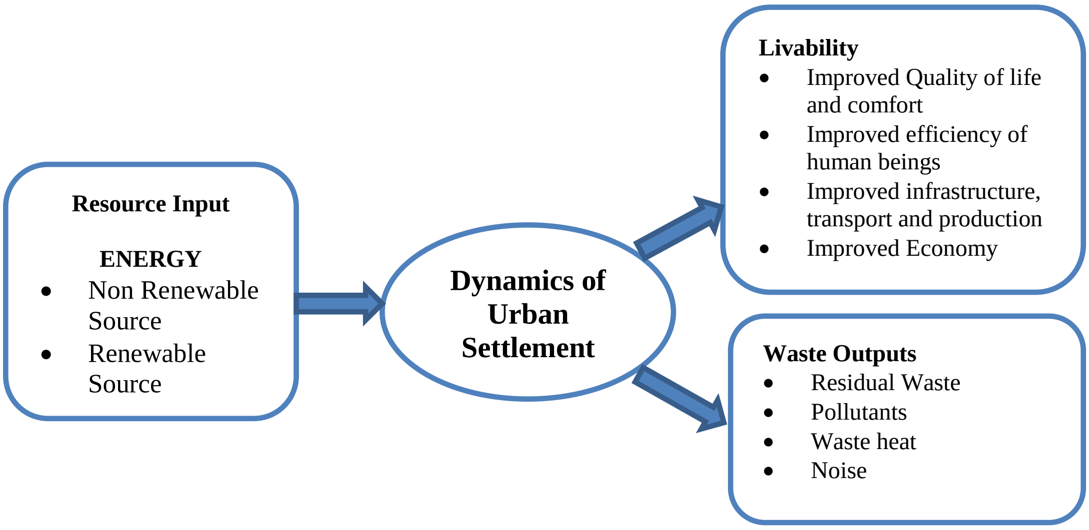


Figure 3.5: Domain Model for Energy
Source: Author

The indicators chosen for assessment of intensity of energy use at macro level is total energy consumption per capita and for appropriate fuel choice is the share of renewable energy in the total energy use. The indicators for access to affordable and basic energy need are percentage of households having proper electricity connection and percentage of households having LPG connection. The indicator chosen for the assessment of energy use by private transport sector is the percentage of households having motorised vehicles.

At micro level, first a quantitative assessment has been done through field surveys on the same indicators of percentage of households having electricity connection, percentage of households having LPG connection, percentage of households having motorised vehicles. An attempt was also made to investigate the reasons for the people continuing with non renewable and polluting sources of fuels. In order to assess the various energy conservation measures the indicators chosen are the percentages of households using renewable energy (solar energy, biogas) and the percentages of households having provision for rain water harvesting and waste water recycling. Access to public services and transport stops within a range from 500m to more than a kilometre of walking distance, achieved by the layout design of neighbourhoods has been chosen as an indicator to assess the energy efficiency.

3.4.5 HOUSING

Housing is one of the basic necessities of life. It is the major consumer of a number of resources and is generally the place where the domestic sector engages in most of its activities interacting with different aspects of physical and human environment. Construction of houses involves a use of different materials such as concrete, clay, steel, timber etc. A large amount of energy is consumed in the building process, directly through transport of materials and indirectly through embodied energy in various energy intensive materials such as cement, glass, steel, aluminium etc. Housing is also a major generator of waste both through the building construction process (demolition waste, construction debris) and also by the use of the occupants (solid waste, sewage etc.). Thus the various construction activities and domestic activities of the households are major contributors of atmospheric, water and noise pollution.

Adequate, appropriate and affordable housing is vital for a satisfactory quality of life. Appropriate housing means secured housing with basic physical and social infrastructure facilities and adequate open space. Housing is an important part of economy and a major component of capital investment. There is a housing shortage in most of the developing countries including India. The tremendous population growth mainly due to rural urban migration in most of the major cities in India results in unplanned growth of the cities with high housing density (overcrowding), overstressed infrastructure, unhealthy living conditions and related environmental problems. Housing crisis results in high property prices and mushrooming of slums with unhygienic living conditions.

3.4.5.1 Selection of Indicators under the 'Housing' domain

Figure 3.6 illustrates the EUMM model applied to the Housing domain. From the environmental perspective stress is on access to adequate, proper and durable housing with sustainable density for satisfaction of basic need of appropriate shelter and quality of life.

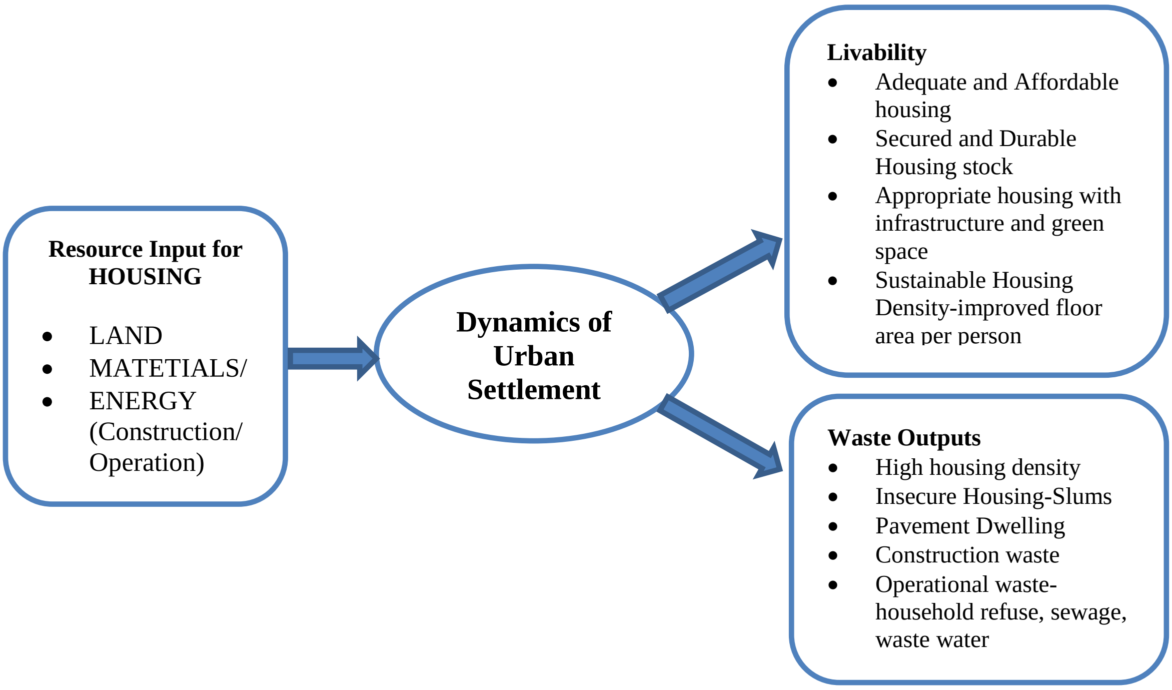


Figure 3.6: Domain Model for Housing
Source: Author

The high population growth and the resulting overcrowding are one of the major causes of urban sustainability problems. Hence housing availability i.e. numbers of houses available per thousand of population; the average household size and the share of households living in one room have been considered as the indicators for accessing adequacy of housing stock, overcrowding and overstressed infrastructure issues at broader level.

In order to assess the availability, non-availability and shortage of proper, durable and secure housing the indicators chosen at macro level are the share of population living in pucca (masonry/durable) houses, the share of population living in slums and the share of population as pavement dwellers.

At the micro level or the neighbourhood level the chosen indicators are housing availability, the average household size and the durability and condition of housing stock in terms of natural light and ventilation.

3.4.6 INFRASTRUCTURE

Urban water supply and sanitation are basic human needs for better quality of life and enhanced productive efficiency of the people. India along with other developing countries is facing a serious challenge of providing basic services and resources to its growing urban population at an unmatched rate.

The domestic, commercial, industrial and other water requirements of urban areas is met by tapping water from natural sources i.e. rivers, streams, wells and lakes. As per the website of Ministry of Water Resources, Government of India, the water demand for various sectors is projected to increase from 813km^3 in 2010 to 1093km^3 in 2025. As per CPCB Report 2009, the National average for per capita water supply is 179 lpcd for class-I cities and 120 lpcd for Class-II Towns and about 78percent of the urban population has access to safe drinking water. Almost eighty per cent of the water supplied for domestic use comes out as wastewater. As per CPCB, 2009 the estimated sewage generation from class-I cities and class-II towns together is 38,254 MLD, out of which only thirty five percent is treated with a large capacity gap, which needs immediate attention. Moreover only about thirty eight per cent of urban population has access to proper sanitation services. This improper collection, treatment and disposal of waste water are a major source of ground water and surface water pollution in India, particularly in and around large urban centres. The contamination of locally available freshwater supplies has serious impacts on public health and ecosystem.

Improper collection, transportation, processing and disposal of Municipal solid waste is a major environmental concern for the urban areas in India. Various studies conducted by CPCB reveals that per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/day and about ninety percent of Municipal solid waste is disposed of unscientifically in open dumps and landfills causing serious health and environmental hazards. MSW generation rate is higher in metro cities compared to smaller towns due to the changing lifestyles and increased purchasing power of urban India.

Thus faced with rapid urbanisation and the accompanying growing demand and growing pollution issues, Indian cities are not in a situation to provide infrastructure services that are adequate, neither quantitatively nor qualitatively.

3.4.6.1 Selection of Indicators under the 'Infrastructure' domain

Figure 3.7 illustrates the EUMM model applied to the Infrastructure domain. From the environmental perspective stress is on access to proper and sufficient infrastructure facilities for basic needs of clean and adequate water and sanitation.

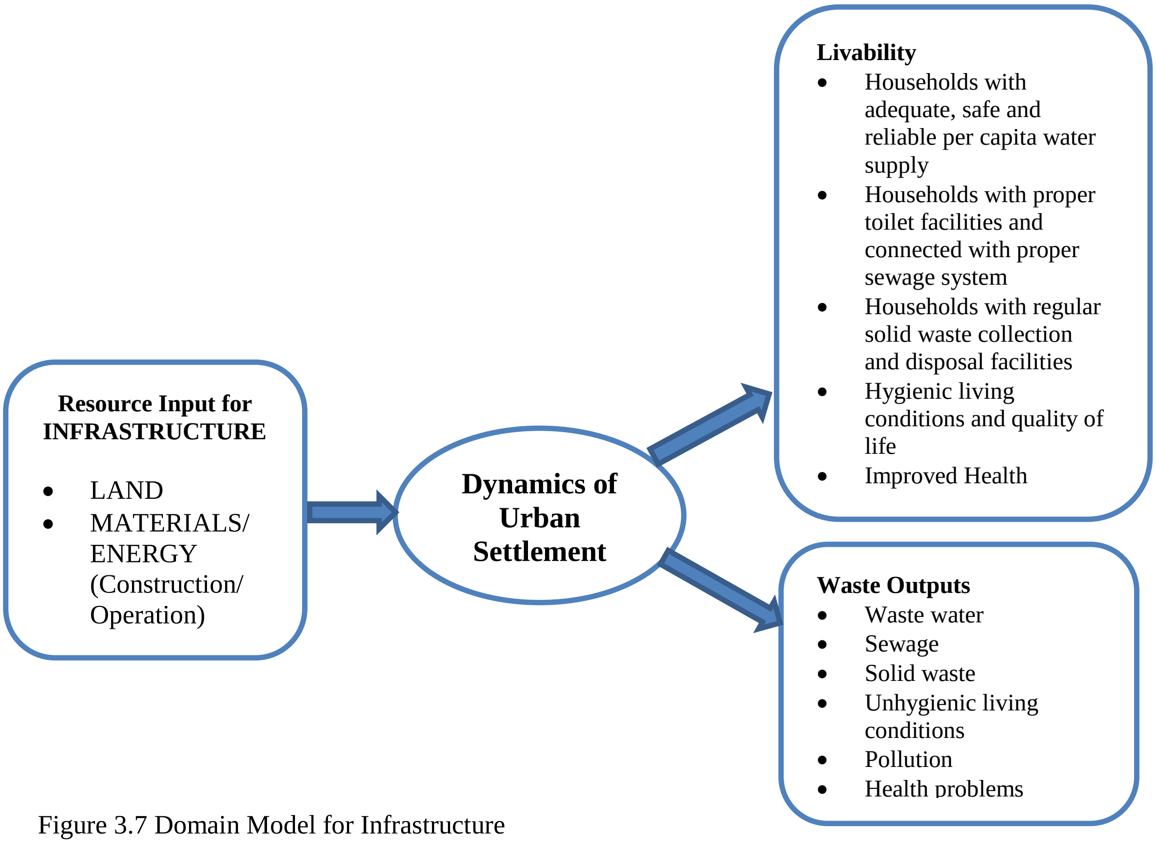


Figure 3.7 Domain Model for Infrastructure
Source: Author

The main function of an urban water system is to deliver safe drinking water and to manage and treat wastewater. All households need to be connected with piped water supply and sewerage system without leakages and pilferage. The storage of water in the household and round the clock availability of water through taps represents higher quality of life. Also, there is equity issue where a section of society does not get water for basic usage, where as another section make wasteful usage of water. Thus the chosen quantitative indicators for assessing the adequacy of water supply and sewage infrastructure at macro level are water supply per capita, percentage of households with potable water supply, percentage of water demand met with piped water supply, percentage of households with source of water within premises, wastewater generation per capita, percentage of households with sewage connection and percentage of households with access to proper toilet facilities within premises.

High per capita solid waste generation put pressure on waste collection, management and disposal and thus per capita solid waste generation and percentage of solid waste collected have been chosen as indicators for assessing the solid waste management facilities at macro level.

At the micro level primarily a quantitative (wherever feasible) & qualitative assessment of the water supply, sewerage and solid waste management infrastructural facilities has been done through the following indicators with a strong feedback from the community: source of water supply (municipal piped supply/ hand pumps/ wells/ community taps/ water tankers/ others), piped water supply reliability (number of hours of supply per day), percentage of households with source of water within premises; mode of Sewage disposal (municipal connection/ pit/septic tanks/open defecation), percentage of households with proper toilet facilities within premises; type of solid waste generation (domestic/ commercial/ industrial/ hospital/ hazardous including e-waste), frequency of solid waste collection (regular/irregular), solid waste segregation (yes/no), solid waste disposal (open dumping/bins/dalaos), frequency of solid waste transportation from dalaos (regular/irregular) and sufficiency of dalaos (numbers).

3.4.7 POPULATION

Society (people) is an essential component which needs to be well cared for environmental and economic wellbeing and plays an important role in the prosperity of a nation. It is fundamental for functioning of domestic sector, commercial sector, delivery of goods and services contributing to the GDP of the nation in the process impacting the economy. Human resource in the form of workforce for the primary, secondary and the tertiary sector is an inevitable necessity in this era to enable the smooth functioning of urban environment and ensuring a better environmental quality.

A gradual shift in attention towards the health and quality of the human resource is imperative for the development and progress of a nation.

However, there is a relation between health and quality of human beings and its impacts on the environment and economy. The robustness and wellbeing of a society depends on a number of raw inputs of which health and education of the population are primary ones and during the process there are inherent inefficiencies which results in the waste by products such as low life expectancy, high infant mortality rates, illiteracy and crime which leads to the depletion in the health and quality human resources and degradation of the society over time.

Also, there are large disparities in the level of health and education, not only among different regions (urban and rural), but also among various sections of the society in the same locality due to economic disparity or government policy implementation. Thus the need of the hour for sustainable development is provision of adequate health and educational services at affordable prices by envisaging the long term benefits of healthy and quality human resource to avoid negative impact on the society and crisis to the environment. This can be achieved by putting in place appropriate policies , implementing them through grass root level programs and by replacing the inefficient for efficient ones.

The promise to ensure universal health and education is common to the Millennium Development Goals (MDGs) and the National Common Minimum Program (NCMP). Further, the government has committed itself to make elementary education a Fundamental Right of every single child in the 6–14 years age group through the introduction of the 83rd Constitutional Amendment (GOI, 2002). Both health and education are rights under the Constitution of India, the latter being a fundamental right. Therefore the government is bound to deliver these services to the citizens.

Only 66 percent of the Indian people are literate (76 percent of men and 54 percent of women). While close to 90 percent children in the 6-11 age group are formally enrolled in primary schools, nearly 40 per cent drop out at the primary stage. (GoI, MHRD Bureau of Planning, Monitoring and Statistics, New Delhi 2013). Almost 13.6 million (forty per cent) children in the age group of 6-14 years remained out of school as on March 2005, four years after the launch of the Sarva Shiksha Abhiyan. Half of India's schools have a leaking roof or no water supply, 35 percent have no blackboard or furniture, and close to ninety percent have no functioning toilets. The official teacher-student norm is 1:40, yet in some states classes average is one teacher per eighty children. The prescribed norm of a school being available within the radius of one kilometre is still not being fulfilled. Malnutrition, hunger and poor health remain core problems, which comprehensively affect attendance and performance in classes. The added burden of home chores and child labour influence a large number of children, especially girls, to drop out of school even after the mid-day meal scheme. (GoI, SES, 2010)

India accounts for more than twenty percent of global maternal and child deaths, and the highest maternal death toll in the world estimated at 138,000.United Nations calculations show that India's spending on public health provision, as a share of GDP is the 18th lowest in the world.(WHO,2010)

Approximately sixty seven percent of the population in India does not have access to essential medicines. Infant Mortality Rate (IMR) in India was 67.6 in 1998-99 and has come down to 57 in 2005-06. Kerala heads the progress made so far with an IMR of 15/1000 births. Uttar Pradesh has the worst IMR in the country of 73/1000 births. Maternal Mortality Rate (MMR) is currently 4 deaths per 1000 births. India accounts for the largest number of maternal deaths in the world. Seventy nine percent of the children between the age of 6-35 months, and more than fifty percent of women, are anaemic, and 40 percent of the maternal deaths during pregnancy and child-birth relate to anaemia and under-nutrition. There are 585 rural hospitals compared to 985 urban hospitals in the country. Out of the 6, 39,729 doctors registered in India, only 67,576 are in the public sector. (UNDP, 2010).

3.4.7.1 Selection of Indicators under the 'Population' domain

Figure 3.8 illustrates the EUMM model applied to the domain of Population. The population growth and density affects the natural and built in resources apart from the quality of life by exerting consumption pressure and by generation of waste. From the environmental perspective stress is on controlled population growth which can be ecologically sustained in an area and; a healthy and literate society which would contribute to the economy by sensitively and judiciously transforming the natural resources to desirable services

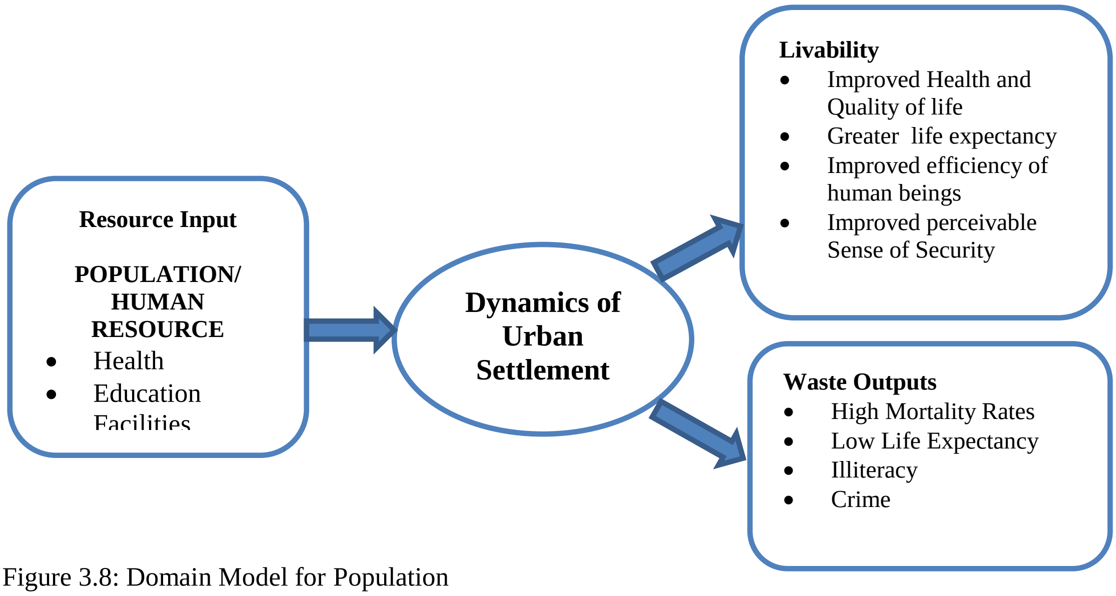


Figure 3.8: Domain Model for Population
Source: Author

The indicators chosen for assessment of society wellbeing at macro level are population growth rate, literacy, health and poverty. The indicators for access to affordable and basic health care need are number of government hospitals per 1000 people, infant mortality rate and average life expectancy. The indicator chosen for the assessment of literacy is percentage of literate people. The indicator chosen to assess poverty is percentage of households below poverty line.

At micro level a quantitative assessment has been done through field surveys on the total population, level of education, access to basic health facilities in the vicinity, incidences of diseases, adherence to all major vaccinations to children, age of the household members, no. of deaths per household in past one year and average income per household.

3.4.8 FINANCE

Economic progress is essential for social and environmental well-being and contributes immensely in the overall development and prosperity of a nation. It is fundamental as it affects the GDP. Economy in the form of per capita income and employment opportunities is an inevitable input to determine the functioning of urban environment and ensuring quality of life. An increase in employment opportunities and better employment options would ensure financial well-being of the society

Capital is required to transform natural resources to desirable services or outputs and there is a strong impact of employment and per capita income on the environment and health of the human beings.

Economy is generated from a range of raw inputs and during the process there are inherent inefficiencies such as disparities, rich-poor divide, depletion of resources over time etc. Also, there are large disparities in the level of employment and per capita income, not only among different regions (urban and rural), but also among various sections of the society in the same locality.

Thus the need of the hour for economic efficiency is easy access to facilities like land, labour, capital etc., ease of doing business for creating employment opportunities, financial wellbeing and security. However this needs to be addressed with provision of adequate clean energy services at affordable prices to minimise environmental impacts.

The Indian economy is expanding at a fast pace, boosting living standards and reducing poverty nationwide. Further reforms are now necessary to maintain strong growth and ensure that all Indians benefit from it

The latest OECD Economic Survey of India finds that the acceleration of structural reforms and the move toward a rule-based macroeconomic policy framework are sustaining the country’s longstanding rapid economic expansion.
India’s recent growth rates of more than 7 percent annually as the strongest among G20 countries. It identifies priority areas for future action, including continuing plans

to maintain macroeconomic stability and further reduce poverty, additional comprehensive tax reforms and new efforts to boost productivity and reduce disparities between India's various regions.

India provides a welcome counter-point to a global economy that has been under-performing for years. Reforms are historic and are bearing fruit, growth is strong and other macroeconomic indicators are improving. Maintaining the reform momentum will be critical to boosting investment and creating the quality jobs needed to ensure strong and inclusive growth for future generations, with all segments of society benefitting from it. It further points out that inflation is under control and current account deficit narrowed with tax compliances increasing along with ease of doing business.

The report points out the need to make income and property taxes more growth-friendly and redistributive. A comprehensive tax reform could help raise revenue to finance much-needed social and physical infrastructure, promote corporate investment, enable more effective redistribution and strengthen the ability of states and municipalities to better respond to local needs, according to the Survey.

The OECD points out that achieving strong and balanced regional development will also be key to promoting inclusive growth. Inequality in income and in access to core public services between states and between rural and urban areas is currently large across India, while rural poverty is pervasive. Continuing efforts to improve universal access to core public services is essential.

Recent changes in India's federalism model have given states more freedom and incentives to modernise regulations and tailor public policies to local circumstances. Ranking states on the ease of doing business is opening a new era of structural reforms at the state level and will help unleash India's growth potential. Further benchmarking among states and strengthening the sharing of best practices, particularly on labour regulations and land laws, could add to the reform momentum.

Raising living standards in poorer states will require increasing productivity in the agricultural sector. With employment expected to gradually shift away from the agricultural sector, urbanisation will gather pace. Thus, better urban infrastructure will be needed to fully exploit cities' potential for job creation, productivity gains and improving the quality of life. (OECD, 2011)

3.4.8.1 Selection of Indicators under the 'Finance' domain

Figure 3.9 illustrates the EUMM model applied to the Finance domain. From the environmental perspective stress is on reducing unemployment, poverty, crime through improved employment and entrepreneurship opportunities, better purchasing power, financial wellbeing and security and hence improved quality of life.

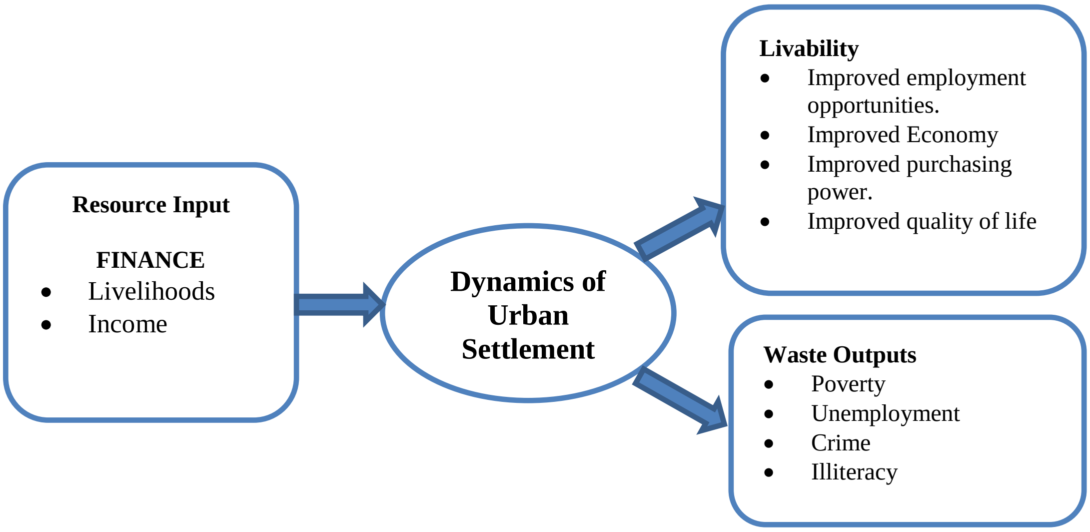


Figure 3.9: Domain Model for Finance
Source: Author

The indicators chosen for assessment of economy and employment at the macro level are GDP, per capita annual income and percentage of population employed in the overall economy. At micro level, first a quantitative assessment has been done through field surveys on the sub sets of the same indicators for accessing economic efficiency. The chosen indicators are average income per household, per capita monthly expenditure and percentage of households having employed members.

3.5 RECOMMENDED SET OF INDICATORS

In the previous section, a set of core indicators for state of the environment reporting at the national or city level and a set of additional indicators for assessing the urban ecosystem at micro level have been identified under each prioritised domain of study with focus on resource dynamics and effectively covering the major urban environmental issues of the urban settlements in India.

The selection of final indicator set for the present research work has been made keeping in mind the sustainability determinants along with data availability at macro level and scope of collecting data for that parameter at micro level. Care has been taken to choose a set of indicators which are not only concise, simple, easily understandable, interpretable and comparable across cities or settlements but also analytically and scientifically sound.

The list of final recommended set of indicators along with the identified data sources are given in the following table (Table3.1). The baseline information that is needed to properly interpret the results of the indicators in the form of policies and action plans have been provided in the subsequent chapters.

Table 3.1: Recommended Set of Urban Environmental Sustainability Indicators at Macro level and Micro level

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE/ STANDARD
AIR Maintaining air quality and reducing pressure on the atmosphere	SO_2 concentration (µg/m^3)	Households using biomass/kerosene for cooking/other domestic purpose (%)	(A) CPCB (B) • Household Survey • Reconnaissance Survey • Stakeholders/ Community feedback • RWAs/Councillors Office • NGOs • Aerial Image/local maps
	NO_2 concentration (µg/m^3)	Households / establishments using DG sets (%)	
	PM_{10} concentration (µg/m3)	Emissions from small scale industries/workshops (yes/no)	
		Emissions from burning of solid waste/dry leaves (daily/ frequently/ occasionally/ rarely/never)	
		% of paved (black topped) road length/area of total road	
		% of road with road-side green/plantation	
DOMAIN	**MACRO INDICATORS (A)**	**MICRO INDICATORS (B)**	**DATA SOURCE/ STANDARD**

WATER Maintaining water resources and quality and reducing pressure on the water systems	Average DO concentration (mg/l)	Households with municipal sewage connection (%)	(A) CPCB (B) • Household Survey • Reconnaissance Survey • Stakeholders/ Community feedback • RWAs/Councillors Office/Municipality / Public Health Department • NGOs • Aerial Image/local maps
	Average BOD concentration (mg/l)	Open dumping of solid waste/ dumping in storm water drains (daily/frequently/occasionally/ rarely/never)	
	Total Coliform concentration (MPN/100ml)	Contamination of storm water runoff (agricultural fields,/landfills/chemical working sites/others) (yes/no)	
		Incidences of water borne diseases(very frequently/occasionally/ rarely/very rarely/never)	
DOMAIN	**MACRO INDICATORS (A)**	**MICRO INDICATORS (B)**	**DATA SOURCE/ STANDARD**
LAND	Population density	Population Density (person/ sq km)	

Balanced built land use and urban green and reducing demographic pressure for development	(person/ sq km)		(A) CDP/Master Plans/Forest Survey of India (B) • Zonal Plans/Local Area Plans • Aerial Images • Reconnaissance Survey • Stakeholders/ Community feedback • Household Survey
	Green spaces/person (m^2)	% of Floating Population (Residential Characteristics)	
		Per Capita Green Space (sq.m./person)	
		Composite Surface runoff based on the % of different types of surfaces (%)	
		Impervious surface ratio in the total land area (%)	
		Measurement of Albedo of different surfaces by their area percentages (%)	
		Contamination of land- dumping of hazardous waste/chemicals (yes/no)	
DOMAIN	**MACRO INDICATORS (A)**	**MICRO INDICATORS (B)**	**DATA SOURCE/ STANDARD**

HOUSING Access to proper and durable housing for satisfaction of basic need of Shelter	Housing availability (No. of houses/1000 population)	Housing availability (No. of houses/1000 population)	(A) Census of India (B) • Municipality • Zonal Plans/Local Area Plans • Reconnaissance Survey • Stakeholders/Community feedback • RWAs/Councillors Office/ NGOs
	Average household size (no.)	Average Household size(no.)	
	Share of households with one room (%)	Share of population living in pucca (durable) houses (%)	
	Share of population living in pucca (durable) houses (%)	Share of population living in houses with proper natural light and ventilation (%)	
	Share of population living in slums (%)		
	Share of population as Pavement dwellers (%)		

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE/ STANDARD
INFRASTRUCTURE	Water supply per capita (lpcd)	Households with potable municipal water supply service (%)	(A)

Access to infrastructure for satisfaction of basic needs of clean and adequate water and sanitation	Households with potable water supply service (%)	Households with source of water within premises (%)	• Census of India • CPCB • CDP/Master Plan (B) • Municipality • Zonal Plans/Local Area Plans • Reconnaissance Survey • Stakeholders/Community feedback • RWAs/ Councillors Office/Municipality / Public Health Department • NGOs
	Households with source of water within premises (%)	Piped water supply reliability (no. of hours of supply /day)	
	Households with sewage connection (%)	Households with municipal sewage connection (%)	
	Households with access to proper toilet facilities within premises (%)	Households with access to proper toilet facilities within premises (%)	
	Solid waste generation Per capita (kg/cap/year)	Quantity of industrial/hospital/hazardous waste generation (Very High, High, Medium, Low, VeryLow)	
		Frequency of solid waste collection (daily, alternate days/thrice a week/twice a week/weekly)	
		Solid waste segregation (yes/no)	
INFRASTRUCTURE		Open dumping of solid waste (daily/frequently/occasionally/ rarely/never)	

Contd.…		Sufficiency of dalaos for solid waste dumping (yes/no)	
		Frequency of solid waste transportation from dalaos (daily, alternate days/thrice a week/twice a week/weekly)	
DOMAIN	**MACRO INDICATORS (A)**	**MICRO INDICATORS (B)**	**DATA SOURCE/ STANDARD**
ENERGY	Households with electricity connection (%)	Households with electricity connection (%)	(A)

Efficient energy use by sensible use of resources and minimisation of waste	Households with LPG connection (%)	Households with LPG connection (%)	• Census of India • Ministry of Statistics and Programme Implementation, Govt. of India (B) • Zonal Plans/Local Area Plans • Aerial Images • Reconnaissance Survey • Stakeholders/Community feedback • RWAs/Councillors Office/Municipality • NGOs
	Households using renewable source of energy - solar energy, biogas (%)	Households with motorised vehicles (petrol/ diesel consumption) (%)	
	Households with motorised vehicles (petrol/ diesel consumption) (%)	Households using renewable source of energy - solar energy, biogas (%)	
		Households with Rain water harvesting provision (%)	
		Households with waste water recycling provision (%)	
		Access to public services and transport stops within walking distance (less than 500m/ 500m-750m/ 750m-1km / >1km)	

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE/ STANDARD

<table>
<tr>
<td rowspan="6">POPULATION
Access to provisions and infrastructure for satisfaction of basic needs of proper health and education for a better quality of life.</td>
<td>Literacy Rate (%)</td>
<td>Literacy Rate (%)</td>
<td rowspan="6">(A)
• Census of India
• Ministry of Statistics and Programme Implementation, Govt. of India
(B)
• Zonal Plans/Local Area Plans
• Aerial Images
• Reconnaissance Survey
• Stakeholders/Community feedback
• RWAs/Councillors Office/Municipality
• NGOs</td>
</tr>
<tr>
<td>Health facility (no. of Hospital beds/1000 population)</td>
<td>Access to basic health facilities in the vicinity (less than 500m/ 500m-750m/ 750m-1km / >1km)</td>
</tr>
<tr>
<td rowspan="2">Infant Mortality Rate (Nos)</td>
<td>Incidences of diseases among children below 5 years of age (very frequently/occasionally/ rarely/very rarely/never).</td>
</tr>
<tr>
<td>Adhered to all mandatory and major vaccinations till the age of 5 years. (%)</td>
</tr>
<tr>
<td>Average Life Expectancy (in yrs.)</td>
<td>Average age of Household.(years)</td>
</tr>
<tr>
<td>Households below poverty line (%)</td>
<td>Average Income per household (Rs)</td>
</tr>
</table>

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE/ STANDARD
FINANCE Access to facilities like land, labour, capital and entrepreneurship for ease of doing business for creating employment opportunities, or finding gainful employment for financial wellbeing and security.	City GDP (in Rs)	Income Growth Rate (%)	(A) • Census of India • Ministry of Statistics and Programme Implementation, Govt. of India (B) • Zonal Plans/Local Area Plans • Aerial Images • Reconnaissance Survey • Stakeholders/Community feedback • RWAs/ Councillors Office/Municipality • NGOs
	Per capita Income (in Rs)	Per capita monthly income (Rs./Month)	
		Per capita expenditure on electricity consumption (Household electricity bill) (Rs./Month)	
	Employment Rate (%)	Employed people per household	

Source: Author

3.6 DEVELOPMENT OF ENVIRONMENTAL PERFORMANCE INDEX

3.6.1 What is an Index?

An 'index' is defined as a set of aggregated or weighted parameters or indicators (OECD, 1993).

Babbie (2004) says that an index is "A type of composite measures that summarises and ranks orders several specific observations and represents same in more general terms"

The relationship between the indicator, data and indexes is explained by Peter Newton (2001) in 'Data book on Urban Indicators for cities' naming it as 'Data Triangle'.(Fig.3.10)

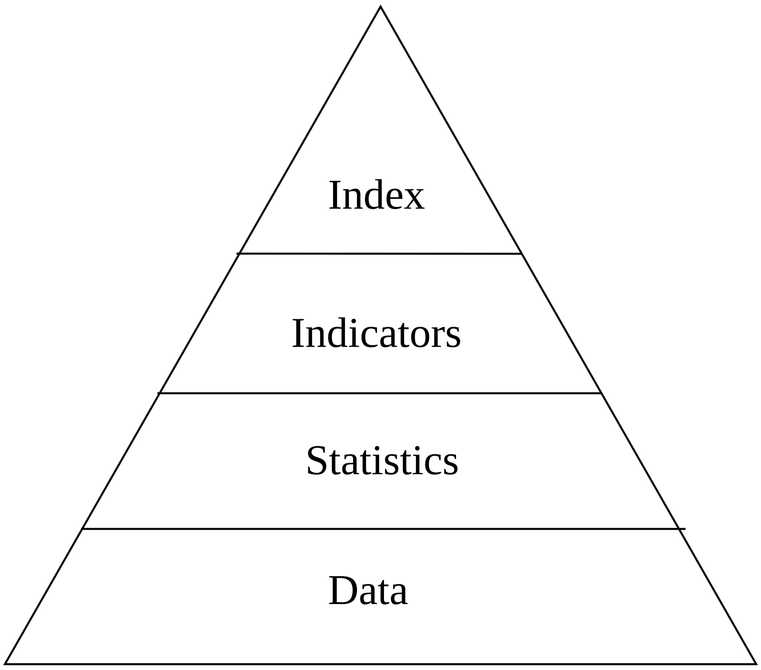


Fig.3.10 Relationship between Data, Statistics, Indicators and Index

Source: Newton, 2001

Composite indicators or an index are increasingly been recognised as useful tools in policy analysis, public communication, environment and development. It is often easier to interpret composite indicators by the general public than to understand trends across a group of separate indicators and they are useful in comparing performance of cities or countries (Saltelli, 2007).

Typology and classification of variables and design of indexes has invited a lot of debate (Dhakal,2001; de villa and Westfall,2001).There is a range of opinions about using indexes as a tool for explaining a situation, decision making and policy formulation.

In the literature many suggestions are made on selection of variables, assignment of weights and method of aggregation for arriving at a composite indicator or an index. In any such exercise, especially in the developing countries, data collection and availability of relevant data is a major issue. Problems related to aggregation of variables and assigning weight are discussed at length, but have not been conclusively resolved (Craley, 1981).

Mahavir (2006) has suggested that a researcher could categorise data either as essential or desirable. Then the researcher may work with limited data and could avoid unnecessary data collection. This is especially relevant and useful for those places where neither enough resources for collection of data nor adequately compiled data/ data banks are available. Literature suggests that it is always beneficial to select the type of variables depending on the nature of the task on hand.

Normalisation is required prior to any data aggregation as an index as the indicators in a data set often have different measurement units (OECD Handbook, 2008).

Exercises which deal with dynamic situations require regular review, monitoring and updating of indexes. Generally there are many ways given for assigning weights to various variables and components of indexes. Mostly stress is given on local variables for various community based indexes. There are several case studies on local indexes covering various aspects and issues related to cities and community in developed countries. Index based studies on cities in developing countries are limited.

The consistency of data and its interpretation at various levels is a major challenge, Unambiguous definition and clarity is a challenge in case of qualitative indicators.

Even in case of quantitative indicators process of collection of information and reliability may cause some problems.

The studies based on indexes have also invited a lot of criticism as these measures tend to oversimplify complex situations while putting forth a new concept. Research on construction of indexes and choice of their constituents is an evolving filed of knowledge.

3.6.1.1 Index based initiatives

Some of the most talked about index measures in the field of urban development and environment is 'ecological footprint' and 'environmental space'. These are used to capture sustainability of a given setting and the impact on environmental resources by the settlement. In the field of social sciences some of the talked about indexes are 'Human Development Index', 'City Development Index' 'GDI' etc. In India, Planning Commission has made some work in this direction.

3.6.1.1.1 Human Development Index

In 1990, UN started with an idea of expressing development in terms of an index which gave rise to a number of index development exercises. Human development index being the most popular among several index developed by various international agencies. Now, at the global level variety of indexes are in use for expressing relative measurement of different countries in different sectors.

Various technical details, theoretical and conceptual dilemmas related to HDI are discussed and highlighted by Jahan (2000 and 2002), Dhakal (2001), Kaul (2005), and Kundu et al. (2002). Now Gender Empowerment Index and Poverty Index are also made part of Human Development reports.

Human Development Index (HDI) has changed interpretation of development which was earlier considered only economic performance. It keeps people and their wellbeing at centre. HDI is a measure of three components, Indicators of longevity, educational attainment with standard of living. With Human Development Index, Gender

Empowerment Index and Poverty Indexes also gained popularity, HDI is also being criticised for being too simplistic. HDI ranking of any country does not reflect qualitative aspects associated with a place. (Atkinson et al., 1997; Jahan, 2000 and 2002)

3.6.1.1.2 City Development Index

It is a composite index developed by UN. "The city Development Index was developed to rank cities according to their level of development. The CDI is to date considered the best single measure of the level of development in the cities. The technique to construct the City Development Index is similar to that used by UNDP for their Human Development Index. Separate sub-indexes are constructed in combination to create a composite index. This CDI is based on five sub-indexes - City Product , Infrastructure, Waste, Health and education- the values of which range from 0 to 100. The CDI correlates well with the national Human Development Index, but because there is considerable variation between cities in any particular country, it provides a better measure of real city conditions than national level HDI". (UNCHS, 2001)

3.6.1.1.3 Index based Initiatives in India

A major initiative was undertaken by the Planning Commission of India in 2001 to evaluate the development process with the help of seventy indicators and three composite indexes.

The report focused on three critical dimensions of wellbeing namely ability to live a long and healthy life, ability to read, write and acquire knowledge and ability to enjoy decent standard of living and have a socially meaningful life. An extensive state level database was prepared covering the seventy indicators. The entire data set has been compiled on at least two points of time: early eighties and early nineties.

The Planning Commission of India also attempted three composite indexes. A Human Development Index which incorporated inflation and inequality adjusted per capita consumption expenditure; a Human Poverty Index encompassing longevity deprivation captured by the indicator persons not expected to survive beyond age 40 years; and a composite indicator on educational deprivation and composite indicator on economic deprivation-Gender Equality Indexes using the same methodology as HDI.

Despite its contextual significance and ability to capture the concerns of Indian people, the Human Development Report and its indexes were not able to address the growing importance of environmental issues. They were also not able to integrate several aspects of sustainability.

In another initiative, the task of formulating a comprehensive set of sustainable development indicators has been taken up by the Government of India. This was to take further the decisions taken at Rio and Johannesburg summits. This involves formulation of a comprehensive set of indicators which are relevant in the urban, rural and other geographical regions for sustainable development. The second issue is addressing data requirements for aggregation of local indicators at national level.

Kaul (2005) has carried out a review of indicator initiatives in India and arrived at a conclusion that HUDI and similar exercises are undertaken in India also but these initiatives do not address importance of environmental issues. He says, "Work has already been done by several agencies across the World in formulating indicators of sustainable development. These would provide some guidance but the final framework will need to address the specific circumstances of the Indian reality."

Most of the above mentioned indicator and index exercises are top down or are expert or professional driven. Now even bottom up indicator development approaches are becoming popular. Participation of people is considered valuable for indicator development. There is a shift from purely expert driven indicator exercises to community driven approaches where community also participates in developing indicators for specific, selected aspects. In case of India more efforts are required for understanding and relating these interpretations to bring change at grass root level.

3.6.2 Environmental Performance Index

A suitable index adds measurability to a concept. In order to keep the conceptual value intact, it is important to understand the criteria for choosing the constituents of an index, the number of constituents, the relative importance and method for combining them. At times periodicity of measurements (time) is also incorporated in the index development. An index may be a combination of many sub-indexes.

Following points may be considered in constructing an Index:

1. Choice of appropriate set of constituents of an index (domains, determinants, indicators and parameters)
2. Choice of suitable mathematical relationship amongst them
3. Choice of assignment of weights.
4. Periodicity of measurement of constituents and calculation.

The present research work focuses on two variants of Environmental Performance Index. When the weightages based on experts opinion are assigned to the constituents of EPI i.e. Statistical Data of the secondary (census / published reports and statistics by Govt. organisations) available at macro level using Principal Component Analysis, the index is called EPI-Macro. This index would measure the environmental performance of cities at macro level on the identified broad indicators.

In the second variation, when the weightages based on the experts opinion to the constituents of EPI is assigned to the primary data collected from the feedback of people, stakeholders and the on the basis of perception on ground at micro level, the index is called EPI-Micro. This index would measure the environmental performance of urban settlements at neighbourhood level (micro level) on the identified detailed indicators.

The index constructed with secondary data EPI-Macro cannot be repeated frequently to observe the changes as the available data is collected on a decadal basis or at a certain time interval. However EPI-Micro can be used more frequently with annual feedback and active participations of the local residents and stakeholders.

EPI-Macro helps in presenting a statistical picture of a settlements environmental profile and EPI- Micro helps in recording people's perception to identify gaps between perceptions and reality. Both the index variants put together produce a more realistic picture and include both top-down and bottom up approach.

3.6.2.1 Constructing the EPI-Macro: the steps

1. Collection of Data

Data of the urban settlements, on the identified indicators at the macro level, to be collected from CPCB, Master Plans, Forest Survey of India, Census of India and Ministry of Statistics and Programme Implementation, Govt. of India.

2. Converting into Positive Indicator Values

In the given situation there are two types of indicators - positive and negative indicators. An indicator is classified as positive if an increase in the value of indicator indicates an improvement in the environment. e.g. Total Coliform is a negative indicator and has been converted to positive indicator by inversing it. Similarly in another instance the indicator percentage of households below poverty line has been converted to positive indicator instead by looking into percentage of households above poverty line. This has been done keeping in mind that in the subsequent steps we aim to add up values of various parameters and domains (themes) through absolute numbers and evaluate the overall growth achieved in the direction of sustainability.

Score of Negative Parameter (converted into positive values)

$$= \frac{Value_{Maximum} - Value_{Actual}}{Value_{Maximum} - Value_{Minimum}}$$

3. Calculating Mean (Average)

After gathering data for each of the indicators mean (average) is calculated. The statistical formula is

$$\overline{x_j} = \frac{1}{n}\sum_{j=0}^{j=n} x_j$$

4. Calculating Standard Deviation

After calculating mean (average), standard deviation is calculated for each of the indicators. The statistical formula is:

$$s_j = \sqrt{\frac{1}{(n-1)}\sum_{j=1}^{j=n}\left(x_j - \bar{x}\right)^2}$$

5. Normalising/Standardising the Data Set:

Using mean and standard deviation calculated in step 3 and step 4 mentioned above, the entire data set is normalised / standardised so as to make the resulting data set with mean (average) equal to zero and standard deviation equal to one. This step eliminates the impact of different 'size' of values of indicators.

For example the population of cities could be in the range of millions while literacy rate could be in decimal points. After normalisation/standardisation both, population and literacy rate will have a mean as zero and standard deviation as one. The statistical formula is:

$$z_{i,j} = \frac{(x_{i,j} - \bar{x_j})}{s_j}$$

z_{ij} stands for z-score or normalised/standardised value of observation x_{ij}.

This Z score value of every indicator for each city has been termed as CIV (Comparative Indicator Value) for that indicator.

6. Assigning Weights to the Domains (based on Experts opinion)

In the process of measuring the Environmental Performance of a City, domains and indicators play an important role. In the process of arriving at an index, selection of suitable indicators and fixing their number becomes a difficult task. Further, in most of the index related exercises assigning weight to each component of the index is equally challenging. In the present study there are eight contributors identified as the domains of the Environmental performance of a settlement.

Usually, for simplicity, in index based exercises contribution of all the domains is taken to be equal, but in reality it may not be always so. Therefore it is important to find appropriate contribution of each domain in the environmental health of a settlement.

Expert planners who have worked in the field of urban and environmental planning and familiar with the vital issues involved in the city planning process at the national level were consulted in course of this study.

They were interviewed and their opinion was collected for finding weights to be assigned to each domain. Each domain individually was given a weightage out of 10 by each expert (not a ranking). The final weight assigned to each domain is calculated by taking average of weights assigned by each individual expert.

7. Calculating Environmental Performance Index (EPI) for each domain

The Environmental Performance Index for each domain of the city is derived by averaging the Z-score values computed for each of the indicators in the domain and multiplying it with the weightages given by experts as described in the process in the previous point.

EPI (Z_{Air}) =Average Z scores (A_1, A_2,…, A_n) X weightages given by experts

Where A_1, A_2 and A_n are the various indicators under the domain of air.

8. Calculating Environmental Performance Index (Macro) for each city

The Environmental Performance Index (Macro) for each city is calculated by summing up the EPI of each domain and getting the final score.

EPI (Macro) = ∑ {EPI (Air) + EPI (Water) + ……+ EPI (Popn.) +EPI (Economy)}

9. Ranking of the Cities Based on the EPI (Macro) Score

Based on the individual Environmental Performance Index (Macro) for each city the Scores are arranged in a descending order. The city obtaining the highest EPI (Macro) Score is assigned the first ranking and the one with the least score the last ranking.

3.6.2.2 Constructing the EPI-Micro: the steps

1. Collection of Data

Data of the urban settlements, on the identified indicators at the micro level, to be collected from primary survey, field survey, stakeholders survey, local offices, master plans, zonal plans, electoral list

2. Assigning a Score, a 'Comparative Indicator Value' (CIV) to each indicator through a Likert Scale

The environmental performance of each indicator under the identified domains shall be assessed on a sustainability scale of 1to 5 where 1 score is attributed to the worst performance and 5 score has been attributed to the best performance. The Likert sale has been used for quantitative assessment of the indicators. This scale can be used to ascribe a quantitative value to a qualitative data, in statistical analysis to make it amenable. A numerical value is assigned to each potential choice and a mean figure for all the responses is computed at the end of the evaluation or survey.

3. Calculating Environmental Performance Index Micro (EPI Micro) for each domain

The Environmental Performance Index for each domain of the city is derived by averaging the CIV values computed for each of the indicators in the domain and multiplying it with the weightages given by experts as described in the process in the previous point.

EPI (CIV_{Air}) =Average CIV scores ($A_1, A_2, \ldots, A_n$) X weightages given by experts

Where A_1, A_2 and A_n are the various indicators under the domain of air.

4. Construction of the Index:

Calculating Environmental Performance Index (Micro)

EPI (Micro) = ∑ {EPI (Air) + EPI (Water) + ………+ EPI (Popn.) +EPI (Economy)}

5. Ranking of the Settlements Based on the EPI (Micro) Score

Based on the individual Environmental Performance Index (Micro) for each settlement the Scores are arranged in a descending order. The settlement obtaining the highest

EPI (Macro) Score is assigned the first ranking and the one with the least score the last ranking.

3.6.2.3 Calculating Correlation

It is of interest to know how much does a variable change when another variable is also changing. There may or may not be any cause among these changes. Statistically, the correlation between any two variables zj and zj' is given by:

$$r_{j,j'} = \frac{1}{(n-1)} \sum_{j=1}^{j=n} z_{i,j} \text{ X } z_{i,j'}$$

For e.g., there could be a square matrix with number of rows and columns equal to the number of indicators. All the diagonal elements of this matrix R were equal to one, since the indicators were normalised /standardised before calculating the correlation.

The range value of the coefficient of correlation R determines the degree of strength between the indicators. The strength according to the range value of R is given in the Table 3.2.

Table 3.2: Degree of strength between the indicators with respect to the corresponding range value of the coefficient of correlation (R)

Strength	**Range value of R**
Feebly Correlated	(0.4 < R <0.5)
Moderately Correlated	(0.5 < R <0.6)
Strongly Correlated	(R >0.6)
Negatively Correlated	R is negative

CHAPTER 4
APPLICATION OF ENVIRONMENTAL PERFORMANCE INDEX AT MACRO LEVEL: A CASE STUDY OF MILLION PLUS CITIES IN INDIA

4.1 URBAN SETTLEMENTS IN INDIA

The term 'urban' is related to towns or cities and an urban settlement is an enlarged settlement in which the majority of the employed inhabitants are engaged in non-agricultural activities with a domination of secondary and tertiary sector. As per the Census of India 2011, the definition of an urban area/settlement is as following:

a) All places with a municipality, corporation, cantonment board or notified town area committee, etc.
b) All other places which satisfied the following criteria:
    i. A minimum population of 5,000;
    ii. At least 75 per cent of the male main working population engaged in non-agricultural pursuits; and
    iii. A density of population of at least 400 persons per sq. km.

The urban settlements which satisfy the conditions mentioned in category (a) are known as statutory towns as these towns are notified under law by the concerned State/UT Government and have local bodies like municipal corporations, municipalities, municipal committees etc., irrespective of their demographic characteristics. Whereas the urban settlements which satisfy the conditions mentioned in category (b) are known as Census Towns.

The census towns are further grouped on the basis of the population size. The towns which have at least one hundred thousand persons as population are categorized as Class I towns and out of these towns, which have a population of one million or above, are known as Million Plus Cities, which are the major urban settlements in the country. The growth of urban settlements in India as per census 2001 and census 2011 data is given in the Table 4.1:

Table 4.1 Growth of Urban Settlements in India (2001-2011)

Details	2001	2011
Total No. of Towns	5161	7935
Statutory Towns	3799	4041
Census Towns.	1362	3894
Class I Towns/cities	384	475
Million Plus cities	35	53

Source: Census Data, 2001-2011

As per Census 2011, there are 7935 towns in the country comprising of 4041 Statutory Towns and 3894 Census Towns. There is a net increase of 2774 towns in the total number of towns in the country since 2001. A total of 377.1 million people are residing in these urban centers accounting for 31.16 per cent of the total population of India in 2011.

Out of 7935 towns in 2011, 475 qualify as Class-I towns/Cities with a net increase of 91 cities since 2001 and accommodates in total 264.9 million persons accounting for around 70 percent of the total urban population of the country.

Out of 475 cities in 2011, 53 cities qualify as Million Plus Cities having a population of one million or above, with a net increase of 18 cities with a population of million plus since 2001. These 53 million plus cities are the key urban centers in the country accommodating around 160.7 million persons accounting for 42.6 percent of the total urban population. There has been an increasing concentration of urban population in the Million Plus Cities in India. In 1981, 26 percent of the total urban population was living in million plus cities, which increased to 42.6 percent of the total urban population in 2011. The trend of growth of million plus cities in India from 1981-2011 is given in Table 4.2 below:

Table 4.2 Growth of Million Plus Cities in India (1981-2011)

Details	1981	1991	2001	2011
No. of Million Plus Cities	12	23	35	53
Urban Population in Million Plus Cities	42	70	108	160.7
Percentage of Population in Million Plus Cities to Total Urban Population	26	32	37.8	42.6

Source: Census Data, 1981-2011

Urbanisation is a natural consequence of economic changes that take place as a country develops. Urbanisation helps to contribute to the growth process at large. Cities and metropolitan areas, i.e., the major urban areas are major contributors to national economies and play a key role as nodes in global markets. This is manifested in the increasing contribution of urban sector to national income. For instance, in 1950-51 the contribution of urban sector to India's GDP was estimated at only 29 per cent, which increased to 47 per cent in 1980-81. The urban sector presently contributes about 62 per cent to 63 per cent of the GDP and is expected to increase to 75 per cent by 2021 (Planning Commission, Government of India). Moreover, at a time of deepening globalisation and increasing international competition for investment, metropolitan regions have become the targets of a wide range of development and interventions.

The positive role of urbanisation is often eclipsed by the evident deterioration in the physical and natural environment and quality of life in the urban areas. The real challenge lies in rethinking the urbanisation process to incorporate environmental sustainability taking the best advantage of economic momentum inherent in urbanisation.

4.1.1 Selecting Urban Settlements for Case Study at Macro Level

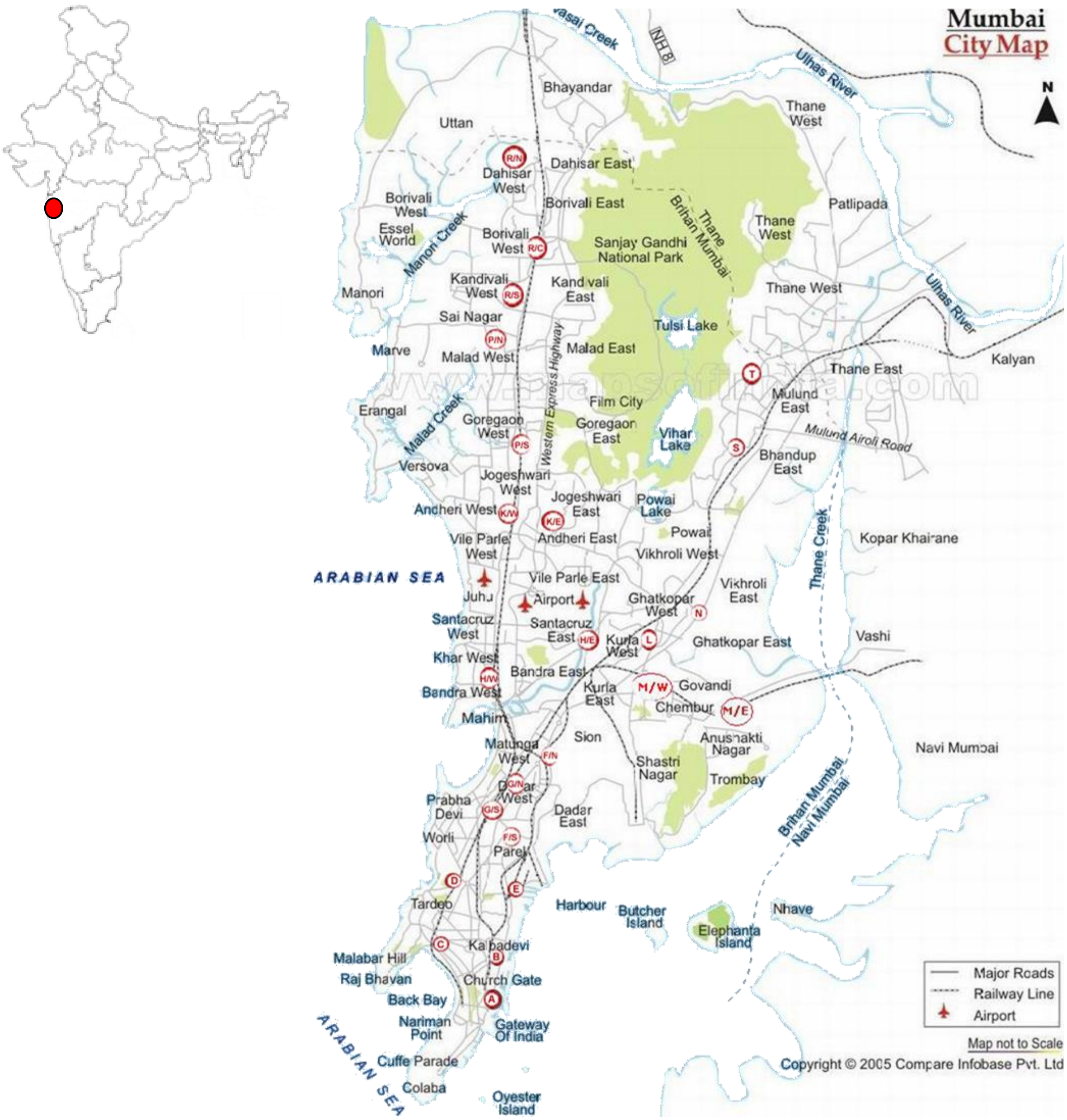
In the beginning of the twenty first century, there were 18 megacities in the world, 10 of which were in Asia and 3 being in India only. UN-DESA, 2011 report, which analyses the urbanisation trends over the world, the future urban population will be increasingly concentrated in large cities of one million or more inhabitants, where the megacities of at least 10 million inhabitants will experience the largest percentage increase. This increasing urban concentration in very large cities is a trend being observed world over and urbanisation in India is also treading on the same line.

Amongst the Million Plus Cities in India, there are three very large urban agglomerations with more than 10 million persons each, which are known as ‘Mega Cities’. An Urban agglomeration is a continuous urban spread constituting of a town and its adjoining urban outgrowth; or two or more contiguous towns with or without their outgrowths and; or a city and one or more adjoining towns with their outgrowths together forming contiguous stretch. These Mega Cities in India are Greater Mumbai UA, Delhi UA and Kolkata UA in order of their decreasing size of population and accounts for roughly around more than 30 percent of the total urban population residing in the 53 million plus cities in 2011. During the last decade of 2001-2011, Delhi UA witnessed the highest population growth of 26.69 per cent followed by Greater Mumbai UA with a population growth of 12.05 per cent. Kolkata UA witnessed the least population growth of 6.87 per cent only (Census, 2011). Though the growth of population in all the three Mega Cities has slowed down in the last decade compared to the previous one, Delhi UA and Mumbai UA are still having a considerable population growth.

The National Capital Territory (NCT) of Delhi, the administrative capital of India and the Greater Mumbai, the financial capital of India apart from being the capital of Maharashtra State, are the two most populous and important million plus cities in the country, forming a part of the two largest urban agglomerations in India. Apart from these there are six more cities in India which have a population of above five million these include Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune .They are the face of major urban settlements in India and need to be at par with the other major global megacities. At present they are witnessing a lot of population concentration pressure due to huge in-migration, as they are the seat of economic development of the country and present a plethora of employment opportunities. Hence, there is an utmost need to look into the urban environmental sustainability of these cities so that they can maintain their quality of life and urban environment without crumbling under the pressure of population density and resulting infrastructural demands and environmental degradation.

4.2 A BRIEF ABOUT THE SELECTED URBAN SETTLEMENTS

4.2.1 MUMBAI- A Brief about the City



Map 4.1: Mumbai City Map

Source: MCGM

Location	Mumbai, the capital city of the Indian state of Maharashtra, is located at the western coast of India at the latitude of 18°55'N and longitude 72°54'E and at an elevation of 14m (46 ft.).
Area	The total area of Mumbai city is approximately 603 sq.km. Mumbai city consists of two distinct regions: Mumbai City district and Mumbai Suburban district, which form two separate revenue districts of Maharashtra. The city district region is also commonly referred to as the Island City or South Mumbai. The island city spans 67.79 sq.km (26 sq.mi.), while the suburban district spans 370 sq.km(143 sq.mi.), together accounting for 437.79 sq.km (169 sq.mi.) under the administration of Municipal Corporation of Greater Mumbai, also known as Brihanmumbai Municipal Corporation (BMC). The remaining area belongs to Defence, Mumbai Port Trust, Atomic Energy Commission and Borivali National Park, which are not under the jurisdiction of the BMC. Greater Mumbai Municipal Corporation forms a part of the Mumbai Metropolitan Region that extends over an area of 4355 sq.km and comprises of Municipal Corporations of Greater Mumbai, Thane, Kalyan, Navi Mumbai and Ulhasnagar; 15 municipal towns; 7 non municipal urban centers; and 995 villages. Its administrative limits cover Mumbai city and Mumbai suburban Districts and parts of Thane and Raigad district. There are 40 planning Authorities in the Region that are responsible for the micro level planning of the different areas.
Population	As per 2011 Census Municipal Corporation of Greater Mumbai- 12,478,447
Geography	Mumbai lies at the mouth of the Ulhas River on the western coast of India, in the coastal region known as the Konkan. It is located on the

	Salsette Island, which is partially shared with the Thane district. Mumbai is bounded by the Arabian Sea to the west. Many parts of the city lie just above sea level, with elevations ranging from 10 m (33 ft) to 15 m (49 ft). The city has an average elevation of 14 m (46 ft). Northern Mumbai (Salsette) is hilly and the highest point in the city is 450 m (1,476 ft) at Salsette in the Powai–Kanheri ranges. There are five non-perennial rivers in Greater Mumbai- Dahisar River, Poisar River, Oshiwara River, Mithi River and Mahul River/Creek. In the absence of perennial rivers, harnessing of surface water became inevitable through lakes and ponds. At present Water supply to Mumbai city is dependent on six lakes- Tulsi, Vihar, Tansa, Upper Vaitarna, Bhatsa and Mumbai-III. Three small rivers, the Dahisarr, Poisar and Oshiwara originate within the Sanjay Gandhi National Park (SGNP), the only remaining forest area in Mumbai today, while the polluted Mithi River originates from Tulsi Lake and gathers water overflowing from Vihar and Powai Lakes. The coastline of the city is indented with numerous creeks and bays, stretching from Thane creek on the eastern to Madh Marve on the western front. The eastern coast of Salsette Island is covered with large mangrove swamps, rich in biodiversity, while the western coast is mostly sandy and rocky. Soil cover in the city region is largely sandy owing to its proximity to the sea. In the suburbs, the soil cover is largely alluvial and loamy. The underlying rock of the region is composed of black Deccan basalt flows and their acidic and basic variants. Mumbai sits on a seismically active zone owing to the presence of 23 fault lines in the vicinity. The area is classified as a Seismic Zone III region.
Climate	Mumbai has tropical wet and dry climate with seven months of dryness and peak of rains in July. The cooler season from December to February is followed by the summer season from March to June. The

	period from June to about the end of September constitutes the south-west monsoon season, and October and November form the post-monsoon season. The average total annual rainfall is 2,146.6 mm (85 in) for the Island City, and 2,457 mm (97 in) for the suburbs. In the Island City, the average maximum temperature is 31.2 °C (88 °F), while the average minimum temperature is 23.7 °C (75 °F).
Economic structure	Mumbai is India's financial and commercial capital and it generates 6.16 percent of the total GDP. As of 2009, Mumbai's GDP was approximately Rs 13,000 Crores and its per-capita income in 2010 was nearly Rs1,25,000 which was almost two times the national average. Mumbai is the world's 29th largest city by GDP. Mumbai was ranked among the fastest cities in India for business start-up in 2009. Headquarters of a number of Indian financial institutions such as the Bombay Stock Exchange, Reserve Bank of India, National Stock Exchange, the Mint, as well as numerous Indian companies such as the Tata Group, Essel Group and Reliance Industries are located in Mumbai. Most of these offices are located in downtown South Mumbai which is the nerve centre of the Indian economy. Until the 1970s, Mumbai owed its prosperity largely to textile mills and the seaport, but the local economy has since then diversified to include finance, engineering, diamond-polishing, healthcare and information technology which have become the key sectors contributing significantly to the city's economy. State and central government employees make up a large percentage of the city's workforce. Mumbai also has a large unskilled and semi-skilled self-employed population, who primarily earn their livelihood as hawkers, taxi drivers, mechanics and other such professions. The port and shipping industry is well established, with Mumbai Port being one of the oldest and most significant ports in India. Dharavi, in central Mumbai, has an increasingly large recycling industry, processing recyclable waste from other parts of the city.

4.2.2 DELHI - A Brief about the City

Map 4.2: Delhi City Map

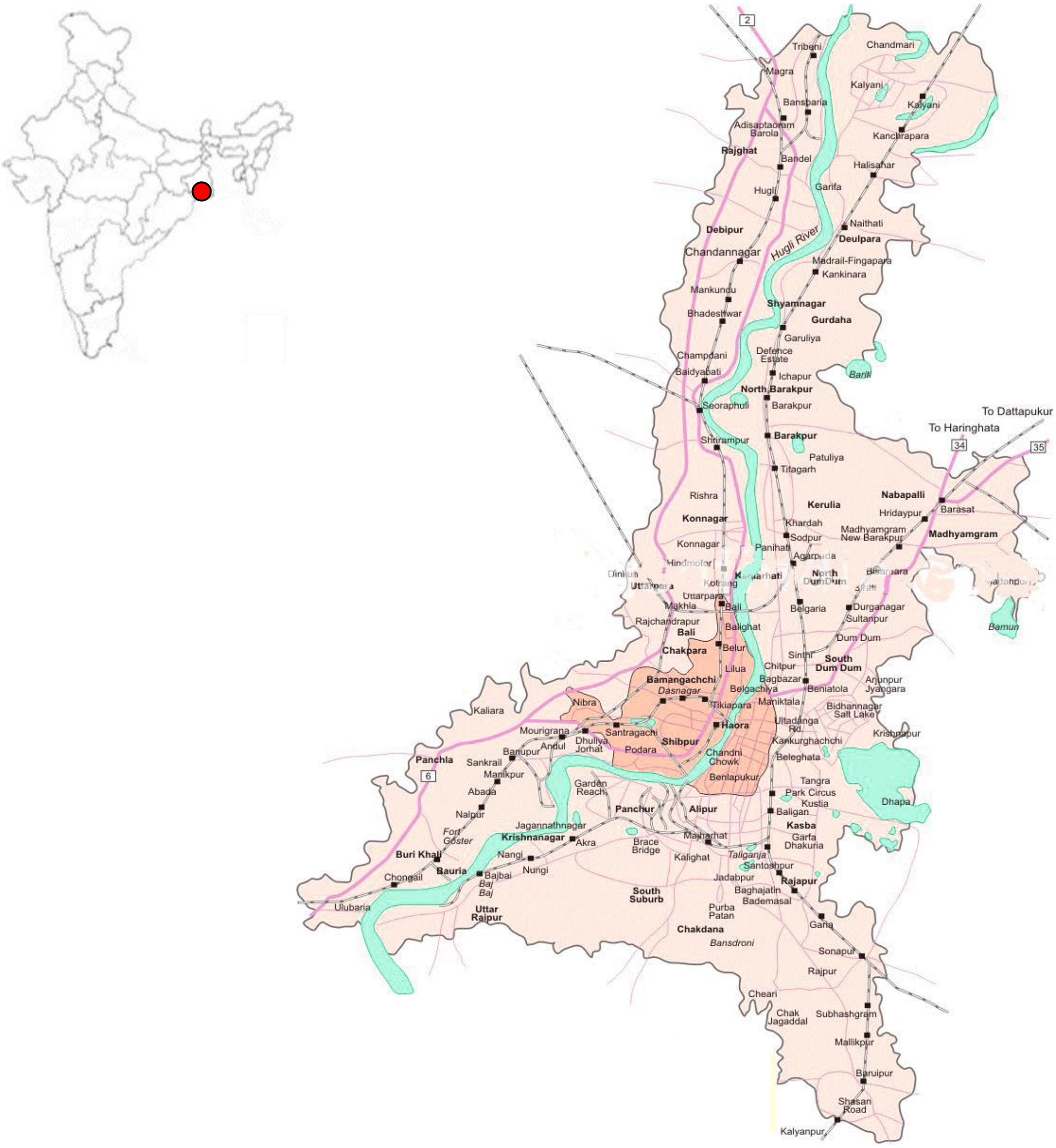
Source: www.indiamapsonline.com

Location	The capital city of Delhi is located in the fertile northern plains of India between the latitudes of 28-24'-17" and 28-53'-00" North and longitudes of 760-50'-24" and 77o-20'-37" East. It shares the borders

	with the States of Uttar Pradesh and Haryana.
Area	The National Capital Territory of Delhi (NCTD) has an area of about 1483 sq.km with a maximum length of 51.90 Kms and maximum width of 48.48 kms. NCTD area consists of the following Municipal areas: • New Delhi Municipal corporation (NDMC) area at the core covering an area of 42.74 sq.km • Municipal Corporation of Delhi (MCD) area covering an area of 1397 sq.km i.e. 94% of the area of the city • Delhi Cantonment Board (DCB) area between the airport and the NDMC area, covering an area of 42.97 sq.km. The National Capital Territory of Delhi (NCTD) is a part of the National Capital Region (NCR) i.e. the metropolitan area encompassing the entire NCT Delhi as well as urban areas surrounding it in neighbouring states of Haryana, Uttar Pradesh and Rajasthan spread over an area of 46,208 sq.km
Population	As per 2011 Census (in million) NCTD - 16,753,235, out of which; Delhi Municipal Area -11,007,835
Geography	The Yamuna River and the Aravalli Hill ranges covered with forest called the Ridges are the two main geographical features of the city. For the city of Delhi river Yamuna is the main source of drinking water. There is a forest cover of 11.5% of the total area in Delhi. The mineral resources for Delhi are primarily sand and stone which are used mainly for construction related activities.
Climate	Delhi has a semi-arid climate with hot summers, average rainfall and moderate winters.

	Summers are long and extremely hot starting from early April to mid-October and temperature can rise to 40-45 degrees. Immense build-up of particulate matter in the atmosphere is a regular feature during the summer months when dust storms become frequent. Winter starts in late November and peaks in January with a minimum temperature falling to 4 to 5 degree Celsius. February, March, October and November are climatically the better months. The average annual rainfall in Delhi is around 611 mm majority of which is in monsoon months - July, August and September. Heavy rainfall in the catchment area of the Yamuna results in a flood situation for the city.
Economic structure	Delhi is rapidly emerging as a world class metropolis and has one of the fastest growing economies in the country with a 15 percent average annual compounded growth rate of GSDP in 2002-03. Delhi's economy is driven by the service sector which accounts for 78 percent of its GSDP (Gross State Domestic Product) and provides employment to 58 percent of the working force. The per capita income at Rs 1,36,690/- in 2010 is more than double the national average of Rs 60,172/-, in fact the highest in the country and acts as a magnet for immigration from other states. The analysis of sectoral growth reveals that the contribution of primary sector and secondary sector is decreasing and the tertiary sector or the service sector comprising of trade, hotels and restaurants, transport, storage, communication, real estate, business services, banking and insurance and other services is the major contributor to the economy of Delhi.

4.2.3 KOLKATA- A Brief about the City



Map 4.3: Kolkata City Map

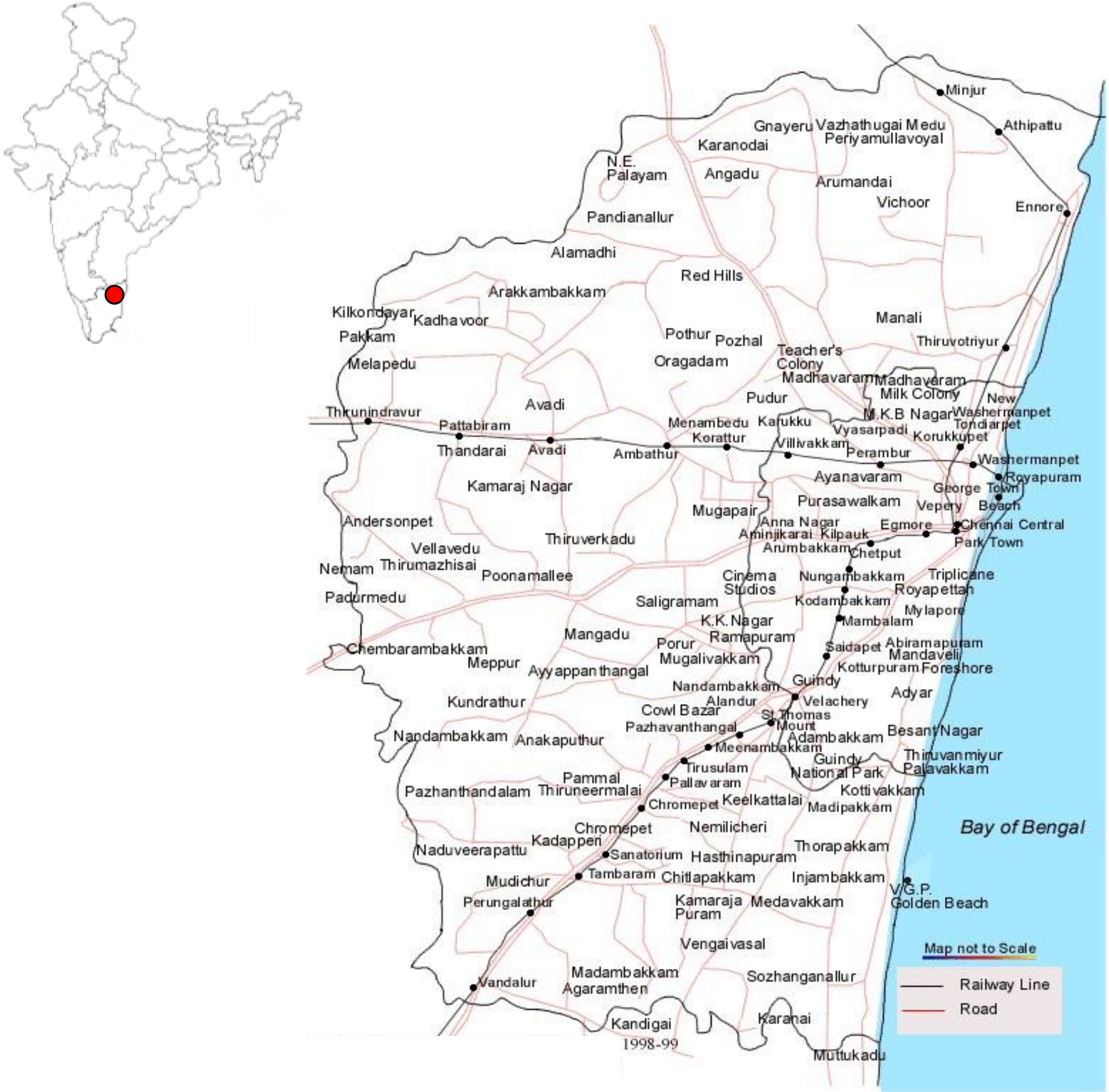
Source: Geography Blog

Location	One of the biggest cities of India, **Kolkata** is a capital of West Bengal state and is located on the Hooghly River. The latitude and longitude coordinates of Kolkata are 22°-33'- 47.47" North, 88° - 21'- 46.94"East.

Area	Kolkata, which is under the jurisdiction of the Kolkata Municipal Corporation (KMC), has the total area of 185 sq.km. The Kolkata metropolitan area is spread over 1,886.67 sq.km and comprises 3 municipal corporations (including Kolkata Municipal Corporation), 39 local municipalities and 24 Panchayat samitis. Suburban areas in the Kolkata metropolitan area incorporate parts of the following districts: North 24 Parganas, South 24 Parganas, Howrah, Hooghly, and Nadia. The east–west dimension of the city is comparatively narrow, stretching from the Hooghly River in the west to roughly the Eastern Metropolitan Bypass in the east—a span of 9–10 km. The north–south distance is greater, and its axis is used to section the city into North, Central, and South Kolkata.
Population	As per 2011 census Population of Kolkata Municipal Area- 4,496,694
Geography	Kolkata is located in the eastern part of India. It has spread linearly along the banks of Hooghly River. The city is near sea level, with the average elevation being 17 feet. It is located atop the western part of the hinge zone which is about 25 km wide at a depth of about 45,000 m (148,000 ft) below the surface. The whole area is in the Ganges Deltaic plain which starts within 100 km south to the city. Most of the city was originally marshy wetlands, remnants of which can still be found especially towards the eastern parts of the city. As with most of the Indo-Gangetic Plain, the soil and water are predominantly alluvial in origin.
Climate	Kolkata has a Tropical wet-and-dry climate, with summer monsoons. The annual mean temperature is 26.8 °C (80 °F); monthly mean

	temperatures range from 19 °C to 30 °C (67 °F to 86 °F)and maximum temperatures can often exceed 40 °C (104 °F) during May–June. Winter tends to last from December to early-February, with the lowest temperatures hovering in the 12 °C — 14 °C range during December and January. The highest recorded temperature is 43 °C (111 °F) and the lowest is 5 °C (41 °F). Monsoon is the most notable phenomenon in the climate of the city. Maximum rainfall occurs during the monsoon in August (306 mm) and the average annual total is 1,582 mm. Early morning mists and evening smog occur often due to temperature inversions. Summer is dominated by strong south westerly monsoon winds, often during early summer, spells of thunderstorm and heavy rains lashes the city, bringing some relief from the heat and intolerable humidity.
Economic structure	Kolkata is the main business, commercial and financial hub of eastern India and the main port of communication for the North-East Indian states, It is one of the most important metros of India. It is home to India's oldest, and also India's second-largest stock exchange company – The Calcutta Stock Exchange. Kolkata is home to a major port, an international airport and many nationally and internationally reputed colleges and institutions aimed at supplying a highly skilled work force. South Asia's first metro railway service was the Kolkata Metro. There are a few of the oldest and front line banks and PSUs in India—such as UCO Bank, Allahabad Bank, United Bank of India and Tea Board of India—were founded and is headquartered in Kolkata. The oldest operating photographic studio in the world, Bourne & Shepherd, is also based in the city. The Standard Chartered Bank has a major branch in Kolkata. Kolkata is also the headquarters of Botanical Survey of India and Zoological Survey of India and many more organisations and companies.

4.2.4 CHENNAI- A Brief about the City



Map 4.4: Chennai City Map

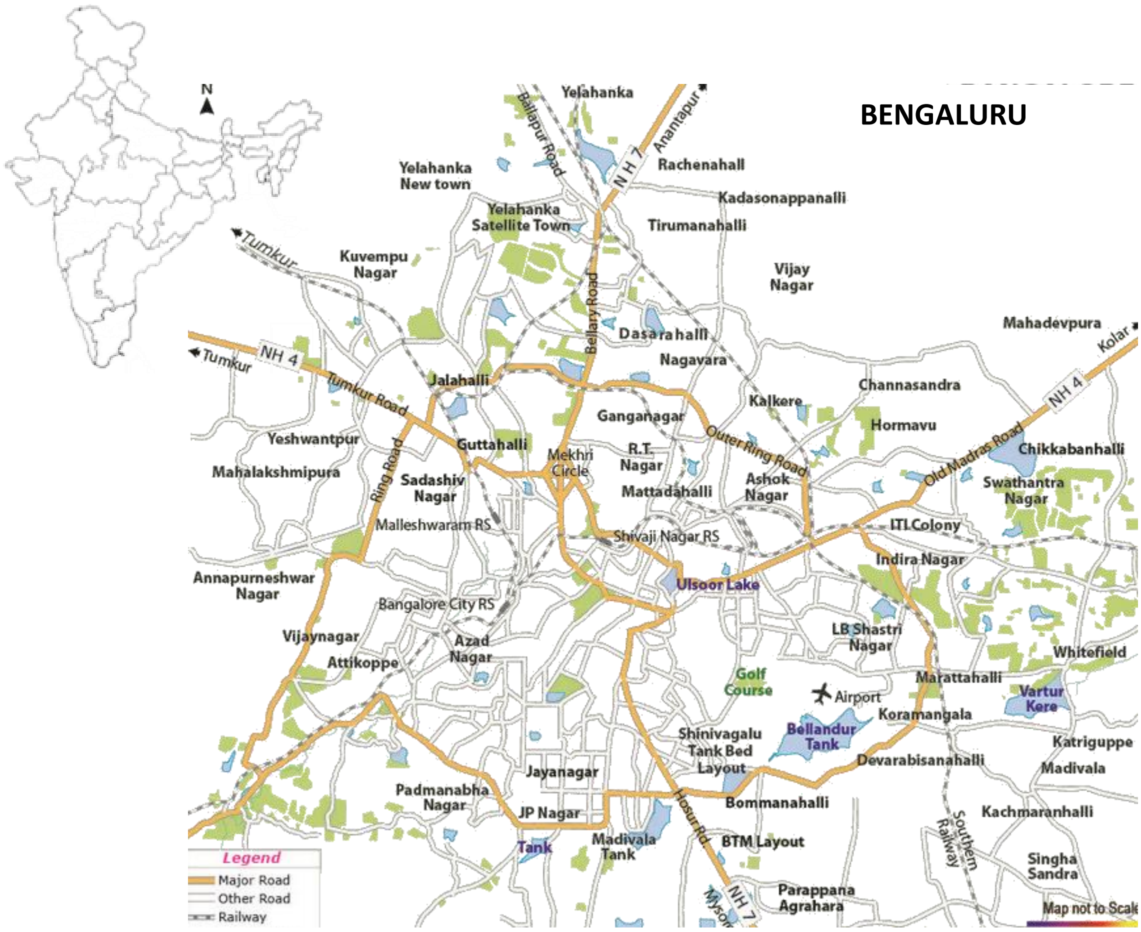
Source: Geography Blog

Location	Chennai is the capital of the Indian state of Tamil Nadu. Located on the Coromandel Coast of the Bay of Bengal, it is one of the biggest cultural, economic and educational centres in South India. It lies at the average elevation of 6.7 metres (22 ft) between the latitude of 13° 5'0" N and longitude 80° 16'0"E.

Area	The total area of Chennai city is approximately 426 sq.km.
Population	As per 2011 Census Population of Chennai City- 4681087
Climate	Chennai has a tropical wet and dry climate. The city lies on the thermal equator and is also on the coast, which prevents extreme variation in seasonal temperature. The hottest part of the year is late May to early June, known regionally as *Agni Nakshatram* ("fire star") or as *Kathiri Veyyil*, with maximum temperatures around 35–40 °C (95–104 °F). The coolest part of the year is January, with minimum temperatures around 19–25 °C (66–77 °F). The city gets most of its seasonal rainfall from the north–east monsoon winds, from mid–October to mid–December. Cyclones in the Bay of Bengal sometimes hit the city. The highest annual rainfall recorded is 257 cm (101 in) in 2005. Prevailing winds in Chennai are usually south-westerly between April and October and north-easterly during the rest of the year. Historically, Chennai has relied on the annual rains of the monsoon season to replenish water reservoirs, as no major rivers flow through the area. Chennai has a water table at 2 metres for 60 percent of the year.
Economic structure	The Chennai Metropolitan Area is one of the largest city economies of India. Chennai is nicknamed "The Detroit of India", with more than one-third of India's automobile industry being based in the city. Recent estimates of the economy of the entire Chennai Metropolitan Area have ranged from US$58.6 to US$66 billion (GDP), ranking it as one of the top most productive metro areas of India and the third highest GDP per capita. The metropolitan area doesn't include the nearby industrial zones of Sholinganallur, Siruseri, Oragadam and Sriperumbudur. Chennai has an economic base anchored by the automobile, software

	services, medical tourism, hardware manufacturing and financial services. Other important industries include petrochemicals, textiles and apparels. The Chennai Port and Ennore Port contribute greatly to its importance. Since the late 1990s, software development and business process outsourcing and more recently electronics manufacturing have emerged as major drivers of the city's economic growth. The city is now the second largest exporter of IT and IT enabled Services in the country behind Bengaluru. The Mahindra World City, New Chennai, a Special Economic Zone (SEZ) with one of the world's largest high technology business zones, is currently under construction in the outskirts of Chennai. It also includes the World's largest IT Park by Infosys. Chennai is known as the Detroit of Asia. The city accounts for 60 per cent of India's automotive exports, which leads it to be called as 'The Detroit of Asia'. Chennai has a market share of around 30% of India's automobile industry and 35% of its auto components industry. A large number of the automotive companies including several global automotive companies such as BMW, Hyundai, Ford, Nissan, Renault, Mitsubishi, TVS Motor Company, Ashok Leyland, Caterpillar, Royal Enfield, TI Cycles, TAFE, Dunlop, MRF, Daimler, Yamaha and Apollo Tyres have manufacturing plants in and around Chennai. Chennai leads in the health care sector and is considered the Health Capital of India. Home to some of India's best health care institutions such as Apollo Hospitals, the largest health care provider in Asia,[27] MIOT Hospitals, Sankara Nethralaya, Sri Ramachandra Medical Center, Fortis Healthcare, Dr.Mehtas Hospitals, Sundaram Medical Foundation (SMF), Madras Medical Mission (MMM), Frontier Lifeline & K.M. Cherian Heart Foundation, Chettinad Health City and Adyar Cancer Institute, Chennai is a preferred destination for medical tourists from across the globe. Chennai attracts about 45% of all health tourists arriving in India from abroad in addition to 30% to 40% of domestic tourists.

4.2.5 BENGALURU- A Brief about the City



Map 4.5: Bengaluru City Map

Source: Geography Blog

Location	Bangalore now known as Bengaluru lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 900 m (2,953 ft). It is located at 12°58′N 77°34′E / 12.97°N 77.56°E.
Area	Bengaluru covers an area of 804.83 sq.km. The majority of the city of Bengaluru lies in the Bengaluru Urban district of Karnataka and the surrounding rural areas are a part of the Bengaluru Rural district. The Government of Karnataka has carved out the new district of Ramanagara from the old Bengaluru Rural district.

Population	As per 2011 Census, population of Bengaluru is 8,425,970.
Geography	The topology of Bengaluru is generally flat, though the western parts of the city are hilly. The highest point is Vidyaranyapura Doddabettahalli, which is 962 metres (3,156 feet) and is situated to the north-west of the city. No major rivers run through the city, although the Arkavathi and South Pennar cross paths at the Nandi Hills, 60 kilometres (37 miles) to the north. River Vrishabhavathi, a minor tributary of the Arkavathi, arises within the city at Basavanagudi and flows through the city. The rivers Arkavathi and Vrishabhavathi together carry much of Bengaluru's sewage. A sewerage system, constructed in 1922, covers 215 km2 (83 sq. m.) of the city and connects with five sewage treatment centres located in the periphery of Bengaluru. Bengaluru has a handful of freshwater lakes and water tanks, the largest of which are Madivala tank, Hebbal lake, Ulsoor lake, Yediyur Lake and Sankey Tank. Groundwater occurs in silty to sandy layers of the alluvial sediments. The Peninsular Gneissic Complex (PGC) is the most dominant rock unit in the area and includes granites, gneisses and magmatites, while the soils of Bengaluru consist of red laterite and red, fine loamy to clayey soils. Vegetation in the city is primarily in the form of large deciduous canopy and minority coconut trees. Though Bengaluru has been classified as a part of the seismic zone II (a stable zone), it has experienced quakes of magnitude as high as 4.5
Climate	Bengaluru has a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation, it usually enjoys a more moderate climate throughout the year, although occasional heat waves can make summer somewhat uncomfortable. The coolest month is January with an average low temperature of 15.1 °C (59.2 °F) and the hottest month is April with an average high temperature of 35 °C (95 °F). The highest temperature ever recorded

	in Bengaluru is 39.2 °C (103 °F) (recorded on 24 April 2016) as there was a strong El Nino in 2016. There were also unofficial records of 41 °C (106 °F) on that day. The lowest ever recorded is 7.8 °C (46 °F) in January 1884. Winter temperatures rarely drop below 14 °C (57 °F), and summer temperatures seldom exceed 36 °C (97 °F). Bengaluru receives rainfall from both the northeast and the southwest monsoons and the wettest months are September, October and August, in that order. The summer heat is moderated by fairly frequent thunderstorms, which occasionally cause power outages and local flooding. Most of the rainfall occurs during late afternoon/evening or night and rain before noon is infrequent.
Economic structure	Bengaluru was the fastest-growing Indian metropolis after New Delhi between 1991 and 2001, with a growth rate of 38% during the decade. With an economic growth of 10.3%, Bengaluru is the second fastest-growing major metropolis in India, and is also the country's fourth largest fast-moving consumer goods (FMCG) market. Bengaluru is called as the *Silicon Valley of India* because of the large number of information technology companies located in the city which contributed 33% of India's ₹1,442 billion (US$22 billion) IT exports in 2006–07. Bengaluru's IT industry is divided into three main clusters – Software Technology Parks of India (STPI); International Tech Park, Bengaluru (ITPB); and Electronics City. UB City, the headquarters of the United Breweries Group, is a high-end commercial zone. Infosys and Wipro, India's third and fourth largest software companies are headquartered in Bengaluru, as are many of the global *SEI-CMM Level 5 Companies*. The growth of IT has presented the city with unique challenges. Ideological differences are there between the city's IT moguls, who demand an improvement in the city's infrastructure, and the state government, whose electoral base is primarily the people in rural Karnataka.

4.2.6 HYDERABAD- A Brief about the City

Map 4.6: Hyderabad City Map

Source: www.indiamapsonline.com

Location	Hyderabad is situated in the southern part of Telangana in south-eastern India. It lies on the banks of the Musi River, in the northern part of the Deccan Plateau, at the Average elevation of about 536 metres above sea level (1,607 ft). It is located 17°12' N and 78°18' E.

Area	Greater Hyderabad covers 217 sq km with an average altitude of 542 metres (1,778 ft). The Greater Hyderabad Municipal Corporation (GHMC) oversees the civic infrastructure of the city's 30 "circles", which together encompass 150 municipal wards. Each ward is represented by a corporator, elected by popular vote. The GHMC was formed in April 2007 by merging the Municipal Corporation of Hyderabad (MCH) with 12 municipalities of the Hyderabad, Ranga Reddy and Medak districts covering a total area of Hyderabad. The jurisdictions of the city's administrative agencies are, in ascending order of size: the Hyderabad Police area, Hyderabad district, the GHMC area ("Hyderabad city") and the area under the Hyderabad Metropolitan Development Authority (HMDA). The HMDA is an apolitical urban planning agency that covers the GHMC and its suburbs, extending to 54 *mandals* in five districts encircling the city. It coordinates the development activities of GHMC and suburban municipalities and manages the administration of bodies such as the Hyderabad Metropolitan Water Supply and Sewerage Board.
Population	As per 2011 Census Hyderabad city has population of 6,731,790;
Geography	Hyderabad lies on predominantly sloping terrain of grey and pink granite, dotted with small hills, the highest being Banjara Hills at 672 metres (2,205 ft). Most of the area has a rocky terrain and some areas are hilly spreading on the North and South bank of the river Musi, a tributary of Krishna. The Hussain Sagar Lake is centrally located in the city and connecting the Hyderabad and Secunderabad twin cities. Geomorphologically the area is divided into (1) Residual Hills (2) Pediment inselberg complex (3) Shallow to moderate weathered pediplains and (4) Valley hills. The city has numerous lakes referred

	to as sagar, meaning "sea". Examples include artificial lakes created by dams on the Musi, such as Hussain Sagar (built in 1562 near the city centre), Osman Sagar and Himayat Sagar. As of 1996, the city had 140 lakes and 834 water tanks (ponds).
Climate	Hyderabad has a tropical wet and dry climate bordering on a hot semi-arid climate. The annual mean temperature is 26.6 °C (79.9 °F); monthly mean temperatures are 21–33 °C (70–91 °F). Summers (March–June) are hot and humid, with average highs in the mid-to-high 30s Celsius; maximum temperatures often exceed 40 °C (104 °F) between April and June. The coolest temperatures occur in December and January, when the lowest temperature occasionally dips to 10 °C (50 °F). May is the hottest month, when daily temperatures range from 26 to 39 °C (79–102 °F); December, the coldest, has temperatures varying from 14.5 to 28 °C (57–82 °F). Heavy rain from the south-west summer monsoon falls between June and September, supplying Hyderabad with most of its mean annual rainfall. Since records began in November 1891, the heaviest rainfall recorded in a 24-hour period was 241.5 mm (10 in) on 24 August 2000. The highest temperature ever recorded was 45.5 °C (114 °F) on 2 June 1966, and the lowest was 6.1 °C (43 °F) on 8 January 1946.[51] The city receives 2,731 hours of sunshine per year; maximum daily sunlight exposure occurs in February.
Economic structure	Recent estimates of the economy of Hyderabad's metropolitan area have ranged from ₹2,920 billion ($40 billion) to₹5,407 billion $74 billion (GDP), and have ranked it either fifth most productive metro area of India. Hyderabad is the largest contributor to the gross domestic product (GDP), tax and other revenues, of Telangana, and the sixth largest deposit centre and fourth largest credit centre

	nationwide, as ranked by the Reserve Bank of India (RBI) in June 2012. Its per capita annual income in 2011 was ₹45,300. Hyderabad's commercial markets are divided into four sectors: central business districts, sub-central business centres, neighbourhood business centres and local business centres. Many traditional and historic bazaars are located throughout the city, Laad Bazaar being the prominent among all is popular for selling a variety of traditional and cultural antique wares, along with gems and pearls. The development of HITEC City, a township with extensive technological infrastructure, prompted multinational companies to establish facilities in Hyderabad. The city is home to more than 1300 IT and ITES firms that provide employment for 407,000 individuals; the global conglomerates include Microsoft, Apple, Amazon, Google, IBM, Yahoo!, Oracle Corporation, Dell, Facebook, CISCO, and major Indian firms including Tech Mahindra, Infosys, Tata Consultancy Services (TCS), Polaris, Cyient and Wipro. In 2009 the World Bank Group ranked the city as the second best Indian city for doing business. The city and its suburbs contain the highest number of special economic zones of any Indian city. Like the rest of India, Hyderabad has a large informal economy that employs 30% of the labour force. According to a survey published in 2007, it had 40–50,000 street vendors, and their numbers were increasing. Among the street vendors, 84% are male and 16% female and four fifths are "stationary vendors" operating from a fixed pitch, often with their own stall.

4.2.7 AHMEDABAD- A Brief about the City

Map 4.7: Ahmedabad City Map

Source: www.indiamapsonline.com

Location	Ahmedabad is located at 23.03°N 72.58°E ; in western India at an elevation of 53 metres (174 ft). The city sits on the banks of the River Sabarmati, in north-central Gujarat.

Area	Ahmedabad covers an area of 464 sq km. Ahmedabad is divided by the Sabarmati into two physically distinct eastern and western regions. The eastern bank of the river houses the old city, which includes the central town of Bhadra. This part of Ahmedabad is characterised by packed bazaars, the *pol* system of closely clustered buildings, and numerous places of worship. The western part of the city houses educational institutions, modern buildings, residential areas, shopping malls, multiplexes and new business districts centred around roads such as Ashram Road, C. G. Road and Sarkhej-Gandhinagar Highway.
Population	As per 2011 Census Population of Ahmedabad is 5,633,927
Geography	Ahmedabad lies at 23.03°N 72.58°E in western India at 53 metres above sea level on the banks of the Sabarmati river, in north-central Gujarat. It covers an area of 464 sq.km. The Sabarmati frequently dried up in the summer, leaving only a small stream of water and the city is in a sandy and dry area. However with the execution of the Sabarmati River Front Project and Embankment, the waters from the Narmada river have been diverted to the Sabarmati to keep the river flowing throughout the year, thereby eliminating Ahmedabad's water problems. The steady expansion of the Rann of Kutch threatened to increase desertification around the city area and much of the state; however, the Narmada Canal network is expected to alleviate this problem. Except for the small hills of Thaltej-Jodhpur Tekra, the city is almost flat. Three lakes lie within the city's limits—Kankaria, Vastrapur and Chandola. Kankaria, in the neighbourhood of Maninagar, is an artificial lake developed by the Sultan of Gujarat, Kutb-ud-din, in 1451.

	Ahmedabad is divided by the Sabarmati into two physically distinct eastern and western regions. The eastern bank of the river houses the old city, which includes the central town of Bhadra. This part of Ahmedabad is characterised by packed bazaars, the pol system of closely clustered buildings, and numerous places of worship.
Climate	Ahmedabad has a hot, semi-arid climate, with marginally less rain than required for a tropical savannah climate. There are three main seasons: summer, monsoon and winter. Apart from the monsoon season, the climate is extremely dry. The weather is hot from March to June; the average summer maximum is 43 °C (109 °F), and the average minimum is 24 °C (75 °F). From November to February, the average maximum temperature is 30 °C (86 °F), the average minimum is 13 °C (55 °F), and the climate is extremely dry. Cold northerly winds are responsible for a mild chill in January. The southwest monsoon brings a humid climate from mid-June to mid-September. The average annual rainfall is about 800 millimetres (31 in), but infrequent heavy torrential rains cause local rivers to flood and it is not uncommon for droughts to occur when the monsoon does not extend far west. The highest temperature in the city was recorded on 18 and 19 May 2016 which was 50 °C (122 °F).
Economic structure	The first Indian textile mill, the Ahmedabad Spinning and Weaving Company Limited, was established in 30 May 1861 by Ranchhodlal Chhotalal followed by the establishment of a series of textile mills such as the Calico Mills, Bagicha Mills and Arvind Mills. By 1905 there were about 33 textile mills in the city. The textile industry further expanded rapidly during the First World War, and benefited from the influence of Mahatma Gandhi's Swadeshi movement, which promoted the purchase of Indian-made goods. Ahmedabad was known as the "Manchester of the East" for its textile industry.

	The city is the largest supplier of denim and one of the largest exporters of gemstones and jewellery in India. The automobile industry is also important to the city; after Tata's Nano project, Ford and Suzuki are planning to establish plants near Ahmedabad. Two of the biggest pharmaceutical companies of India — Zydus Cadila and Torrent Pharmaceuticals – are based in the city. The Nirma group of industries, which runs a large number of detergent and chemical industrial units, has its corporate headquarters in the city. The city also houses the corporate headquarters of the Adani Group, a multinational trading and infrastructure development company. The information technology industry has developed significantly in Ahmedabad, with companies such as Tata Consultancy Services opening offices in the city. A NASSCOM survey in 2002 on the "Super Nine Indian Destinations" for IT-enabled services ranked Ahmedabad fifth among the top nine most competitive cities in the country. The city's educational and industrial institutions have attracted students and young skilled workers from the rest of India. Ahmedabad houses other major Indian corporates such as: Rasna, Wagh Bakri, Nirma, Cadila Pharmaceuticals, and Intas Biopharmaceuticals. Ahmedabad is the second largest cotton textile centre in India after Mumbai and the largest in Gujarat. Many cotton manufacturing units are currently running in and around Ahmedabad. Textiles are one of the major industries of the city. Gujarat Industrial Development Corporation has acquired land in Sanand taluka of Ahmedabad to set up three new industrial estates.

4.2.8 PUNE- A Brief about the City

Map 4.8: Pune City Map

Source: www.indiamapsonline.com

Location	Pune is the second largest city in the Indian state of Maharashtra and the ninth most populous city in the country. Situated 560 metres (1,837 feet) above sea level on the Deccan plateau on the right bank of the Mutha River. The latitude and longitude of Pune are 18° 32' 42.6876" N and 73° 53' 2.1912" E.
Area	The total area of Pune city is approximately 807.2 sq.km. The city of Pune is divided into the following zones: Old city- established and developed during the Maratha rule and Peshwa administration, and are referred to as the old city. New City (Inner District)- Bounded on the north by the Mula-Mutha River. New City

	(Outer District)- Several education institutes are located in the Kothrud, Nagar Road, Bund Garden Road neighbourhoods. Inner Suburbs- Home to large IT Parks.
Population	As per 2011 census Population of the Pune city is 5,751,182
Geography	Pune is 560 m (1,840 ft) above sea level on the western margin of the Deccan plateau. It is on the leeward side of the Sahyadri mountain range, which forms a barrier from the Arabian Sea. It is a hilly city, with its highest hill, Vetal Hill, rising to 800 m (2,600 ft) above sea level. Just outside the city, the Sinhagad fort is at an altitude of 1,300 metres (4,300 feet). It lies between 18° 32" North latitude and 73° 51" East longitude. Pune is 1,533 kilometres (953 mi) south of Delhi, 844 kilometres (524 mi) north of Bengaluru, and 149 kilometres (93 mi) south-east of Mumbai by road.Central Pune is at the confluence of the Mula and Mutha Rivers. The Pavana and Indrayani Rivers, tributaries of the Bhima River, traverse the north-western outskirts of metropolitan Pune. Pune lies very close to the seismically active zone around Koyna Dam, about 100 km (62 mi) south of the city, and has been rated in Zone 3 (on a scale of 2 to 5, with 5 being the most prone to earthquakes) by the India Meteorological Department. Pune has experienced some moderate- and many low-intensity earthquakes in its history.
Climate	Pune has a hot semi-arid climate bordering with tropical wet and dry with average temperatures ranging between 19 to 33 °C (66 to 91 °F). Pune experiences three seasons: summer, monsoon, and winter. Typical summer months are from mid-March to June often extending till 15 June, with maximum temperatures sometimes reaching 42 °C (108 °F). The warmest month in Pune is May; although summer doesn't end until mid-June. The city often receives heavy dusty winds in May (and humidity remains high). Even during the hottest months, the nights are usually cool due to Pune's high altitude. The monsoon lasts from

	June to October, with moderate rainfall and temperatures ranging from 22 to 28 °C (72 to 82 °F). Most of the 722 mm (28.43 in) of annual rainfall in the city falls between June and September, and July is the wettest month of the year. Hailstorms are not unheard of in this region.Winter traditionally begins in November; November in particular is referred to as the Rosy Cold which can be experienced typically during the festive season of Diwali. The daytime temperature hovers around 26 °C (79 °F) while night temperature is below 9 °C (48 °F) for most of December and January, often dropping to 5 to 6 °C (41 to 43 °F). The lowest temperature ever recorded was 1.7 °C (35 °F) on 17 January 1935. The climate of Pune has changed during the past 3 decades, especially since the rapid expansion of the industrial belts
Economic structure	As one of the largest cities of India and major centre of learning with several colleges and universities, Pune is emerging as a prominent location for IT and manufacturing. Pune has the eighth largest metropolitan economy and the sixth highest per capita income in the country. Automotive companies such as Bajaj Auto, Tata Motors, Mahindra & Mahindra, Mercedes Benz, Force Motors (Firodia-Group), Kinetic Motors, General Motors, Land Rover, Jaguar, Renault, Volkswagen, and Fiat have set up greenfield facilities near Pune, often citing it as India's "Motor City”. The Kirloskar Group, was the first to bring industry to Pune by setting up Kirloskar Oil Engines Ltd. in 1945 at Kirkee in Pune. The Group was originally set up in Kirloskarwadi. Kirloskar Brothers Limited (India's largest manufacturer and exporter of pumps and the largest infrastructure pumping project contractor in Asia, Kirloskar Oil Engines (India's largest diesel engine company, Kirloskar Pneumatics Co. Ltd., and other Kirloskar companies are based in Pune. The Hinjewadi IT Park (officially called the Rajeev Gandhi IT Park) is a project being started by MIDC to house the IT sector in Pune. When completed, it is expected to encompass an area of about 2,800 acres (11 km^2). The estimated investment in the project is Rs 600 billion (US$9.3

	billion).To facilitate economic growth, the government made liberal incentives in its IT and ITES Policy, 2003 and leased properties on MIDC land. The IT sector employs more than 70,000 people. Software giant Microsoft intends to set up a 7 billion (US$110 million) project in Hinjewadi. Pune has also emerged as a new startup hub in India with tech startups like Pubmatic, Firstcry.com, Storypick.com, etc

4.3 ENVIORNMENTAL PROFILE OF THE EIGHT SELECTED (FIVE MILLION PLUS) CITIES

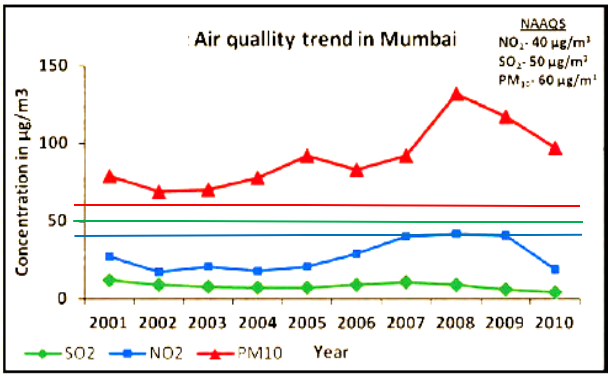
The present environmental status of the eight selected cities has been discussed under the following resource based domains as identified in the previous chapter:

- Air
- Water
- Land
- Energy
- Housing
- Infrastructure
- Population
- Finance

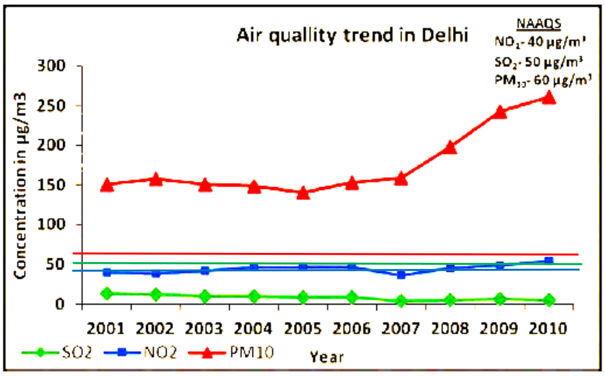
4.3.1 Air

Urbanisation in India is more rapid in million plus cities. Increase in industrial activities, population both endemic and floating and vehicular population etc. have led to a rapid increase in environmental problems, one of them being air pollution. An inventory of air pollutants is a necessary first step towards control of air pollution. Air pollutants can be natural or may be the result of various anthropogenic activities like industrial emissions. Meteorological factors play a critical role in ambient concentrations of air pollutants. Ambient air quality monitoring is required to determine the existing quality of air, evaluation of the effectiveness of control programme and to identify areas in need of restoration and their prioritization. The ambient air quality monitoring is being carried out regularly in the metropolitan cities by respective SPCBs and CPCB. The decadal trend of air quality for the period 2001-2010 of the eight selected million plus cities with respect to the CPCB permissible National Ambient Air Quality Standards (NAAQS) of annual average of SO_2, NO_2 and PM_{10} concentration is given in Table 4.3.

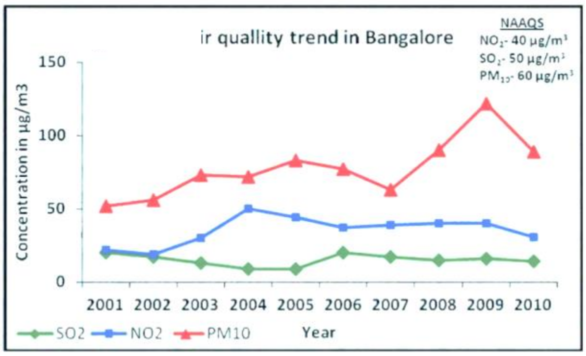
Table 4.3: DECADAL AIR QUALITY TREND, 2001-2010



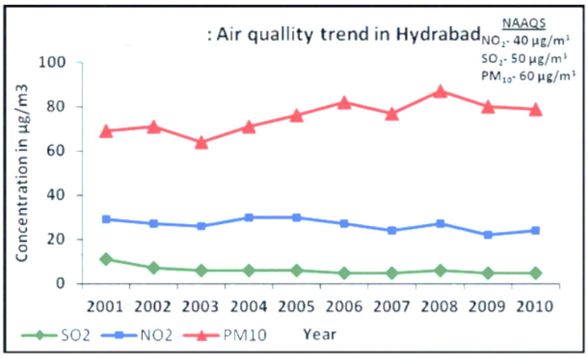
A decreasing trend for SO_2 and its levels are well within the permissible NAAQS limits and; an increasing trend for NO_2 till 2007 almost touching the threshold of permissible limit, followed by stagnation and a decreasing trend during 2009-10. The PM_{10} levels shows an increasing trend till 2008 followed by a decreasing trend during 2008-10, though exceeding the permissible limit in all the years.



A decreasing trend for SO_2 and its levels are well within the permissible NAAQS limits in all the years and; a fluctuating trend for NO_2 over the years crossing the permissible limit or almost at the threshold in few years. However, an increasing trend for PM_{10} has been observed over the years exceeding the permissible NAAQS limit in all the years.

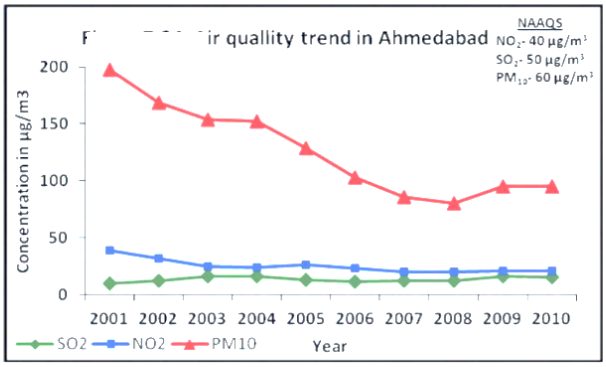


A decreasing trend for SO_2 observed till 2005, then a sudden increase between 2005-06, followed by a gradual subtle decrease till 2010, however SO_2 levels are well within the permissible NAAQS limits in all the years and; an increasing trend for NO_2 till 2004 almost exceeding the threshold of permissible limit in 2004-05, followed by a slight decrease though almost at the threshold till 2009, and a decreasing trend during 2009-10 bringing it within the permissible limits. The PM_{10} levels shows an increasing trend till 2005 followed by a decreasing trend during 2005-07 and a sudden shoot up between 2007-09 followed by a decline 2009 onwards, though exceeding the permissible limit in all the years.

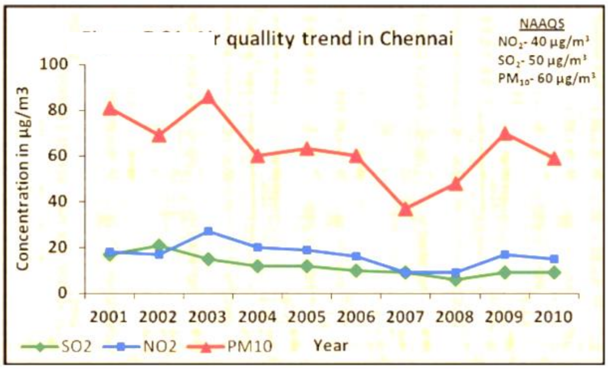


A decreasing trend for SO_2 and its levels are well within the permissible NAAQS limits and; almost stable trend of NO_2 till 2010 within the permissible limits. The PM_{10} levels shows an increasing trend till 2008 followed by a slight decrease during 2008-10, though exceeding the permissible limit in all the years.

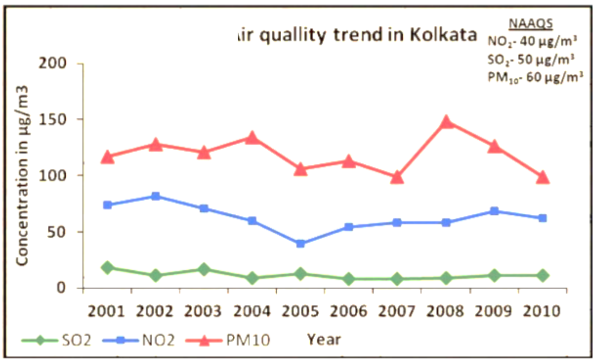
DECADAL AIR QUALITY TREND, 2001-2010



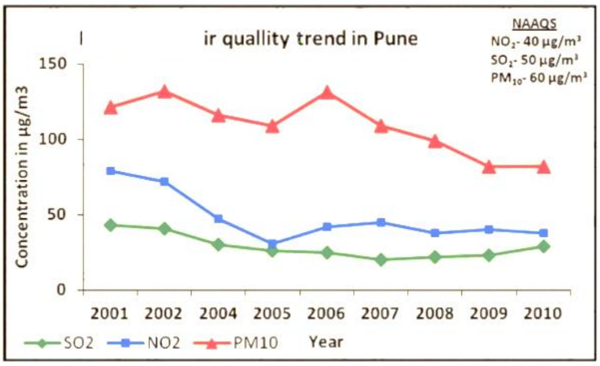
A slight increase in SO_2 levels during 2001-10, though well within the permissible NAAQS limits and; a decreasing trend of NO_2 till 2010, which was almost touching the threshold of permissible limit during 2001.The PM_{10} levels shows a continuous decreasing trend till 2008 followed by a slight increase during 2008-10, though exceeding the NAAQS permissible limit in all the years.



A decreasing trend for SO_2 and its levels are well within the permissible NAAQS in all the years and; a fluctuating trend for NO_2 over the years though well within the permissible limit in all the years. Overall a decreasing trend for PM_{10} has been observed between 2001-07, with the values within the permissible limits from 2006 onwards. However PM_{10} values exceed the permissible limits in 2009 and is almost at the threshold in 2010.



An almost stable trend for SO_2 and its levels are well within the permissible NAAQS limits in all the years and; a fluctuating trend for NO_2 over the years beyond the permissible limits in all the years except touching the threshold in 2005. A fluctuating trend for PM_{10} has been observed over the years with the values above the permissible limits in all the years.



An almost decreasing trend for SO_2 and its levels are well within the permissible NAAQS limits in all the years and; a decreasing trend for NO_2 between 2001-05 with almost stagnant values between 2006-10 almost at the threshold. A fluctuating trend for PM_{10} has been observed over the years with the values above the permissible limits in all the years.

Source: CPCB, 2001-2010

An analysis of ten years air quality data of eight selected million plus cities reveals a decreasing trend of SO_2. This may be attributed to various interventions that have taken place in recent years such as reduction in sulphur in diesel, use of cleaner fuel such as CNG in metro cities, change in domestic fuel from coal to LPG etc. NO_2 concentration has remained more or less stable over the years despite increase in sources like vehicles. The reason for this may be various intervention measures that have taken place such as improvement in vehicle technology and other vehicular pollution control measures like alternate fuel etc. PM_{10} concentration shows fluctuating trend. Vehicular emissions are a major source of PM_{10}. Increasing number of vehicles may be a reason for this trend. The other reasons being emission from gensets, small scale industries, biomass incineration, suspension of traffic dust, natural dust, commercial and domestic use of fuel etc. (CPCB, 2010)

The Figure 4.1 below shows the air quality status in terms of annual average of SO_2, NO_2 and PM_{10} concentration of the eight selected cities with respect to NAAQS limits based on CPCB 2010 data.

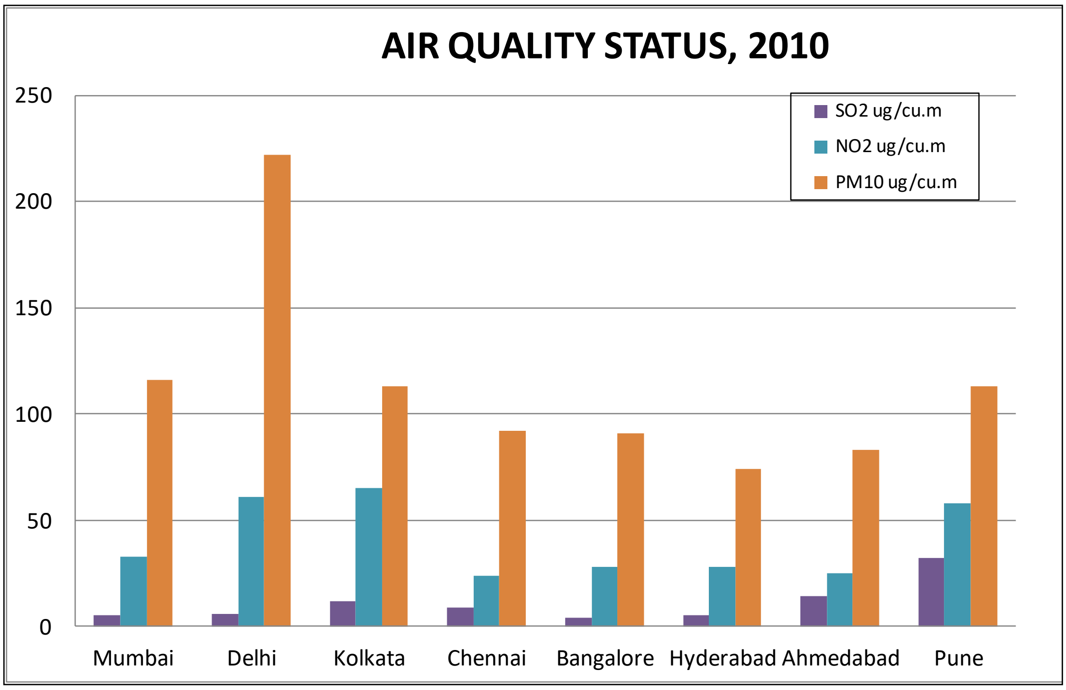


Figure 4.1: Air Quality Status of Eight Selected Cities (2010)

Source: CPCB

As per CPCB the pollution level of a city or town can be categorised broadly as low, moderate, high and critical based on an exceedance factor i.e. the ratio of annual mean concentration of a pollutant with that of respective NAAQS (Refer Annexure I). Based on the CPCB classification, the pollution levels in the selected cities can be categorised as given below in Table 4.4 (based on CPCB, 2010 data).

Table 4.4: Categorisation of Pollution Level in selected Million Plus Cities, 2010

CITY	SO_2 µg/cu.m	SO_2 EF (NAAQS - <50)	NO_2 µg/cu.m	NO_2 EF (NAAQS - <40)	PM_{10} µg/cu.m	PM_{10} EF (NAAQS- <60)
Mumbai	5	0.1	33	0.83	116	1.93
Delhi	6	0.12	61	1.53	222	3.70
Kolkata	12	0.24	65	1.63	113	1.88
Chennai	9	0.18	24	0.60	92	1.53
Bengaluru	4	0.08	28	0.70	91	1.52
Hyderabad	5	0.1	28	0.70	74	1.23
Ahmedabad	14	0.28	25	0.63	83	1.38
Pune	32	0.64	58	1.45	113	1.88

Source: CPCB, 2010

AQ Categories	CRITICAL	HIGH	MODERATE	LOW
EF	>1.5	1.0-<1.5	0.5-<1.0	<0.5

As per CPCB 2010 data and its analysis in Table 4.4 above, seven out of eight cities, Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad fall in LOW pollution category with respect to annual average SO2 concentration and only Pune falls in MODERATE pollution category with respect to annual average SO2 concentration. Pune is at eight position amongst the top ten cities identified at national level by CPCB in terms of highest annual average of SO_2 values during 2010 (National Ambient Air Quality Status & Trends In India-2010,CPCB). SO_2 levels are on the higher side in most parts of the Pune City due to vehicular pollution and the nearby industrial belt located in Pimpri Chinchwad.

As per CPCB 2010 data and its analysis in Table 4.4 above, Mumbai, Chennai, Bengaluru, Hyderabad, Ahmadabad falls in LOW pollution category with respect to annual average NO_2 concentration, however Delhi, Kolkata, falls in CRITICAL pollution category with respect to annual average NO_2 concentration and Pune falls in HIGH pollution category with respect to NO_2 concentration. Kolkata falls at ninth position amongst the top ten cities identified at national level by CPCB in terms of highest annual average of NO_2 values during 2010 (National Ambient Air Quality

Status & Trends In India-2010, CPCB). Kolkata air pollution is on the rise and the 'diesel capital' is now being viewed as the 'lung-cancer capital'. Nearly 65 per cent of the new cars in Kolkata are diesel driven. Moreover, 45 per cent of the total oil consumption by the city's vehicle users is constituted by diesel. That's nearly half the fleet of vehicles adding to pollution in Kolkata. In Kolkata commercial vehicles account for a big chunk of total vehicles plying on the road. Almost 99 per cent commercial vehicles in the city are diesel-driven, thus further polluting the air. Traditionally, people of Kolkata have opted for public transport or walking to move around the city. But with high influx of cheap vehicles, and increase in purchasing power, a good habit seems to be disappearing from the city.

As per CPCB 2010 data and its analysis in Table 4.4 above, six out of eight cities Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Pune falls in CRITICAL pollution category with respect to annual average PM_{10} concentration and Hyderabad, Ahmadabad falls in HIGH pollution category with respect to annual average PM_{10} concentration. Delhi tops amongst the ten cities identified at national level by CPCB in terms of highest annual average of PM_{10} values during 2010 (National Ambient Air Quality Status & Trends In India-2010, CPCB). The particulate matter pollution is extremely critical in Delhi as its percentage deviation from the threshold value is very high. .The transport, industrial and domestic sectors are the major contributors to the rise in ambient air pollution levels though certain natural sources such as desert dust transported during dust storms also contribute to the pollution load ofnPM_{10} levels The vehicular pollution is the biggest contributor to the ambient air pollution levels in the city. There has been a tremendous increase in the number of vehicles in Delhi over the past decade and it has led to a rise in consumption of petroleum products mainly petrol and diesel. Diesel is also being used in generator sets used in industries, commercial establishments and housing complex. The other major contributors to air pollution are fuel combustion in the various activities in the domestic and industrial sector especially the thermal power plants. The coal based thermal power plants at Rajghat, Indraprastha and Badarpur are the major power generators in the city along with major contributors of PM_{10} emissions. In the winters the stubble burning across the northern plains of India also result in a lot of pollution in the city which is aggravated by the meteorological conditions.

4.3.2 Water

Water pollution of rivers is one of the major environmental issue in India. Major rivers flowing through the Indian cities are polluted because of disposal of untreated sewage, industrial effluents and solid waste.

The water quality management in India is performed under the provision of Water (Prevention and Control of Pollution) Act, 1974. The basic objective of this Act is to maintain and restore the wholesomeness of national aquatic resources by prevention and control of pollution. The Act does not define the level of wholesomeness to be maintained or restored in different water bodies of the country. The Central Pollution Control Board (CPCB) has tried to define the wholesomeness in terms of protection of human uses, and thus, taken human uses of water as base for identification of water quality objectives for different water bodies in the country. Since the natural water bodies have got to be used for various competing as well as conflicting demands, the objective is aimed at restoring and/or maintaining natural water bodies or their parts to such a quality as needed for their best uses. Thus, a concept of "designated best use" (DBU) was developed. The Central Pollution Control Board has classified water resources of the country according to their uses for setting water quality objectives for different water bodies. The classification system is given in Table 4.5 below:

Table 4.5: Primary water quality criteria for various uses of fresh water

Designated Best-Use	Class of water	Criteria
Drinking Water Sources without conventional treatment but after disinfection	**A**	Total Coliforms (TC) Organism MPN/100ml shall be 50 or less; pH between 6.5 and 8.5; Dissolved Oxygen (DO) 6mg/l or more; Biochemical Oxygen Demand (BOD)5 days 20^0C 2mg/l or less
Outdoor bathing (Organised)	**B**	TC Organism MPN/100ml shall be 500 or less; pH between 6.5 and 8.5; DO 5mg/l or more; BOD 5 days 20^0C 3mg/l or less
Drinking water source after conventional treatment and disinfection	**C**	TC organism MPN/100ml shall be 5000 or less; pH between 6 to 9; DO 4mg/l or more; BOD 5 days 20^0C 3mg/l or less

Propagation of Wild life and Fisheries	**D**	pH between 6.5 and 8.5; DO 4mg/l or more; free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, Controlled waste disposal	**E**	pH between 6.0 to 8.5; Electrical conductivity at 25^0C micro mhos/cm Max.2250; SAR Max. 26; Boron Max, 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Source: CPCB

Mithi River flows through the island of the city of **Mumbai** and get the water discharges of the Powai and Vihar lakes. The river has been polluted by dumping of industrial waste, raw sewage, organic waste and municipal waste.

River Yamuna is one of the most polluted rivers of India and the longest and the second largest tributary river of the Ganges. The water quality is worst especially around **Delhi** stretch with sewage, garbage and industry waste. Delhi contributes to 70 per cent of the pollution load of the entire river.

In **Kolkata, the Hooghly River** or the Bhāgirathi-Hooghly, called 'Ganga' traditionally, is an approximately 260-kilometre-long distributary of the Ganges River in West Bengal. It splits from the Ganges as a canal in Murshidabad District at the Farakka Barrage.

The **Cooum River** is the shortest classified river draining into the Bay of Bengal. This river is about 72 km in length, flowing 32 km in the urban part and the rest in rural part. Cooum River flows through the major corporation zones of **Chennai-** Kilpauk, Nungambakkam and Triplicane for a total length of 16 kilometres and; the river is highly polluted in this urban area. Polluted Part of the Cooum River is fed by pesticides of corporation zones and heavy metals from the industry in Kilpauk and Triplicane.

Vrishabhavathi River of **Bengaluru** is a minor river and one of the tributary of the Arkavathy River. The river flows through the south of the Bengaluru city and highly polluted due to domestic and agricultural sources and pollution from industrial waste.

Hyderabad stands on the banks of **Musi River**. Musi River is a tributary of the Krishna River in the Deccan Plateau flowing through Telangana state in India, which divides the historic old city and the new city of Hyderabad. Musi River is highly polluted in Hyderabad and among most polluted rivers in country.

Sabarmati River is one of the major west flowing river of Gujarat flowing through the city of **Ahmedabad** and third most polluted river in the country. It originates from Aravalli hill ranges in Rajasthan and flows towards the Gulf of Cambay in Gujarat.

Mula-Mutha River is formed by the confluence of Mula and Mutha rivers in the city of **Pune** and high level of Pollution is released into the river at Pune.

As per the CPCB Report- Status of water quality in India, 2010, the water quality of major water resources/ rivers of the eight selected million plus cities on the major parameters of DO, BOD and Total Coliform in comparison with the water quality standards by CPCB (Refer Table 4.3) is given in the **Table 4.6** below:

Table 4.6: Water Quality of Major Rivers of selected Million Plus Cities, 2010

		Dissolved Oxygen (mg/l)	**B.O.D (mg/l)**	**Total Coliform (MPN/100ml)**
	Water Quality Criteria (Designated Best Use-Class of Water 'C')	*>4mg/l*	*<3mg/l*	*<5000 MPN/100ml*
a)	Mithi River, Mumbai	3.4	31.5	1767
b)	Yamuna River, Delhi	0.5	32	31276922
c)	Hoogly River, Kolkata	4.1	23	1076670
d)	Cooum River, Chennai	0.3	22	56321
e)	Vrishabhavathi River, Bengaluru	3.5	32	160000
f)	Musi River, Hyderabad	6.0	34	2385
g)	Sabarmati Rive, Ahmedabad	0.7	31	1932
h)	Mula-Mutha, Pune	5.4	32	1261

Source: CPCB, 2010

The analysis of 2010 water quality data indicates that organic pollution as indicated by Biochemical Oxygen Demand (BOD) and Coliform counts, continue to be the major water quality issue. This is mainly due to discharge of untreated domestic waste water from the urban centres. The municipal corporation at large are not able to treat the increasing load of municipal sewage flowing into water bodies. Secondly, the receiving water bodies also do not have adequate water for dilution. Therefore the oxygen demand and bacterial pollution is increasing day by day.

4.3.3 LAND

In order to assess the demographic pressure on the land, the total population, decennial population growth rate and population density details of the eight cities over the period 2001-2011 are given in Table 4.7:

Table 4.7: Population Growth and Density, 2001-2011

	CITY	Population 2001	Population 2011	Decadal Pop. Growth Rate (%)	Area (sq.km)	Density (p /sq. km)	Density (p /ha)
1.	**Mumbai**	**11978450**	**12478447**	**4.17**	**603**	**20694**	**206.94**
2.	**Delhi**	**13850507**	**16753235**	**20.96**	**1483**	**11297**	**112.97**
3.	**Kolkata**	**4572876**	**4496694**	**-1.67**	**185**	**24306**	**243.06**
4.	**Chennai**	**4343645**	**4681087**	**7.76**	**426**	**10988**	**109.88**
5.	**Bengaluru**	**5101000**	**8425970**	**65.2**	**804.83**	**10872**	**108.72**
6.	**Hyderabad**	**3637483**	**6731790**	**85.1**	**217**	**18172**	**181.72**
7.	**Ahmedabad**	**4525013**	**5633927**	**24.5**	**464**	**12142**	**121.42**
8.	**Pune**	**3760640**	**5751182**	**52.9**	**807.2**	**7125**	**71.25**
	National Average			*17.6 (census)*			*125-175 (UDPFI)*

Source: Census of India, 2001-2011, Statistical Abstract of the cities

Mumbai city experienced substantial population growth rates after independence due to high levels of industrial development and growth in the suburban areas of Greater Mumbai jurisdiction. However, **the decennial population growth rate of the Mumbai city in the last decade 2001-2011 at 4.17 per cent has been quite low compared to the national average at 17.6 per cent** and this can be attributed primarily due to an economic slowdown and saturation in population densities especially in the island city area of Greater Mumbai. The population in the island city area has more-or-less stabilised over the years, while most of the growth has been experienced in the suburbs. The city witnesses significant migration every year (CDP, Mumbai & Census 2011).

Delhi has been one of the fastest growing cities in the country. **During 2001-2011, a population growth rate of approximately 21 per cent has been observed against**

the national average of 17.6 per cent (Census 2011). A large part of the rapid growth of the capital city has been due to high level of migration.

At a time when the population of metropolitan cities across India is on the rise, **Kolkata has suffered a dip in its population in the past decade of 2001-2011**. Amongst all the districts in the state it was Kolkata alone, which recorded **negative growth rate at -1.67%.** "One of the major reasons behind this could be the migration of people. While the young generation is migrating to other cities and abroad for employment, some are being pushed to the outskirts due to skyrocketing real estate prices in the city "(Indian Institute of Population Sciences, Mumbai,2008).

During 2001-2011, the city of Chennai recorded a population growth rate of approximately 7.76 per cent against the national average of 17.6 per cent (Census 2011). However, surrounding districts of the city showed phenomenal growth, indicating a shifting center of gravity in metropolises. Declining populations in some of the metropolises is notable though unsurprising. These cities are unable to absorb further migration due to high cost of living.

The **city of Bengaluru grew from about 5.1 million people in 2001 to 8.4 million in 2011 with a phenomenal decadal growth rate of 65.2%,** which can be attributed to the increase in the official city area of 226 square kilometres under the erstwhile Bengaluru Mahanagara Palike (BMP) to 716 square kilometres in 2007 with the creation of Bruhat Bengaluru Mahanagara Palike.

The area under the **Hyderabad** municipality increased from 170 square kilometres to 650 square kilometres in 2007 when the Greater Hyderabad Municipal Corporation was created. As a consequence, **the total population leaped from 3,637,483 in 2001 census to 6731790 in 2011 census, an increase of over 85.06%.**

Ahmedabad being largest city of Gujarat has a tremendous potential for future growth. **During 2001-2011, Ahmedabad recorded a population growth rate of approximately 24.5 per cent, much higher than the national average of 17.6 per cent** (Census 2011). Ahmedabad is getting urbanised at a rapid pace, with the increasing number of employment generation and development opportunities being the fuel for the same.

During 2001-2011, the city of Pune recorded a population growth rate of approximately 52.9 per cent, much higher than the national average of 17.6 per

cent (Census 2011). Migrating Population is one of the prime reasons behind such a fast growth in population. Pune has seen an immense growth in its population because of fast urbanisation and occupation opportunities.

As per UDPFI guidelines 2014, Ministry of Urban Development, Government of India the **suggested gross population density for a settlement size of a metropolitan city is 125-175 persons per hectare** (Refer Annexure-III).

In comparison with the UDPFI population density guidelines, the city of Kolkata with a population density of 243 persons per hectare, city of Mumbai with a population density of 207 persons per hectare and Hyderabad with a population density of 182 persons per hectare as per census 2011exceeds the gross population density as suggested by UDPFI guidelines.

On the other hand as per census 2011, the population density of Ahmedabad at 121 persons per hectare, Delhi at 113 persons per hectare, Chennai at 110 persons per hectare and Bengaluru at 109 persons per hectare is well below the desired UDPFI guidelines. The city of Pune recorded the lowest population density amongst the eight selected cities at71 persons per hectare.

As per the State of Forest Report, 2011 of Forest Survey of India and population and area data from Census 2011 and CDPs, per capita green space of the eight cities is given below (Table 4.8) .

Table 4.8: Per Capita Green Space of the selected Million Plus Cities, 2011

	CITY	**Green Space/ Person (sq.m)**
1.	Mumbai	1.24
2.	Delhi	18.0
3.	Kolkata	4.50
4.	Chennai	0.81
5.	Bengaluru	2.01
6.	Hyderabad	0.50
7.	Ahmedabad	1.34
8.	Pune	2.24
	Standards	**>9**
	Organisation/Source	**WHO**

Source: State of Forest Report, 2011 of Forest Survey of India and Census of India, 2011

International minimum standard for urban green space per city dweller as suggested by WHO and adopted by the publications of Food and Agriculture Organisation (FAO) is 9 sq.m. per capita.

As evident from the Table 4.8 above, seven out of eight cities namely Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune fall quite short in meeting the WHO International minimum standard for urban green space per city dweller. Only in the city of Delhi, the per capita green space of approximately 18sqm/person is almost double the WHO standards and needs to be sustained.

4.3.4 Housing

The housing status of the eight cities in comparison with national average, as per Census 2011 is given in the Table 4.9 below:

Table 4.9: Housing Status of Eight selected Million Plus Cities, 2011

CITY	Occupied Census houses for Residential / cum other use (%)	Total No. of HH	Housing Avail -ability (No./ 1000 popl'n)	Avg. HH Size (No. of ppl)	Share of HH one room (%)	Share of Popl'n in Pucca houses (%)	Share of Popl'n in Slums (%)	Share of House less popl'n (%)
Mumbai	63.99	637738	60.2	4.68	62.70	90.4	41.90	0.30
Delhi	80.96	3340538	281.7	5.02	32.20	70.3	14.60	2.66
Kolkata	78.69	964183	93.0	4.96	42.50	93	29.60	0.49
Chennai	86.87	1106567	152.2	4.18	38.60	91.1	28.50	0.36
Bengaluru	81.74	2377056	383.5	4.64	33.20	93.3	8.50	0.16
Hyderabad	85.45	881512	138.8	4.36	30.20	94.6	29.57	0.04
Ahmedabad	77.85	1494656	345.8	4.96	39.10	95.8	4.41	0.15
Pune	78.26	2076607	637.0	4.52	41.80	92.6	0.40	0.02
India(Avg.)			*>208.12*	*4.78*	*32.1*	*83.7*	*17.36*	*0.25*

Source: Census of India, 2011

In Mumbai as per census 2011, 63.99 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 637738 numbers of households with an average household size of 4.68 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 61houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 62.7 per cent of the total number of households have one room which is quite high than the national urban average of 32.1 per cent. The number of households living in ‘pucca’ houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 90.4 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in ‘pucca’ houses. In the city of Mumbai 41.9 per cent of the total population is living in slums, which is more than double the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.30 per cent of the total population whereas the national urban average is 0.25 per cent.

In the NCT Delhi as per the census 2011, 80.96 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 3340538 numbers of households with an average household size of 5.02 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 282 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 32.2 per cent of the total number of households is living in one room household which is almost equal to the national urban average. The number of households living in ‘pucca’ houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 70.3 per cent of the total households whereas the national urban average is 83.7 per cent of total household are living in ‘pucca’ houses. In the capital 14.6 per cent of the total population is living in slums, which is lower than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 2.66 per cent of the total population quite higher than the national urban average of 0.25 per cent.

In Kolkata as per the census 2011, 78.69 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 964183 numbers of households with an average household size of 4.96 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 93 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 42.5 per cent of the total number of households have one room which is quite high than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 93 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Kolkata 29.6 per cent of the total population is living in slums, which is more than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.49 per cent of the total population whereas the national urban average is 0.25 per cent.

In Chennai as per the census 2011, 86.87 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 1106567 numbers of households with an average household size of 4.18 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 153 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 38.6 per cent of the total number of households have one room which is quite high than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 91.1 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Chennai 28.5 per cent of the total population is living in slums, which is more than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.36 per cent of the total population whereas the national urban average is 0.25 per cent.

In Bengaluru as per the census 2011, 81.74 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 2377056 numbers of households with an average household size of 4.64persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 384 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 33.2 per cent of the total number of households have one room which is little higher than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 93.3 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Bengaluru, 8.50 per cent of the total population is living in slums, which is less than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.16 per cent of the total population whereas the national urban average is 0.25 per cent.

In Hyderabad as per the census 2011, 85.45 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 881512 numbers of households with an average household size of 4.36 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 139 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 30.20 per cent of the total number of households has one room which is little less than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 94.6 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Hyderabad 29.57 per cent of the total population is living in slums, which is more than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.04 per cent of the total population whereas the national urban average is 0.25 per cent.

In Ahmedabad as per the census 2011, 77.85 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 1494656 numbers of households with an average household size of 4.96 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 346 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 39.10 per cent of the total number of households has one room which is higher than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 95.8 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Ahmedabad, 4.41 per cent of the total population is living in slums, which is less than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.15 per cent of the total population whereas the national urban average is 0.25 per cent.

In Pune as per the census 2011, 78.26 per cent of the total number of occupied census houses is being used for residential or residential cum other use purpose accommodating around a total of 2076607 numbers of households with an average household size of 4.52 persons per household against the national urban average of 4.78 persons per household. The housing availability is approximately 637 houses per thousand of population against the national urban average of 208 houses per thousand of population. Around 41.80 per cent of the total number of households have one room which is quite high than the national urban average of 32.1 per cent. The number of households living in 'pucca' houses (built with materials such as stone, brick, cement, concrete, R.C.C and timber and tiles) is approximately 92.6 per cent of the total households which is more than the national urban average where 83.7 per cent of total household are living in 'pucca' houses. In Pune 0.40 per cent of the total population is living in slums, which is quite less than the national urban average where 17.36 per cent of the total urban population is living in slums. The share of shelter less population is 0.02 per cent of the total population whereas the national urban average is 0.25 per cent.

4.3.5 Infrastructure

The Infrastructure status of the eight cities in comparison with the Urban India Average, wherever feasible, through information from various sources such as Census 2011 and CPCB Reports is given in the Table 4.10 below:

Table 4.10: Infrastructure Status of Eight selected Million Plus Cities, 2011

CITY	Per Capita water Supply (lpcd)	HH with Potable water supply (%)	HH with source of water within premise (%)	HH with sewage connection (%)	HH with Access to proper Toilets (%)	Per Capita Solid Waste (kg/day)
Mumbai	204	97.8	98.3	87.4	67	0.436
Delhi	292	81.3	78.4	96.3	89.4	0.475
Kolkata	202	88.1	89.3	94.37	94.9	0.383
Chennai	133	82.1	84.2	98	95.6	0.657
Bengaluru	112	79.1	81.2	97.5	94.8	0.484
Hyderabad	145	97.8	87.5	84.3	98.5	0.382
Ahmedabad	150	84.7	86.2	89.8	83	0.585
Pune	194	94.2	94.6	96.3	73.8	0.312
Ref. Standard/Avg.	274	62	71.2	32.7	81.4	0.5
Source	CPHHEO	Census	Census	Census	Census	CPCB

Table 4.8 lists the per capita water supply of the eight selected cities as per the data of CPCB, 2008. As per the CPHHEO manual, MoUD the required per capita water supply in metropolitan cities is 274 lpcd. As per the CPHHEO standards, Delhi is the only city meeting the criteria with per capita water supply of 292 lpcd (Refer Annexure-IV).

Considering the national average of per capita water supply of 179 lpcd for class I cities, the city of Mumbai at 204 lpcd, 2Delhi at 292 lpcd, Kolkata at 202 lpcd and

Pune at 194 lpcd lies well above the national average. However **the city of Chennai at 133 lpcd, Bengaluru at 112 lpcd, Hyderabad at 145 lpcd and Ahmedabad at 150 lpcd fails to meet the national average of per capita water supply in class I cities.**

As per census 2011, 98 per cent of total households in Mumbai , 81 per cent of the total number of households in Delhi , 88 percent of the total number of households in Kolkata, 82 per cent of the total number of households in Chennai, 79 per cent of the total number of households in Bengaluru, 98 per cent of the total number of households in Hyderabad, 85 per cent of the total number of households in Ahmedabad and 94 per cent of the total number of households in Pune have potable water supply against the 62 per cent of total households having potable water supply in urban India. Hence **all the selected cities exceed the national average in terms of percentage of households having potable water supply**.

Also as per census 2011, 98.3 per cent of total households in Mumbai , 78.4per cent of the total number of households in Delhi , 89.3 percent of the total number of households in Kolkata, 84.2 per cent of the total number of households in Chennai, 81.2 per cent of the total number of households in Bengaluru, 87.5 per cent of the total number of households in Hyderabad, 86.2 per cent of the total number of households in Ahmedabad and 94.6 per cent of the total number of households in Pune have the water supply source within the premises against the 71.2 per cent of the total households having source of water within premises in urban India. Hence **all the selected cities exceed the national average in terms of percentage of households having source of water within premises.**

As per census 2011, 87.4 per cent of total households in Mumbai , 96.3 per cent of the total number of households in Delhi , 94.37 percent of the total number of households in Kolkata, 98 per cent of the total number of households in Chennai, 97.5 per cent of the total number of households in Bengaluru, 84.3 per cent of the total number of households in Hyderabad, 89.8 per cent of the total number of households in Ahmedabad and 96.3 per cent of the total number of households in

Pune have proper sewage connection against the 32.7 per cent of total households having sewage connection in urban India. Hence **all the selected cities well exceed the national average in terms of percentage of households having sewage connection.**

Similarly, as per census 2011, 67 per cent of total households in Mumbai , 89.4 per cent of the total number of households in Delhi , 94.9 percent of the total number of households in Kolkata, 95.6 per cent of the total number of households in Chennai, 94.8 per cent of the total number of households in Bengaluru, 98.5 per cent of the total number of households in Hyderabad, 83 per cent of the total number of households in Ahmedabad and 73.8 per cent of the total number of households in Pune have access to proper toilet facilities within the premises against the 81.4 per cent of the total households having access to toilet facilities within premises in urban India. Hence, **except Mumbai and Pune, the other six cities exceed the national average in terms of percentage of households having access to toilet facilities within premises.**

As per CPCB Report, 2010-2011per capita solid waste generation is 0.44kg/cap/day in Mumbai, 0.48 kg/cap/day in Delhi, 0.38 kg/cap/day in Kolkata, 0.66 kg.cap/day in Chennai, 0.48 kg/cap/day in Bengaluru, 0.38 kg/cap/day in Hyderabad, 0.59 kg/cap/day in Ahmedabad and 0.31 kg/cap/day in Pune against the average per capita waste generation in Urban India at 0.5 kg/capita/day. **The per capita solid waste generation is highest in the city of Chennai followed by Ahmedabad and lowest in the city of Pune. The other five cities have the per capita solid waste generation in the range of 0.4 to 0.5 kg/cap/day.**

4.3.6 ENERGY

The energy status mainly in terms of fuel choice and ownership of private motorised vehicles, of the eight cities in comparison with the average of Urban India as per Census 2011 is given in the Table 4.11.

As per census 2011, 98.1 per cent of the total number of households in Mumbai, 99.1 per cent of total households in Delhi, 96.2 per cent households in Kolkata, 99.1 per cent households in Chennai, 98 per cent households in Bengaluru, 98.7 per cent households in Hyderabad, 97.4 per cent households in Ahmedabad and 92.7 per cent households in Pune have electricity connection against the 92.67 per cent of total households having electricity connection in urban India. Thus **all the selected cities either meet or exceed the national average in terms of percentage of households having electricity connection.**

Table 4.11: Energy Status of Eight selected Million Plus Cities, 2011

CITY	HH with Electricity Connection (%)	HH with LPG Connection (%)	HH using Renewable source (%)	HH with Motorised Vehicle (%)
Mumbai	98.1	78.1	0.12	29.2
Delhi	99.1	90.0	0.15	60.0
Kolkata	96.2	64.7	0.16	21.1
Chennai	99.1	82.3	0.04	59.8
Bengaluru	98.0	75.3	0.18	61.8
Hyderabad	98.7	66.0	0.03	64.0
Ahmedabad	97.4	64.6	0.09	58.0
Pune	92.7	67.9	0.13	62.0
India (Average)	92.67	64	0.03	44.9

Source: Census of India, 2011

Similarly 78.1 per cent of the total number of households in Mumbai, 90 per cent of total households in Delhi, 64.7 per cent of the total households in Kolkata, 82.3 per cent households in Chennai, 75.3 per cent households in Bengaluru, 66 percent households in Hyderabad, 64.6 per cent households in Ahmedabad and 67.9 per cent households in Pune have LPG connection against the 64 per cent of the total households having LPG connection in urban India. Hence **all the selected cities either meet or exceed the national average in terms of percentage of households having LPG connection**.

The percentage of households using renewable source of energy such as solar energy and biogas in these cities are: in Mumbai 0.12 per cent, in Delhi 0.15 per cent, in Kolkata .16 percent, in Chennai 0.04 per cent, in Bengaluru 0.18 per cent, in Hyderabad 0.03 per cent, 0.09 per cent in Ahmedabad and 0.13 per cent in Pune whereas 0.04 per cent of the total households in Urban India use renewable source of energy. **Thus all the cities have met the national average of households using renewable source of energy.**

In Mumbai 29.2 per cent of the total households own motorised vehicles, whereas in Delhi 60 per cent, 21.1 per cent in Kolkata, 59.8 per cent in Chennai, 61.8 per cent in Bengaluru, 64 per cent in Hyderabad, 58 per cent in Ahmedabad and 62 per cent of the total households in Pune own motorised vehicles against 44.9 per cent of the total households in Urban India own motorised vehicles. **Thus only in the city of Mumbai and Kolkata, private ownership of motorised vehicles by the households is less than the national average. The other six cities exceed the national average in terms of percentage of households owning motorised vehicles. This may be attributed to the fact that both the cities are linear in growth as most of the people use the railways as the preferred mode of transport.**

4.3.7 POPULATION

Social well-being and quality of life of the population of the eight metropolitan cities in comparison with urban India average, as per census 2011, is given in Table 4.12 below through literacy rate, hospital beds per 1000 population, infant mortality rate, average life expectancy and households below poverty line.

Comparing the literacy rates amongst the eight cities Chennai has the highest literacy at 90.18 percent closely followed by Mumbai with a percentage of 89.21. Third is Bengaluru with a healthy 87.67 percent followed closely by Kolkata and Delhi with 86.31 percent and 86.30 percent respectively. Next is Pune with a percentage of 86.15 followed by Hyderabad with a percentage of 83.26. Last but not the least is Ahmedabad with a percentage of 79.31 percentage of literate population.

Another very important factor for social wellbeing i.e., Hospital beds per thousand population, when a comparison was done among these eight cities it was found out that Pune, Bengaluru and Chennai all the three tie with 2.1 beds per thousand population and top the charts . They are closely followed by Hyderabad in the second place with 1.5 beds per thousand population. The third position is taken by Delhi with 1.4 beds per thousand population. The fourth ranked city is Ahmedabad with a 0.9 beds per thousand population followed by Kolkata and Chennai who have 0.8 beds per thousand population.

Table 4.12: Quality of Life of the Population of Eight selected Million Plus Cities, 2011

	MUMBAI	**DELHI**	**KOLKATA**	**CHENNAI**	**BENGALURU**	**HYDERABAD**	**AHMEDABAD**	**PUNE**	**INDIA**
Literacy Rate (%)	89.21	86.3	86.31	90.18	87.67	83.26	79.31	86.15	89.21
Hospital beds/1000 population.	0.8	1.4	0.8	2.1	2.1	1.5	0.9	2.1	0.7
Infant Mortality Rate (Nos.)	20	18	20	16	11.6	20	13.45	22	40.5
Average Life Expectancy (in Years)	63.7	73.2	63.9	68.3	64.0	67.2	66.5	62.3	66.1
HH below poverty line (%)	19.6	9.91	21.93	8.7	7.3	7.92	5.43	4.89	21.12

Source: Census of India, 2011

In terms of the infant mortality rate Pune has the highest infant mortality rate of 22 followed by Mumbai, Kolkata and Hyderabad with an infant mortality rate of 20 are tied in the second spot together. In the third place is Delhi with an infant mortality rate of 18 followed by Chennai in the fourth position with an infant mortality rate of 16.In the fifth position is occupied by Ahmedabad with an infant mortality rate of 13.45and by far the best is Bengaluru with an infant mortality rate of 11.6 and occupying the sixth position.

In terms of the average life expectancy Delhi tops the chart with 73.2 years followed by Chennai with an average life expectancy of 68.3 years. In the third position is the city of Hyderabad with an average life expectancy of 67.2 years followed by Ahmedabad with an average life expectancy of 66.5 years. The fifth city in this order is Bengaluru with an average life expectancy of 64.The sixth and the seventh position is occupied by Kolkata and Mumbai with an average life expectancy of 63.9 years and 63.7 years respectively. In the eighth position in terms of average life expectancy is Pune with 62.3 years.

In the factor for percentage of households below poverty line the first spot is occupied by Kolkata with 21.93 percent followed by Mumbai with a percentage of 19.6.The third rank city in this indicator is Delhi with 9.91percentage household below poverty line next is Chennai with a percentage of 8.7 . Fifth city in this indicator ranking is Hyderabad with 7.92 followed by Bengaluru with 7.3 percent. The city of Ahmedabad is ranked seventh in this indicator with a percentage of 5.43 and last ranked among these cities is Pune with 4.89 percentage of households below poverty line.

4.3.8 FINANCE

Economic status or financial wellbeing of the eight metropolitan cities in comparison with urban India average, as per census 2011, is given in the Table 4.13 below through the indicators of GDP, per capita annual income and percentage of population employed.

Table 4.13: Financial Wellbeing of Eight selected Million Plus Cities, 2011

	MUMBAI	DELHI	KOLKATA	CHENNAI	BENGALURU	HYDERABAD	AHMEDABAD	PUNE
GDP (in Billion Rs)	13585	10855	9750	4290	5395	4810	4160	3120
Per capita annual income (Rs)	1,25,000	1,36,690	40540	64200	53331	45300	53813	52600
Percentage of population employed (%)	80.6	70.7	78.8	80.9	96.4	73	77.7	93.7

Source: Census of India, 2011

Amongst the cities the GDP of Mumbai is the highest with an overall amount of Rs 13,585 billion closely followed by Delhi at Rs 10,855 billion and Kolkata occupies the third position with an overall amount of Rs 9,750 billion. Next to follow them is Bengaluru with an overall GDP of Rs 5,395billion followed by Hyderabad with a GDP of Rs 4,810billion.This is followed by Chennai with a GDP of Rs 4,290 billion and next by Ahmedabad with a GDP of Rs 4,160 billion. Last but not the least is Pune with a GDP of Rs 3,120 billion which is almost three times more than the national urban average of India which is pegged at Rs 1,345 billion.

In the comparison of per capita annual income of these cities Delhi is the fore most with a figure of Rs 1,36,690 living up to the title of being the new financial capital of the country pushing the city of Mumbai to the second place which has a figure of Rs 1,25,000. In the third place is Chennai at Rs 64,200 followed by Ahmedabad at Rs 53,813. Bengaluru with a per capita income of Rs 53,331 is placed fifth among the cities followed by Hyderabad with a per capita income of Rs 45,300.Kolkata has the least per capita income of Rs 40,540 among the eight cities.

On the indicator of employed population percentage, Bengaluru has the highest percentage of employed people at 96.4 percent followed by Pune with 93.7 percent. These cities are followed by Chennai at 80.9 percent and Mumbai at 80.6 percent .Kolkata with 78.8 percent of population employed is ranked fifth followed closely by Ahmedabad with a percentage of 77.7. Next comes Hyderabad with a percentage of 73 and last is Delhi with 70.7 percentage of employed population.

4.4 APPLICATION OF ENVIRONMENTAL PERFORMANCE INDEX (MACRO)

Based on the methodology discussed in the previous chapter, the data of the selected indicators were converted into positive indicators (which show improvements towards sustainability), e.g. poverty indicator has been converted to non-poverty indicator (Refer Table 4.14).

Score of Negative Parameter (converted into positive values)

$$= \frac{\text{Value}_{\text{Maximum}} - \text{Value}_{\text{Actual}}}{\text{Value}_{\text{Maximum}} - \text{Value}_{\text{Minimum}}}$$

The indicator values are in different units of measurement and to make them inter-comparable, Z-score normalization technique (Minium et al., 2001) has been used. The statistical formula is:

$z_{i,j} = \frac{(x_{i,j} - \bar{x_j})}{s_j}$ *zij stands for z-score or normalised/standardised value of observation xij.*

In the process of measuring the Environmental Performance of a City, domains and indicators play an important role. In the process of arriving at an index suitable indicators were selected and their numbers were fixed. Subsequently, experts and planners were interviewed and their opinion was collected for finding weights (Refer Annexure VIII) to be assigned to each domain.

Table 4.14 Data Set converted to Positive Indicator Value

DATA CONVERTED TO POSITIVE INDICATOR VALUES

CITY	AIR			WATER			LAND	
CITY	Inverse SO2 µg/cu.m	Inverse NO2 µg/cu.m	Inverse PM10 µg/cu.m	(DO)(mg/l)	Inverse (BOD)(mg/l)	Inverse Coliform converted to log (MPN/100ml)	Inverse Land Population Density (p/Ha)	Green Spaces/Person (sq.m)
Mumbai	0.84	0.49	0.48	3.4	0.21	1767	0.27	1.24
Delhi	0.81	0.06	0.00	0.5	0.17	31276922	0.60	18
Kolkata	0.63	0.00	0.49	4.1	0.92	1076670	0.09	4.5
Chennai	0.72	0.63	0.59	0.34	1.00	56321	0.00	0.81
Bangalore	0.88	0.57	0.59	3.5	0.17	160000	0.86	2.01
Hyderabad	0.84	0.57	0.67	6	0.00	2385	0.33	0.5
Ahmedabad	0.56	0.62	0.63	5.6	0.25	1932	1.00	1.34
Pune	0.00	0.11	0.49	5.4	0.17	1261	0.58	2.24

CITY	HOUSING						INFRASTRUCTURE					
CITY	Housing Availibility (No/1000 ppl)	Avg. HH Size (no. of ppl)	Share of HH one room (%)	Share of HH in Pucca houses(%)	Share of Popn In Slums(%)	Share of Houseless popn(%)	Per Capita Water Consumption (lpcd)	HH with Potable Water Supply (%)	HH with source of water within premise (%)	HH with Sewage Connection(%)	HH with Acess to Proper Toilets (%)	Per Capita Solid Waste (kg/day)
Mumbai	60.2	4.68	37.3	90.4	58.1	99.70	204	97.8	98.3	87.4	67	0.34
Delhi	280	5.02	67.8	70.3	85.4	97.34	292	81.3	78.4	96.3	89.4	0.28
Kolkata	93	4.96	57.5	93	70.4	99.51	202	88.1	89.3	94.37	94.9	0.42
Chennai	152.2	4.18	61.4	91.1	71.5	99.64	133	82.1	84.2	98	95.6	0.00
Bangalore	383	4.64	66.8	93.3	91.5	99.84	112	79.1	81.2	97.5	94.8	0.26
Hyderabad	138.8	4.36	69.8	94.6	70.43	99.96	145	97.8	87.5	84.3	98.5	0.42
Ahmedabad	345.8	4.96	60.9	95.8	95.59	99.85	150	84.7	86.2	89.8	83	0.11
Pune	637	4.52	58.2	92.8	99.6	99.98	194	94.2	94.6	96.3	73.8	0.53

CITY	ENERGY				POPULATION						FINANCE		
CITY	HH with Electricity Connection (%)	HH with LPG Connection(%)	HH using Renewable Source (%)	HH with Motorised Vehicle (%)	Inverse Population Growth	Literacy Rate (%)	Hospital Beds per 1000 popn	Live births per 1000 popn (Nos.)	Average Life Expectancy (in Years)	HH below poverty line (%)	Gross Domestic Product (in Billion Rs)	Per Capita Annual Income (Rs)	Percentage of Population Employed
Mumbai	98.1	28.5	0.12	70.80	88.07	89.21	0.80	980.00	63.7	80.4	13585	1,25,000	80.6
Delhi	99.1	89.9	0.15	40.40	73.04	86.3	1.40	982.00	73.2	90.1	10855	1,36,690	70.7
Kolkata	96.2	64.7	0.16	78.90	93.55	86.31	0.80	980.00	63.9	78.1	9750	40540	78.8
Chennai	99.1	82.3	0.04	40.20	68.09	90.18	2.10	984.00	68.3	91.3	4290	64200	80.9
Bangalore	98	75.3	0.18	38.20	50.56	87.67	2.10	988.40	64.0	92.7	5395	53331	96.4
Hyderabad	98.7	66	0.03	36.00	66.30	83.26	1.50	980.00	67.2	92.1	4810	45300	73
Ahmedabad	97.4	64.6	0.09	42.00	59.50	79.31	0.90	986.55	66.5	94.6	4160	53813	77.7
Pune	92.7	67.9	0.13	38.00	65.51	86.15	2.10	978.00	62.3	95.1	3120	52600	93.7

Source: Author

Table 4.15 Normalised Data Set.

.NORMALISED DATA SET

CITY	AIR			WATER			LAND	
CITY	Inverse SO2 µg/cu.m	Inverse NO2 µg/cu.m	Inverse PM10 µg/cu.m	(DO)(mg/l)	Inverse (BOD)(mg/l)	Inverse Coliform converted to log (MPN/100ml)	Inverse Land Population Density (p/Ha)	Green Spaces/Person (sq.m)
Mumbai	0.63	0.41	-0.06	-0.09	-0.40	0.82	-0.55	-0.44
Delhi	0.53	-1.17	-2.34	-1.42	-0.51	-1.82	0.36	2.42
Kolkata	-0.12	-1.39	0.00	0.23	1.48	-0.91	-1.05	0.11
Chennai	0.20	0.92	0.45	-1.49	1.70	-0.12	-1.31	-0.52
Bangalore	0.74	0.69	0.47	-0.05	-0.51	-0.40	1.12	-0.31
Hyderabad	0.63	0.69	0.84	1.09	-0.95	0.74	-0.38	-0.57
Ahmedabad	-0.34	0.86	0.64	0.91	-0.29	0.79	1.50	-0.43
Pune	-2.28	-1.00	0.00	0.82	-0.51	0.91	0.32	-0.27

CITY	HOUSING						INFRASTRUCTURE					
CITY	Housing Availibility (No/1000 ppl)	Avg. HH Size (no. of ppl)	Share of HH one room (%)	Share of HH in Pucca houses(%)	Share of Popn In Slums(%)	Share of Houseless popn(%)	Per Capita Water Consumption (lpcd)	HH with Potable Water Supply (%)	HH with source of water within premise (%)	HH with Sewage Connection(%)	HH with Acess to Proper Toilets (%)	Per Capita Solid Waste (kg/day)
Mumbai	-1.04	0.05	-2.22	0.03	-1.51	0.25	0.44	1.28	1.64	-1.09	-1.75	0.25
Delhi	0.10	1.16	0.77	-2.42	0.34	-2.43	1.98	-0.90	-1.37	0.64	0.20	-0.10
Kolkata	-0.87	0.97	-0.24	0.35	-0.67	0.04	0.40	0.00	0.28	0.27	0.68	0.72
Chennai	-0.57	-1.59	0.14	0.11	-0.60	0.18	-0.81	-0.80	-0.49	0.97	0.74	-1.70
Bangalore	0.63	-0.08	0.67	0.38	0.76	0.41	-1.18	-1.20	-0.95	0.87	0.67	-0.17
Hyderabad	-0.64	-1.00	0.96	0.54	-0.67	0.55	-0.60	1.28	0.01	-1.69	0.99	0.73
Ahmedabad	0.44	0.97	0.09	0.69	1.04	0.42	-0.51	-0.45	-0.19	-0.62	-0.36	-1.07
Pune	1.95	-0.48	-0.17	0.32	1.31	0.57	0.26	0.80	1.08	0.64	-1.16	1.35

CITY	ENERGY				POPULATION						FINANCE		
CITY	HH with Electricity Connection (%)	HH with LPG Connection(%)	HH using Renewable Source (%)	HH with Motorised Vehicle (%)	Inverse Population Growth	Literacy Rate (%)	Hospital Beds per 1000 popn	Live births per 1000 popn (Nos.)	Average Life Expectancy (in Years)	HH below poverty line (%)	Gross Domestic Product (in Billion Rs)	Per Capita Annual Income (Rs)	Percentage of Population Employed
Mumbai	0.32	-2.14	0.14	1.36	1.23	0.92	-1.13	-0.65	-0.69	-1.4	1.7	1.43	-0.10
Delhi	0.79	1.24	0.68	-0.46	0.17	0.07	-0.11	-0.10	2.01	0.1	1.0	1.74	-1.18
Kolkata	-0.57	-0.15	0.86	1.84	1.62	0.08	-1.13	-0.65	-0.64	-1.7	0.7	-0.83	-0.29
Chennai	0.79	0.82	-1.32	-0.47	-0.17	1.20	1.08	0.45	0.62	0.3	-0.7	-0.19	-0.06
Bangalore	0.28	0.43	1.23	-0.59	-1.41	0.47	1.08	1.66	-0.61	0.5	-0.4	-0.48	1.64
Hyderabad	0.60	-0.08	-1.50	-0.72	-0.30	-0.81	0.06	-0.65	0.30	0.4	-0.6	-0.70	-0.93
Ahmedabad	-0.01	-0.15	-0.41	-0.36	-0.78	-1.96	-0.96	1.15	0.10	0.8	-0.7	-0.47	-0.41
Pune	-2.21	0.03	0.32	-0.60	-0.36	0.03	1.08	-1.20	-1.09	0.9	-1.0	-0.50	1.34

Source: Author

The Environmental Performance Index for each domain of the city is derived by averaging the Z-score values computed for each of the indicators in the domain and multiplying it with the weightages given by experts as described in the process in the previous point.

EPI (Z_{Air}) =Average Z scores ($A_1, A_2, \ldots, A_n$) X weightages given by experts

Where A_1, A_2 and A_n are the various indicators under the domain of air.

The Environmental Performance Index (Macro) for each city is calculated by summing up the EPI of each domain and getting the final score.

City EPI (macro) = ∑ {EPI (Air) + EPI (Water) + ………..+ EPI (Popn.) +EPI (Economy)}

Based on the individual Environmental Performance Index (Macro) for each city the Scores are arranged in a descending order. The city obtaining the highest EPI (Macro) Score is assigned the first ranking and the one with the least score the last ranking.

Collected Data was analysed and correlation and sustainability analysis were carried out. While, correlation analysis explains the inter-relationships between different indicators, the sustainability analysis uses the indicators to compute the domain wise EPI (Environmental Performance Index) values which has been summed up to get city EPI (Environmental Performance Index).

Table 4.16: Table showing the Domain and City wise Environmental Performance Index Values (with expert weightages)

Source:Author

MACRO INDICATORS	WEIGHTAGE	MUMBAI			DELHI			KOLKATA			CHENNAI			BENGALURU			HYDERABAD			AHMEDABAD			PUNE		
		VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE
Inverse SO_2 µg/cu.m		0.84	0.63		0.81	0.53		0.63	-0.12		0.72	0.20		0.88	0.74		0.84	0.63		0.56	-0.34		0.00	-2.28	
Inverse NO_2 µg/cu.m		0.49	0.41		0.06	-1.17		0.00	-1.39		0.63	0.92		0.57	0.69		0.57	0.69		0.62	0.86		0.11	-1.00	
Inverse PM_{10} µg/cu.m		0.48	-0.06		0.00	-2.34		0.49	0.00		0.59	0.45		0.59	0.47		0.67	0.84		0.63	0.64		0.49	0.00	
EPI (Air)	8.20		0.33	2.67		-0.99	-8.14		-0.51	-4.14		0.52	4.28		0.63	5.20		0.72	5.90		0.39	3.18		-1.09	-8.96
(DO)(mg/l)		3.40	-0.09		0.50	-1.42		4.10	0.23		0.34	-1.49		3.50	-0.05		6.00	1.09		5.60	0.91		5.40	0.82	
Inverse (BOD)(mg/l)		0.21	-0.40		0.17	0.92		0.92	1.48		1.00	1.70		0.17	-0.51		0.00	-0.95		0.25	-0.29		0.17	-0.51	
Inverse Coliform converted to log scale (MPN/100ml)		1767.00	0.82		31276922.00	-1.82		1076670.00	-0.91		56321.00	-0.12		160000.00	-0.40		2385.00	0.74		1932.00	0.79		1261.00	0.91	
EPI (Water)	7.80		0.11	0.84		-0.77	-6.04		0.26	2.05		0.03	0.23		-0.32	-2.49		0.29	2.28		0.47	3.68		0.41	3.17
Land Population Density (p/Ha)		0.27	-0.55		0.60	0.36		0.09	-1.05		0.00	-1.31		0.86	1.12		0.33	-0.38		1.00	1.50		0.58	0.32	
Green Spaces/Person (sq.m)		1.24	-0.44		18.00	2.42		4.50	0.11		0.81	-0.52		2.01	-0.31		0.50	-0.57		1.34	-0.43		2.24	-0.27	
EPI (Land)	6.90		-0.49	-3.41		1.39	9.59		-0.47	-3.24		-0.91	-6.31		0.40	2.78		-0.48	-3.29		0.54	3.70		0.02	0.17
Housing Availibility (No/1000 ppl)		60.20	-1.04		280.00	0.10		93.00	-0.87		152.20	-0.57		383.00	0.63		138.80	-0.64		345.80	0.44		637.00	1.95	
Avg. HH Size (no. of ppl)		4.68	0.05		5.02	1.16		4.96	0.97		4.18	-1.59		4.64	-0.08		4.36	-1.00		4.96	0.97		4.52	-0.48	
Share of HH more than one room (%)		37.30	-2.22		67.80	0.77		57.50	-0.24		61.40	0.14		66.80	0.67		69.80	0.96		60.90	0.09		58.20	-0.17	
Share of HH in Pucca houses(%)		90.40	0.03		70.30	-2.42		93.00	0.35		91.10	0.11		93.30	0.38		94.60	0.54		95.80	0.69		92.80	0.32	
Share of Popn not In Slums (%)		58.10	-1.51		85.40	0.34		70.40	-0.67		71.50	-0.60		91.50	0.76		70.43	-0.67		95.59	1.04		99.60	1.31	
Share of Popn with House (%)		99.70	0.25		97.34	-2.43		99.51	0.04		99.64	0.18		99.84	0.41		99.96	0.55		99.85	0.42		99.98	0.57	
EPI (Housing)	7.30		-0.74	-5.40		-0.41	-3.02		-0.07	-0.53		-0.39	-2.82		0.46	3.37		-0.04	-0.31		0.61	4.44		0.58	4.26
Per Capita water Consumption (lpcd)		204.00	0.44		292.00	1.98		202.00	0.40		133.00	-0.81		112.00	-1.18		145.00	-0.60		150.00	-0.51		194.00	0.26	
HH with Potable water supply (%)		97.80	1.28		81.30	-0.90		88.10	0.00		82.10	-0.80		79.10	-1.20		97.80	1.28		84.70	-0.45		94.20	0.80	
HH with source of water within premise (%)		98.30	1.64		78.40	-1.37		89.30	0.28		84.20	-0.49		81.20	-0.95		87.50	0.01		86.20	-0.19		94.60	1.08	
HH with sewage connection(%)		87.40	-1.09		96.30	0.64		94.37	0.27		98.00	0.97		97.50	0.87		84.30	-1.69		89.80	-0.62		96.30	0.64	
HH with Acess to proper Toilets (%)		67.00	-1.75		89.40	0.20		94.90	0.68		95.60	0.74		94.80	0.67		98.50	0.99		83.00	-0.36		73.80	-1.16	
Inverse Per Capita Solid Waste (kg/day)		0.34	0.25		0.28	-0.10		0.42	0.72		0.00	-1.70		0.26	-0.17		0.42	0.73		0.11	-1.07		0.53	1.35	
EPI (Infrastructure)	6.80		0.13	0.87		0.07	0.51		0.39	2.65		-0.35	-2.38		-0.33	-2.21		0.12	0.81		-0.53	-3.63		0.50	3.37
HH with Electricity Connection		98.10	0.32		99.10	0.79		96.20	-0.57		99.10	0.79		98.00	0.28		98.70	0.60		97.40	-0.01		92.70	-2.21	
HH with LPG Connection		28.50	-2.14		89.90	1.24		64.70	-0.15		82.30	0.82		75.30	0.43		66.00	-0.08		64.60	-0.15		67.90	0.03	
HH using Renewable source		0.12	0.14		0.15	0.68		0.16	0.86		0.04	-1.32		0.18	-1.24		0.03	-1.50		0.09	-0.42		0.13	0.32	
HH with Motorised Vehicle		70.80	1.36		40.40	-0.46		78.90	1.84		40.20	-0.47		38.20	-0.59		36.00	-0.72		42.00	-0.36		38.00	-0.60	
EPI (Energy)	7.10		-0.08	-0.56		0.56	3.99		0.50	3.52		-0.04	-0.32		-0.28	-1.98		-0.42	-3.00		-0.23	-1.66		-0.62	-4.37
Inverse Population Growth		88.07	1.23		73.04	0.17		93.55	1.62		68.09	-0.17		50.56	-1.41		66.30	-0.30		59.50	-0.78		65.51	-0.36	
Hospital bedsper 1000 popn		0.80	-1.13		1.40	-0.11		0.80	-1.13		2.10	1.08		2.10	1.08		1.50	0.06		0.90	-0.96		2.10	1.08	
Live births per 1000 popn (Nos.)		980.00	-0.65		982.00	-0.10		980.00	-0.65		984.00	0.45		988.40	1.66		980.00	-0.65		986.55	1.15		978.00	-1.20	
Average Life Expectancy (in Years)		63.70	-0.69		73.20	2.01		63.90	-0.64		68.31	0.62		63.99	-0.61		67.20	0.30		66.50	0.10		62.30	-1.09	
HH Above poverty line (%)		80.40	-1.38		90.09	0.12		78.07	-1.74		91.30	0.31		92.70	0.53		92.08	0.43		94.57	0.82		95.11	0.90	
EPI (Popn.)	7.60		-0.52	-3.98		0.42	3.20		-0.51	-3.86		0.46	3.48		0.25	1.90		-0.03	-0.23		0.07	0.51		-0.13	-1.01
GDP (in Billion Rs)		13585.00	1.71		10855.00	1.00		9750.00	0.72		4290.00	-0.70		5395.00	-0.42		4810.00	-0.57		4160.00	-0.74		3120.00	-1.01	
Per capita annual income (in Rs)		125000.00	1.43		136690.00	1.74		40540.00	-0.83		64200.00	-0.19		53331.00	-0.48		45300.00	-0.70		53813.00	-0.47		52600.00	-0.50	
Population employed(%)		80.60	-0.10		70.70	-1.18		78.80	-0.29		80.90	-0.06		96.40	1.64		73.00	-0.93		77.70	-0.41		93.70	1.34	
EPI (Economy)	6.80		1.02	6.91		0.52	3.55		-0.13	-0.91		-0.32	-2.17		0.25	1.67		-0.73	-4.98		-0.54	-3.68		-0.06	-0.39
EPI Macro (City) $= \sum_{n=0}^{N} EPI$				-2.06			3.64			-4.46			-6.00			8.24			-2.81			6.54			-3.76

4.5 ENVIRONMENTAL PERFORMANCE ANALYSIS OF THE CITIES

This section presents the analysis of each of the eight domains i.e., air, water, land, energy housing, infrastructure population (labour) and finance (capital), under the broad heads of environment, social and economic which influence the sustainability of a city. The selected 32 indicators under the eight domains have been fed with data collected from reliable sources and Z-scores have been computed for relative comparison of the cities (Table 4.15).

The critical analysis of various indicators has been carried out to understand its causes and implications in different cities. Differences have been observed both in terms of socio-economic development and environmental degradation through the cities. Different cities were compared for their comparative performance using the EPI (macro) under each of the domains.

Six parameters have been considered under the environment viz. air, water, forest, bio-diversity, waste, and land. Air quality is a very important part of environmental status. Under the National Air Monitoring Programme (NAMP) and National Air Quality Index (AQI), air quality is measured at different monitoring stations across the cities under the parameters SO_2, NO_2 and PM_{10}. The air indicator values show that the cities like Hyderabad and Bengaluru with less industrial activity and less number of vehicle ownership are comparatively better-off in terms of air quality when compared to the other six cities. However when compared to the permissible limits of NO_2, SO_2 and PM_{10} most of the cities have alarmingly high PM_{10} values. Pune owing to large percentage of two-stroke vehicles scores poorly in terms of SO_2, Kolkata and Ahmedabad with its diesel fed public transport system score poorly in terms of SO_2. Delhi being a heavily populated city shows the most negative value of the PM_{10} indicator due to residual crop burning by other nearby states in winter season when the air is dense and meteorological conditions which abate the air movement. Construction activities also increase the PM_{10} levels apart from the fact that it has the highest vehicle ownership. The NO_2 levels in the city are quite high due to much of its public transport fleet being run on CNG. The experts pointed out the high NO_2 levels in Kolkata were owing to the rise in car count and mushrooming of roadside eateries that burnt coal and wood for fuel. The increase in the vehicle ownership continues to be a cause of worry across all the cities in spite of the fact that all efforts are being made to increase the efficiency of the public transport systems through buses and metros, which clearly points to the failure of the system to address the issues of proper last mile connectivity of the public at large. Coastal cities (like Mumbai, and Chennai) are influenced by the sea breeze effect and hence show lesser air pollution levels. Monitoring of the State Pollution Control Boards improving could possibly be another reason for controlled air pollution or relatively better air quality. In the recent past the National Green Tribunal (NGT) has started taking pro-active measures in tackling and addressing environmental issues and concerns across the country.

Water quality has been considered as an indicator under the domain of water. For this purpose city-wise data was collected from the Central Pollution Control Board (CPCB, 2010). The water quality indicator adopted in this study is based on average violations of different water quality parameters in different cities in their respective water sources. The single biggest reason for water pollution in India is urbanisation at an uncontrolled rate. The rate of urbanisation has only gone up at a fast pace in the last decade or so, but even then it has left an indelible mark on India's aquatic resources. This has led to several environmental issues in the long term like paucity in water supply, generation and collection of wastewater to name a few. The treatment and disposal of wastewater has also been a major issue in this regard. The areas near rivers have seen plenty of towns and cities come up and this has also contributed to the growing intensity of problems. Uncontrolled urbanisation in these areas has also led to generation of sewage water. In the urban areas water is used for both industrial and domestic purposes from waterbodies such as rivers, lakes, streams, wells, and ponds. Worst still, 80 percent of the water that we use for our domestic purposes is passed out in the form of wastewater. In most of the cases, highly urbanised and industrialised cities fail in treating the sewage and effluents satisfactorily before discharging into the water sources (mostly rivers) due to lack of adequate infrastructure. As a result these cities score poorly in terms of DO and high in terms of BOD which depict deterioration of surface water quality and clearly points to tremendous pollution of surface-level freshwater. This is true for almost all the cities covered in this study especially Delhi (Yamuna) and Chennai (Cooum) where the volume of water available in the city stretch also becomes low due to diversion for other purposes further adds to the problem of pollution.

Importance of green spaces in cities is recognised as an important source of recreation, social interaction and health. It also plays a vital role in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development of a city. The current

National Forest Policy (MoEF, 1988) aims at maintaining a minimum of 33 percent of country's geographical area under forest and tree cover. It is observed that the planned cities like Delhi and Bengaluru which have dedicated and earmarked open spaces have better per capita green than the rest. Kolkata which is really not a planned city also scores well due to the Maidan, (a large open green), which is referred to as the lung of the city. However, with growth and development activities the green covers in these cities are facing pressure from other land uses. The depletion of green cover increases the urban vulnerability to climate change, deterioration in air quality, generation of urban heat islands (UHIs), and acute water shortage.

Growing population pressures have led to generation of huge quantities of municipal solid waste and sewage on daily basis with location and approval of landfill sites becoming a challenge for most cities. The Municipal Solid Waste (MSW) amount is expected to increase significantly in the near future as the country strives to attain an industrialised nation status by the year 2020 (Sharma and Shah, 2005; CPCB, 2004; Shekdar et al., 1992). Poor collection and inadequate transportation are responsible for the accumulation of MSW at every nook and corner. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amount of MSW generated daily in metropolitan cities. Unscientific disposal causes an adverse impact on all components of the environment and human health (Rathi, 2006; Sharholy et al., 2005; Ray et al., 2005; Jha et al., 2003; Kansal, 2002; Kansal et al., 1998; Singh and Singh, 1998; Gupta et al., 1998).The quantity of MSW generated in cities depends on a number of factors such as food habits, standard of living, degree of commercial activities and seasons. With increasing urbanisation and changing life styles, Indian cities now generate eight times more MSW than they did in 1947. Presently, about 90 million tonnes of solid waste are generated annually as by-products of industrial, mining, municipal, agricultural and other processes. The amount of MSW generated per capita is estimated to increase at a rate of 1–1.33% annually (Pappu et al., 2007). A host of researchers (Siddiqui et al., 2006; Sharholy et al., 2005; CPCB, 2004) have reported that the MSW generation rates in small towns are lower than those of metro cities, and the per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/ day. It is also estimated that the total MSW generated by 217 million people living in urban areas was 23.86 million tonnes/yr in 1991 and more than 39 million tonnes in 2001. The differences in the MSW characteristics indicate the effect of urbanisation and development. In urban areas, the major fraction of MSW is compostable materials (40–60%) and inert (30– 50%). The relative percentage of organic waste in MSW is generally increasing with a dip in the socio-economic status. Present scenario of waste treatment in India is not very encouraging; the lack of resources such as financing, infrastructure, suitable planning and data, and leadership, are the main barriers in MSW Management. The increase of service demands combined with the lack of resources for municipalities are putting a huge strain on the existing MSWM systems. However certain cities perform better than the others.

The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a city. Cities with high GDP and population growth rate (Bengaluru and Ahmedabad) generate more waste per person compared to other cities.

The cities show more utilisation of land, and hence display pressure on land resources. In the current study, parameters such as population growth rate, literacy, poverty, health infrastructure and access to clean energy and renewable energy and basic amenities have been considered for formulation of an index to depict social development. Housing is an important aspect in the assessing the overall growth and development of city .In this respect the data from the eight cities point to the fact that , growth rate of population is an important parameter to assess the pressures on the existing resources and facilities. Higher rates of population growth and land population density can therefore have negative impact on sustainable development. Population data for the years 2011 and 2001 have been collected from Census 2011 (RGCC, 2011) and Census 2001and decadal growth rates have been calculated. It is observed that Kolkata, Mumbai, Delhi and Chennai have lower population growth rates than the rest which can be attributed to high densities of population and perhaps to higher literacy rates, deflection of migrating population to other close by tier II cities with reasonable opportunities in the rural hinterland. Literacy may lead to better family planning which in turn reduces the natural population growth rate of these cities. However in the case of Kolkata specifically the reason is decline in the fertility rates Therefore, it is imperative to understand if the decline is due to external factors — late marriages, more career orientation or reluctance to have children in general. Rapid lifestyle changes are also impacting fertility in urban areas.

The inter relationship between poverty and environment has been recognised by the World Health Organisation as a major cause and probability of poor health in these cities. Thus, more research for development of a true indicator in this field is required. Health facilities are one of the most important components which indicate development on the social fronts. The data for avail-ability of the total number of beds per 1000 population in a region gives an idea of the state of primary health care facilities in different cities. The indicator shows that smaller cities have shown higher number of beds per 1000 population than the other. Data for life expectancy (at birth) has been collected from MoHFW (2011) and added as an indicator of health status and facilities in the city. The indicator shows that life expectancy is low in cities like Pune, Mumbai and Kolkata which have a strong socio-economic disparity.

4.6 CORRELATION ANALYSIS

Correlation analysis was carried out for 32 indicators for 8 cities. Coefficient of correlation was computed for different pairs of indicators and a correlation matrix was prepared (Table 4.17).

There have been many revelations about the relationships between indicators of same or other themes but care has been taken in doing so. Assumptions have not been made to establish a correlation just by seeing a change in one variable which has caused a change in another. Rather the related indicators were studied and their relationships explored. The significant and logical ones were presented with reference to the study context. Many social indicators have been found to have strong/moderate/inverse correlation with environmental and economic indicators. For example, Population Growth is moderately correlated (r ~ 0.41) with increasing BOD levels in water sources and it points to the increasing pollution as a result of increasing population which is a well-known fact for the Indian cities. Per capita solid waste is moderately correlated (r ~ 0.30) with population growth which reinforces the fact that with increasing population the per capita solid waste production also increases. The correlation between the population and green space in the selected cities is negative (r ~ -0.16) clearly establishes the fact that in the urban context the green spaces are being increasingly threatened by the ever increasing population growth. The relation between the population and the population residing in slums (r ~ 0.70) and houseless population (r ~ 0.50) in these cities also strongly correlated which is a very clear phenomena across all the selected cities. However, the correlation between literacy rate and population growth is negative (r ~ -0.30) pointing it to the fact that with increase in literacy levels helps to bring down the population growth. Population growth shows a negative correlation (r ~ - 0.31) with the increase in per capita annual income.

Air pollution is generally caused due to high levels of SO_2 and PM_{10}, air pollutants which causes pulmonary diseases is again an outcome of increase in motorised vehicles (CPCB, 2012). Current study finds a significant correlation between SO_2 and PM_{10} and motorised vehicles (r ~ 0.57) in million plus Indian Cities. The cities with lesser percentage of LPG connections are dependent on firewood for cooking and have also shown higher percentages of SO_2 and PM_{10}.The indicator PM_{10} also shows a negative correlation (a decrease) with increase in per capita green space (r ~ - 0.96), renewable sources of energy (r ~ -0.04) and average life expectancy (0.62).However, PM_{10} has shown a moderate correlation with GDP (r ~ 0.55) and a strong positive correlation with per capita annual income (r ~ 0.76). The indicators PM_{10} and SO_2 have shown a moderate correlation with the ownership of motorised vehicles (r ~ 0.58) and (r ~ 0.56) pointing to the fact that increase in vehicle ownership leads to the increases of these factors in air. SO_2 is found to be negatively correlated with use of renewable energy in the households (r ~ - 0.01) as moving to renewable energy and cleaner fuel options helps in curbing the SO_2 levels in the air.

India's growing population and economy are driving rapid urbanisation (30% of the population now live in urban areas (Census of India, 2011) and exerting increased pressure on surface and groundwater availability. In rural areas ~ 67% of the population defecate in the open (Census of India, 2011), a practice that poses severe risk to health and safety (Clasen et al., 2010; Mara et al., 2010; Ziegelbauer et al., 2012; Kotloff et al., 2013). In urban areas 80 percent of the population have access to a toilet (Census of India, 2011), but only 30 percent are connected to a sewage pipeline and few pipelines are connected to a treatment plant (Narain, 2012). The impact of these sanitation problems on surface water quality has been documented for many years at individual sample locations or river reaches across India (Bhargava, 1983; Mukherjee et al., 1993; Baghel et al., 2005; Mishra et al., 2009; Central Pollution Control Board, 2010).It is a well-established fact that water quality is deeply influenced by sewage and sanitation condition of the city which in turn has a bearing on the health. The analysis of city level data of water quality measured by Dissolved Oxygen (DO) shows a moderate correlation with percentage of households with proper sewage connection (r ~ 0.58).There is a negative correlation between Dissolved Oxygen (DO) and land population density (r ~ - 0.42) and positive correlation for percentage of population residing in pucca houses (r ~ 0.68).

Table 4.17: Correlation Matrix of 32 indicators for 8 cities

Table 2. Correlation matrix of 32 selected indicators.

	Population Growth	AIR SO2 ug/cu.m	AIR NO2 ug/cu.m	AIR PM10 ug/cu.m	Water [DO][mg/l]	WATER[BOD][mg/l]	WATER Coliform 103 [MPN/100ml]	Land Population Density [p/Ha]	Green Spaces/Person [sq.m]	Housing Availibility [No/1000 ppl]	Avg. HH Size [no. of ppl]	Share of HH one room [%]	Share of HH in Pucca houses[%]	Share of Popn in Slums[%]	Share of Houseless popn[%]	Per Capita water Consumption [lpcd]	HH with Potable water supply [%]	HH with source of water within premise [%]	HH with sewage connection[%]	HH with Acess to proper Toilets [%]	Per Capita Solid Waste [kg/day]	HH with Electricity Connection [%]	HH with LPG Connection [%]	HH using Renewable source	HH with Motorised Vehicle [%]	Literacy Rate [%]	Hospital bedsper 1000 popn	Infant Mortality Rate [Nos.]	Average Life Expectancy [in Years]	HH below poverty line [%]	GDP [in Billion Rs]	Per Capita Annual Income
Population Growth	1																															
AIR SO2 g/cu.m	0.068555	1																														
AIR NO2 ug/cu.m	-0.51501	0.419594	1																													
AIR PM10 ug/cu.m	-0.28277	-0.0737	0.652822	1																												
Water (DO)(mg/l)	0.142709	0.379164	-0.08912	-0.58957	1																											
WATER(BOD)(mg/l)	0.417724	-0.01128	-0.11706	0.108558	0.448242	1																										
WATER Coliform 103 (MPN/100ml)	0.89853	-0.21374	0.492039	0.947792	-0.57425	0.186728	1																									
Land Population Density (p/Ha)	0.659524	-0.46483	-0.01484	-0.02933	-0.42761	-0.64954	-0.06132	1																								
Green Spaces/Person (sq.m)	-0.16947	-0.14935	0.619772	-0.96434	-0.54462	0.114714	0.983248	-0.06198	1																							
Housing Availibility (No/1000 ppl)	0.61761	0.736431	0.202505	0.05238	0.268952	0.389655	0.028261	-0.86238	0.04832	1																						
Avg. HH Size (no. of ppl)	-0.2767	-0.0382	0.512332	0.527674	0.048097	0.132787	0.485389	-0.31175	0.577018	0.028402	1																					
Share of HH one room (%)	-0.60787	0.074914	0.005689	-0.05811	0.025888	-0.11692	-0.30975	0.227001	-0.28412	-0.29111	0.074348	1																				
Share of HH in Pucca houses(%)	0.17076	0.230195	-0.48096	-0.96798	0.685666	-0.12221	-0.97714	-0.0419	-0.9557	0.02772	-0.3892	0.171943	1																			
Share of Popn In Slums(%)	0.702331	-0.57214	-0.14061	-0.07346	-0.23394	-0.32822	-0.13176	0.890837	-0.15445	-0.92111	-0.23091	0.487764	0.017068	1																		
Share of Houseless popn(%)	0.692333	-0.26852	0.502909	0.954087	-0.65677	0.051594	0.986989	0.576125	0.980772	-0.0823	0.503676	-0.23802	-0.97974	-0.03198	1																	
Per Capita water Consumption (lpcd)	-0.54489	0.081411	0.765665	0.914613	-0.34315	0.111534	0.807837	0.041303	0.844582	-0.03348	0.582951	0.159404	-0.82457	0.062905	0.817759	1																
HH with Potable water supply (%)	-0.41666	0.225419	0.040031	-0.26907	0.578845	0.328215	-0.37044	0.157092	-0.38871	-0.16717	-0.24671	0.484154	0.330194	0.420109	-0.40727	0.070726	1															
HH with source of water within premise (%)	-0.4881	0.416396	0.065863	-0.33037	0.479453	0.057362	-0.55581	0.091711	-0.52555	-0.05554	-0.1556	0.808855	0.466227	0.334803	-0.54605	0.000455	0.832115	1														
HH with sewage connection(%)	0.204644	0.26568	0.344021	0.340911	0.588628	-0.45153	-0.2664	-0.11846	0.333767	0.53112	0.016827	-0.25201	-0.31083	-0.44052	0.300917	0.083089	0.735025	-0.44163	1													
HH with Acess to proper Toilets (%)	0.243104	-0.42107	-0.11135	-0.1276	-0.18432	-0.32327	0.09173	0.326341	0.092452	0.255582	-0.17355	-0.79166	-0.00576	-0.03346	0.108527	-0.31348	-0.4725	-0.73298	0.880025	1												
Per Capita Solid Waste (kg/day)	0.304203	-0.38583	-0.60398	-0.10313	-0.53573	-0.40931	0.030146	0.162865	-0.04995	0.236219	-0.13164	-0.11236	-0.04521	0.023026	0.092919	-0.32205	-0.63775	-0.4871	0.235481	0.257171	1											
HH with Electricity Connection	0.042964	-0.92519	-0.50471	0.126041	-0.51871	-0.05501	0.314586	0.457475	0.210258	0.676873	-0.06472	-0.18377	-0.3276	0.484732	0.362747	-0.06003	-0.32272	-0.53567	-0.20224	0.44782	0.618177	1										
HH with LPG Connection	0.468145	0.036918	0.181963	0.334239	-0.43276	-0.18238	0.501327	-0.12802	0.494488	0.432577	-0.03315	-0.8621	-0.42594	-0.50151	0.473502	0.059104	-0.71783	-0.85696	0.640732	0.674773	0.297436	0.147703	1									
HH using Renewable source	-0.61931	-0.01747	0.531412	-0.04083	0.21801	-0.45021	-0.10582	0.425384	0.035486	-0.39106	0.357795	-0.0056	0.160136	0.305549	-0.03351	0.144571	0.117104	0.099748	-0.06356	0.354291	-0.39969	-0.1815	-0.06957	1								
HH with Motorised Vehicle	0.883509	0.583685	0.359512	0.568817	-0.008	0.429595	0.161456	-0.51031	0.049217	0.578291	-0.39481	-0.69747	-0.09601	-0.61098	0.043169	-0.27928	-0.28254	-0.50979	0.169975	0.263511	0.237043	0.086993	0.611031	-0.67686	1							
Literacy Rate (%)	-0.30728	-0.18326	0.094588	0.200388	-0.66139	-0.40393	0.032503	-0.52495	0.042671	-0.24108	-0.47595	0.354146	-0.22554	0.45901	0.111969	0.077516	-0.07651	0.112786	0.463254	-0.06796	0.044275	0.120986	-0.04747	-0.07861	-0.25477	1						
Hospital bedsper 1000 popn	0.657923	0.245586	-0.15909	-0.10835	-0.22589	0.02986	-0.05594	-0.21968	-0.10111	0.554483	-0.65587	-0.47929	0.014172	-0.4252	-0.11848	-0.3679	-0.3021	-0.31796	0.576289	0.266069	0.084374	-0.14313	0.567599	-0.47456	0.72116	0.362348	1					
Infant Mortality Rate (Nos.)	-0.65136	0.410349	0.579098	0.20823	0.191579	0.023672	0.046553	0.301689	0.08153	-0.08704	-0.10083	0.340381	-0.10542	0.347087	0.03823	0.510428	-0.77091	-0.63238	-0.28114	-0.35038	-0.71318	-0.44942	-0.32708	0.322037	-0.34945	0.15622	-0.1885	1				
Average Life Expectancy (in Years)	0.080786	-0.43124	0.030235	-0.62132	-0.61442	0.012537	0.808108	0.169866	0.722287	-0.2203	0.153646	-0.48667	-0.7702	0.027316	0.807446	0.446744	0.729317	-0.71509	0.094925	0.394498	0.447647	0.664521	0.605474	-0.22374	0.366224	-0.0806	0.004243	-0.16601	1			
HH below poverty line (%)	-0.9117	-0.31472	0.352575	0.153893	-0.1471	-0.41923	-0.02743	0.65969	0.064798	-0.71171	0.31685	0.615534	-0.05465	0.749064	0.094565	0.338857	0.263286	0.393145	-0.17399	-0.13323	-0.22496	0.100414	-0.52977	0.663863	-0.96198	0.384725	-0.66264	0.531934	-0.20227	1		
GDP (in Billion Rs)	-0.79046	-0.46586	0.345574	0.559317	-0.35313	-0.02102	0.416123	0.413394	0.450365	-0.58745	0.490456	0.574319	-0.50086	0.615558	0.497592	0.647595	-0.1626	0.20342	-0.1859	-0.32021	0.162187	0.307801	-0.45026	0.26321	-0.71903	0.361818	-0.64014	0.27946	0.149389	0.811845	1	
Per Capita Annual Income	-0.31439	-0.34143	0.170824	0.766545	-0.5839	0.243567	0.69544	0.971221	0.638989	-0.22074	0.604511	0.373888	-0.79004	0.275376	0.716552	0.7139	-0.01327	-0.02532	-0.017	-0.44595	0.095657	0.388017	-0.14802	-0.37633	-0.13929	0.341446	-0.2488	0.13457	3	0.254128	0.742225	1

Source: Author

Across cities in the developing world, there is some evidence that life expectancy is lower and infant mortality higher among the urban poor than among comparable groups in rural and formal urban areas (Bradley, Stephens, Harpham, and Cairncross 1992). The entire population upstream (not only those nearby) contribute to microbial river pollution but urban populations contribute more pollution per capita than rural populations. How much more depends on their respective population densities. (D.G.Milledge et al.,2018).Sewage removal is essential for the public health of the city, but without effective treatment it comes at the cost of accentuated river pollution with associated public health implications for the population downstream(CPCB 2010). The potable quality of water measured by the presence of Total Coliform as one of the important parameters is also found to be positively correlated with the percentage of homeless population in the cities (r ~ 0.98) and moderately correlated with infant mortality rate (r ~ 0.46) and it is affected by the number of households having access to proper toilets (r ~ - 0.09),that with absence of toilets in the households and sometimes proper effluent treatment at the city level results in polluting of the water sources.

Population density in these cities show a strong and positive correlation with the population growth (r ~0.65),share of population in slums (r ~ 0.89) and households below poverty line (r ~ 0.65). Population density show a moderate correlation with share of houseless population (r ~ 0.57).Population density is negatively correlated to green space per person (r ~ - 0.06), housing availability(r ~ -0.86) and literacy rate (r ~ -0.52).

Despite tremendous variations across slums, issues common to all slum settings are a lack of adequate living space, insufficient public goods provision, and the poor quality of basic amenities, all of which lead to low levels of human capital. (Lopez, 2007)

Green Space in the cities is an important factor which determines the health and environment of the city. Urban densification processes, including consolidation and infill development, pose a threat to urban green space.(C. Haaland,C.K.Bosch,2015) In the selected cities for this study green space per person shows a strong correlation with average life expectancy (r ~ 0.72) which points to the fact that cities with more per capita green space show an enhanced life expectancy which may be attributed to its role in mitigating pollution and promoting a better health through its use. Per capita green space also shows a weak positive correlation with GDP (r~0.63) clearly showing that per capita green space decreases with rise in economic growth and strong positive correlation with per capita annual income (r~0.97) which may be read in a manner that with financial affluence of the individual and the city the demand and the intent for creating and preserving the green spaces increases which could also be a result of the people seeking better quality of life through it.

The global expansion of urban slums poses questions for economic research; the global expansion of urban slums poses questions for economic research, as well as problems for policymakers. Some economists (Frankenhoff 1967; Turner 1969; World Bank 2009; Glaeser 2011) have suggested a "modernization" theory of slums: according to this thinking, slums are a transitory phenomenon characteristic slums: according to this thinking, slums are a transitory phenomenon characteristic of fast-growing economies, and they progressively give way to formal housing as fast-growing economies, and they progressively give way to formal housing as economic growth trickles down and societies approach the later stages of economic development. Even if slum areas appear stable in the short- or medium-term, this argument holds, slum living only represents a transitory phase in the life cycle of argument holds, slum living only represents a transitory phase in the life cycle of rural migrants: the slum dwellers or their children eventually move into formal housing within the city, so that the benefits of migration into the slum get passed along from generation to generation.

Absent or deficient water and sewage systems in slums translate into a broad range of health and sanitation issues, whether through direct exposure to bacterial agents, contaminated drinking water, or other channels.(Duflo, Galiani, and Mobarak 2012).

The indicator housing availability is a measure of the social environment and in these cities it shows a positive but moderate and weak correlation with other physical and social infrastructure like number of hospital beds per thousand population (r~0.55), households with sewage connection (r ~0.53) and households with electric connection also increases (r ~ 0.67) which means with the increase in the housing stock the other supporting social and physical infrastructures are enhanced and strengthened. This indicator shows a negative correlation with share of houseless population (r ~ -0.08) which is quite understandable.

Average household size is another important indicator which gives us the measure of the social environment in these urban centres and it shows positive correlation of strong strength with per capita annual income (r ~ 0.60) and moderate strength with city GDP (r ~ 0.49). However literacy rate is negatively correlated with average household size (r ~ - 0.47) which is an indicator of the fact that with increase in the household size the expenditure increases and since the earning members generally are less as a result literacy rates sometimes come down. The study on the 'economic contribution of urban poor in India' has also found that people living as informal settlement dwellers contribute about more than 7.5 per cent to the country's urban GDP.A large proportion of urban poor workforce, which consists of domestic help, vendors and hawkers, construction workers, rag-pickers and rickshaw pullers dwell in informal settlements, slums and resettlement colonies. "The estimate of slums takes into account certain criteria set by Census for settlement to be featured as slums. However, a large chunk of households are left out who are living in similar or poorer dwelling conditions compared to those of slums and therefore. (Bhandari, 2013).

The indicator households with one room has a strong positive correlation with households with source of water within the premise (r ~ 0.80) and households below poverty line (r ~ 0.61) and a negative correlation with the share of houseless population (r ~ - 0.23). Households with pucca houses shows a moderate positive correlation with households with metered electric connection (r ~ 0.36).

In India, slum populations were comprehensively enumerated for the first time in 2001, but discrepancies in the state-level definitions of slums and the refusal of some states to validate the slum statistics resulted in "gross under-estimation/under-coverage of slum populations in the country" (Government of India,2011).The share of population in slums is strongly correlated with households below poverty line (r ~ 0.74) and negatively correlated with household with proper access to toilets (r ~ - 0.03) and sewage connection (r ~ - 0.44).This point to the fact that when these slums increase the infrastructure facilities for these are not met and fall short.

Poverty is quite commonly associated with low per capita incomes, lower literacy rates (Wamba, 2011), lesser access to basic amenities (MoHUPA, 2009) and lower life expectancy (Weiss et al., 1991).The indicator houseless population shows a moderate correlation with increase in GDP (r ~ 0.49) and negative correlation with average life expectancy(r ~ 0.08)

In million plus city datasets, there is high degree of correlation observed between poverty and access to potable water (r ~ 0.56), and household with access to sewage connection (r ~ 0.71), access to toilets (r ~ 0.52), LPG (r ~ 0.52), electricity (r ~ 0.60), sanitation facilities (r ~ 0.59).

Access to clean drinking water, use of cleaner energy options (LPG/ electricity / renewable energy sources) and special attention towards health and hygiene has been found to be positively correlated with better environmental conditions and correspondingly enhanced life expectancy. Life expectancy has been found to be highly correlated with access to clean energy(r ~ 0.63), inverse population growth rates (r ~ 0.80) and lower poverty levels (r ~ 0.6).

Access to basic amenities has been found to be linked strongly with per capita income levels. Delhi with higher per capita income and hence lesser poverty has most of its population covered with tap water supply, LPG fuels, electricity and proper sanitation facilities. However inadequate land availability and high land prices, the housing availability becomes poor resulting more percentage of population living in slums. Higher per capita income levels have also been found to have higher correlation with waste generation but better management practices. This is in line with the philosophy of the Kuznets curve (Dinda, 2004) which indicates enhanced consumption due to affluence and disposable income initially but improved environmental awareness with rising income levels.

In addition to poverty and environmental parameters, life expectancy is also influenced by the type of health infrastructure facilities available in the region. Number of hospital beds available in different cities have shown a moderate correlation with the life expectancy indicator (r ~ 0.38).It can therefore be concluded that the life expectancy of a city depends upon a number of parameters such as the economic conditions, access to basic amenities, environmental factors and health infrastructure.

Poverty levels have shown a moderate correlation and found to be decreasing with increasing literacy rates. Higher literacy rates in cities have been correlated with lower poverty rates (r ~ 0.6), with better choices of energy use e.g. LPG (r ~ 0.54) and improved air quality (r ~ 0.37). Chennai being the most literate state amongst the chosen million plus cities (90% literacy) of the country depicts better access to cleaner fuel like LPG (89%,about 1.5 times the national average) which certainly improves the air quality to some extent.

Access to water within the premise is negatively correlated to infant mortality rate (r ~ - 0.6) which shows that better and safe access to water within the premises ensures better chances of the infants to survive. Access to toilets has a strong and positive correlation with households with LPG (r ~ 0.67) .It has a moderate correlation with electricity connection(r ~ 0.44) and weak correlation with life expectancy (r ~ 0.39). There is a positive and strong correlation observed between potable water supply and sewage connection (r~0.73), average life expectancy(r~0.72).It has a negative correlation with infant mortality rate (r~-0.77).Water supply within premise also is negatively correlated to infant mortality rate (r~0.73). This further reinforces the point that access to potable water supply leads to better quality of life.

Strong positive correlation is also exhibited in between sewage connection and LPG connection in households (r~0.67) and access to proper toilets (r~0.88).Weak positive correlation is observed between sewage connection and literacy (r~0.46). Households with access to proper toilets have a positive correlation with electric connections (r~0.44) and LPG connection(r~0.73).

Average life expectancy shows a positive correlation with access to toilets (r~0.39), households with electric connection (r~0.66), households with LPG connection(r~0.60) and per capita annual income (r~0.50).

Infant mortality rate shows a positive correlation with SO_2 (r~0.41), NO_2 (r~0.57), land population density (r~0.30), per capita water consumption (r~0.51) and households with renewable source of energy(r~0.31).It shows a negative correlation with housing availability (r~ -0.08) ,share of population in pucca houses (r~0.-10), households with potable water supply (r~0.-77), households with source of water within premise (r~ -0.63).

The GDP shows a positive correlation with households with electricity connection(r~ 0.30), literacy rate (r~0.37) and negatively correlated with sewage connection(r~ -0.17), toilet facility within premise (r~0.-32), hospital beds (r~0.-64) and LPG connection (r~0.-45)**.**

4.7 Ranking of the Cities Based on the EPI (Macro) Score

The indices estimated for sustainable development of settlements through Environmental Performance Index (Macro) of the eight selected domains are averaged to calculate the Environmental Performance Index (EPI Macro) of each city. Weightages have been provided to all the eight domains (covering the three themes social, economic and environment of sustainability). These weightages have been assigned to the eight selected domains derived in consultation with expert.

The EPI Macro values estimated in the section are based on the average scores of social, economic and environment themes (covered by the eight domains in this study) of sustainability. It may be noted that EPI Macro thus computed may average out the impact of anti-correlated sub-indicators viz. EPI (Air), EPI (Water)… EPI (Finance) and may not communicate the causal factors for the high or low values of the index. Thus, in order to know these causal factors, the sub-indicators needs be assessed independently. This will also help the policy makers in identifying and taking appropriate corrective actions for specific sub-indicator and will thus help in improving the overall EPI Macro score of the domain and subsequently the city. For instance, Bengaluru performs moderately well in terms of air, land, population (social) and finance (economic) sub-indicators, but performs poorly in sub-indicators of water (environment), infrastructure and energy. Bengaluru still manages to get the top ranking among the eight cities. In case of Chennai though it scores well in terms of population and moderately well in terms of air (environment) and energy. In terms of land and infrastructure it scores poorly and drops to the last rank among the eight cities. This clearly indicates that just due to two poor performing sub-indicator the overall EPI Macro of the city falls down despite other sub-indicators performing relatively better. Thus, in order improve the overall EPI Macro efforts must be targeted to improve the state of the environment while maintaining the other sub-indicators scores in respective domains.

Table 4.18 provides a summary of sustainability indices for various cities along with their rankings. It is evident from the analysis that on a comparative scale, the cities of Bengaluru and Ahmedabad are more sustainable than the rest. However, cities of Chennai, Kolkata, and Pune are not performing well in all the eight domains consistently, and therefore showing low index values.

Table 4.18: Table showing the domain and city wise Environmental Performance Index Values and Ranking

MACRO INDICATORS	WEIGHTAGE	MUMBAI			DELHI			KOLKATA			CHENNAI		
		VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE
Inverse SO2 µg/cu.m		0.84	0.63		0.81	0.53		0.63	-0.12		0.72	0.20	
Inverse NO2 µg/cu.m		0.49	0.41		0.06	-1.17		0.00	-1.39		0.63	0.92	
Inverse PM10 µg/cu.m		0.48	-0.06		0.00	-2.34		0.49	0.00		0.59	0.45	
EPI (Air)	8.20		0.33	2.67		-0.99	-8.14		-0.51	-4.14		0.52	4.28
RANK (AIR)			Rank 5			Rank7			Rank 6			Rank 3	
(DO)(mg/l)		3.40	-0.09		0.50	-1.42		4.10	0.23		0.34	-1.49	
Inverse (BOD)(mg/l)		0.21	-0.40		0.17	0.92		0.92	1.48		1.00	1.70	
Inverse Coliform converted to log scale (MPN/100ml)		1767.00	0.82		31276922.00	-1.82		1076670.00	-0.91		56321.00	-0.12	
EPI (Water)	7.80		0.11	0.84		-0.77	-6.04		0.26	2.05		0.03	0.23
RANK(WATER)			Rank 5			Rank 8			Rank 4			Rank 6	
Land Population Density (p/Ha)		0.27	-0.55		0.60	0.36		0.09	-1.05		0.00	-1.31	
Green Spaces/Person (sq.m)		1.24	-0.44		18.00	2.42		4.50	0.11		0.81	-0.52	
EPI (Land)	6.90		-0.49	-3.41		1.39	9.59		-0.47	-3.24		-0.91	-6.31
RANK(LAND)			Rank 7			Rank 1			Rank 5			Rank 8	
Housing Availibility (No/1000 ppl)		60.20	-1.04		280.00	0.10		93.00	-0.87		152.20	-0.57	
Avg. HH Size (no. of ppl)		4.68	0.05		5.02	1.16		4.96	0.97		4.18	-1.59	
Share of HH more than one room (%)		37.30	-2.22		67.80	0.77		57.50	-0.24		61.40	0.14	
Share of HH in Pucca houses(%)		90.40	0.03		70.30	-2.42		93.00	0.35		91.10	0.11	
Share of Popn not In Slums (%)		58.10	-1.51		85.40	0.34		70.40	-0.67		71.50	-0.60	
Share of Popn with House (%)		99.70	0.25		97.34	-2.43		99.51	0.04		99.64	0.18	
EPI (Housing)	7.30		-0.74	-5.40		-0.41	-3.02		-0.07	-0.53		-0.39	-2.82
RANK (HOUSING)			Rank 8			Rank 7			Rank 5			Rank 6	
Per Capita water Consumption (lpcd)		204.00	0.44		292.00	1.98		202.00	0.40		133.00	-0.81	
HH with Potable water supply (%)		97.80	1.28		81.30	-0.90		88.10	0.00		82.10	-0.80	
HH with source of water within premise (%)		98.30	1.64		78.40	-1.37		89.30	0.28		84.20	-0.49	
HH with sewage connection(%)		87.40	-1.09		96.30	0.64		94.37	0.27		98.00	0.97	
HH with Acess to proper Toilets (%)		67.00	-1.75		89.40	0.20		94.90	0.68		95.60	0.74	
Inverse Per Capita Solid Waste (kg/day)		0.34	0.25		0.28	-0.10		0.42	0.72		0.00	-1.70	
EPI (Infrastructure)	6.80		0.13	0.87		0.07	0.51		0.39	2.65		-0.35	-2.38
RANK (INFRASTRUCTURE)			Rank3			Rank5			Rank2			Rank 7	
HH with Electricity Connection		98.10	0.32		99.10	0.79		96.20	-0.57		99.10	0.79	
HH with LPG Connection		28.50	-2.14		89.90	1.24		64.70	-0.15		82.30	0.82	
HH using Renewable source		0.12	0.14		0.15	0.68		0.16	0.86		0.04	-1.32	
HH with Motorised Vehicle		70.80	1.36		40.40	-0.46		78.90	1.84		40.20	-0.47	
EPI (Energy)	7.10		-0.08	-0.56		0.56	3.99		0.50	3.52		-0.04	-0.32
RANK (ENERGY)			Rank 4			Rank 1			Rank 2			Rank 3	
Inverse Population Growth		88.07	1.23		73.04	0.17		93.55	1.62		68.09	-0.17	
Hospital bedsper 1000 popn		0.80	-1.13		1.40	-0.11		0.80	-1.13		2.10	1.08	
Live births per 1000 popn (Nos.)		980.00	-0.65		982.00	-0.10		980.00	-0.65		984.00	0.45	
Average Life Expectancy (in Years)		63.70	-0.69		73.20	2.01		63.90	-0.64		68.31	0.62	
HH Above poverty line (%)		80.40	-1.38		90.09	0.12		78.07	-1.74		91.30	0.31	
EPI (Popn.)	7.60		-0.52	-3.98		0.42	3.20		-0.51	-3.86		0.46	3.48
RANK (POPULATION)			Rank 8			Rank 2			Rank 7			Rank 1	
GDP (in Billion Rs)		13585.00	1.71		10855.00	1.00		9750.00	0.72		4290.00	-0.70	
Per capita annual income (in Rs)		125000.00	1.43		136690.00	1.74		40540.00	-0.83		64200.00	-0.19	
Population employed(%)		80.60	-0.10		70.70	-1.18		78.80	-0.29		80.90	-0.06	
EPI (Economy)	6.80		1.02	6.91		0.52	3.55		-0.13	-0.91		-0.32	-2.17
RANK (ECONOMY)			Rank 1			Rank 2			Rank 5			Rank 6	
EPI Macro (City) $=\sum_{n=0}^{N} EPI$			-0.26	-2.06		0.79	3.64		-0.54	-4.46		-1.00	-6.00
EPI Macro (City) RANKING				Rank 4			Rank 3			Rank 7			Rank 8

MACRO INDICATORS	BENGALURU			HYDERABAD			AHMEDABAD			PUNE		
	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE	VALUES	CIV	W VALUE
Inverse SO2 µg/cu.m	0.88	0.74		0.84	0.63		0.56	-0.34		0.00	-2.28	
Inverse NO2 µg/cu.m	0.57	0.69		0.57	0.69		0.62	0.86		0.11	-1.00	
Inverse PM10 µg/cu.m	0.59	0.47		0.67	0.84		0.63	0.64		0.49	0.00	
EPI (Air)		0.63	5.20		0.72	5.90		0.39	3.18		-1.09	-8.96
RANK (AIR)		Rank 2			Rank 1			Rank 4			Rank 8	
(DO)(mg/l)	3.50	-0.05		6.00	1.09		5.60	0.91		5.40	0.82	
Inverse (BOD)(mg/l)	0.17	-0.51		0.00	-0.95		0.25	-0.29		0.17	-0.51	
Inverse Coliform converted to log scale (MPN/100ml)	160000.00	-0.40		2385.00	0.74		1932.00	0.79		1261.00	0.91	
EPI (Water)		-0.32	-2.49		0.29	2.28		0.47	3.68		0.41	3.17
RANK(WATER)		Rank 7			Rank 3			Rank 1			Rank 2	
Land Population Density (p/Ha)	0.86	1.12		0.33	-0.38		1.00	1.50		0.58	0.32	
Green Spaces/Person (sq.m)	2.01	-0.31		0.50	-0.57		1.34	-0.43		2.24	-0.27	
EPI (Land)		0.40	2.78		-0.48	-3.29		0.54	3.70		0.02	0.17
RANK(LAND)		Rank 3			Rank 6			Rank 2			Rank 4	
Housing Availibility (No/1000 ppl)	383.00	0.63		138.80	-0.64		345.80	0.44		637.00	1.95	
Avg. HH Size (no. of ppl)	4.64	-0.08		4.36	-1.00		4.96	0.97		4.52	-0.48	
Share of HH more than one room (%)	66.80	0.67		69.80	0.96		60.90	0.09		58.20	-0.17	
Share of HH in Pucca houses(%)	93.30	0.38		94.60	0.54		95.80	0.69		92.80	0.32	
Share of Popn not In Slums (%)	91.50	0.76		70.43	-0.67		95.59	1.04		99.60	1.31	
Share of Popn with House (%)	99.84	0.41		99.96	0.55		99.85	0.42		99.98	0.57	
EPI (Housing)		0.46	3.37		-0.04	-0.31		0.61	4.44		0.58	4.26
RANK (HOUSING)		Rank 3			Rank 4			Rank 1			Rank 2	
Per Capita water Consumption (lpcd)	112.00	-1.18		145.00	-0.60		150.00	-0.51		194.00	0.26	
HH with Potable water supply (%)	79.10	-1.20		97.80	1.28		84.70	-0.45		94.20	0.80	
HH with source of water within premise (%)	81.20	-0.95		87.50	0.01		86.20	-0.19		94.60	1.08	
HH with sewage connection(%)	97.50	0.87		84.30	-1.69		89.80	-0.62		96.30	0.64	
HH with Acess to proper Toilets (%)	94.80	0.67		98.50	0.99		83.00	-0.36		73.80	-1.16	
Inverse Per Capita Solid Waste (kg/day)	0.26	-0.17		0.42	0.73		0.11	-1.07		0.53	1.35	
EPI (Infrastructure)		-0.33	-2.21		0.12	0.81		-0.53	-3.63		0.50	3.37
RANK (INFRASTRUCTURE)		Rank 6			Rank 4			Rank8			Rank 1	
HH with Electricity Connection	98.00	0.28		98.70	0.60		97.40	-0.01		92.70	-2.21	
HH with LPG Connection	75.30	0.43		66.00	-0.08		64.60	-0.15		67.90	0.03	
HH using Renewable source	0.18	-1.24		0.03	-1.50		0.09	-0.42		0.13	0.32	
HH with Motorised Vehicle	38.20	-0.59		36.00	-0.72		42.00	-0.36		38.00	-0.60	
EPI (Energy)		-0.28	-1.98		-0.42	-3.00		-0.23	-1.66		-0.62	-4.37
RANK (ENERGY)		Rank 6			Rank 7			Rank 5			Rank 8	
Inverse Population Growth	50.56	-1.41		66.30	-0.30		59.50	-0.78		65.51	-0.36	
Hospital bedsper 1000 popn	2.10	1.08		1.50	0.06		0.90	-0.96		2.10	1.08	
Live births per 1000 popn (Nos.)	988.40	1.66		980.00	-0.65		986.55	1.15		978.00	-1.20	
Average Life Expectancy (in Years)	63.99	-0.61		67.20	0.30		66.50	0.10		62.30	-1.09	
HH Above poverty line (%)	92.70	0.53		92.08	0.43		94.57	0.82		95.11	0.90	
EPI (Popn.)		0.25	1.90		-0.03	-0.23		0.07	0.51		-0.13	-1.01
RANK (POPULATION)		Rank 3			Rank 5			Rank 4			Rank 6	
GDP (in Billion Rs)	5395.00	-0.42		4810.00	-0.57		4160.00	-0.74		3120.00	-1.01	
Per capita annual income (in Rs)	53331.00	-0.48		45300.00	-0.70		53813.00	-0.47		52600.00	-0.50	
Population employed(%)	96.40	1.64		73.00	-0.93		77.70	-0.41		93.70	1.34	
EPI (Economy)		0.25	1.67		-0.73	-4.98		-0.54	-3.68		-0.06	-0.39
RANK (ECONOMY)		Rank 3			Rank 8			Rank 7			Rank 4	
EPI Macro (City) $=\sum_{n=0}^{N} EPI$		1.07	8.24		-0.57	-2.81		0.76	6.54		-0.39	-3.76
EPI Macro (City) RANKING			Rank 1			Rank 5			Rank 2			Rank 6

Source: Author

Sustainability of a city to a large extent depends upon the economic capacity and robustness. Economic sustainability is important not only for socio-economic development but also for environmental preservation. Kuznets curves also demonstrate the fact that most pollution problems appear to begin improving before countries' per capita incomes reaches $800 (Grossman and Krueger, 1995). EPI values estimated for different domains for the selected cities were interpreted by exploring its linkages with these important parameters. A positive correlation has been observed between EPI (macro) values and per capita income across various cities. The cities with higher incomes have shown better EPI Macro values. The Kuznets curve claims that after reaching a certain economic level, the quality of life improves and community awareness to preserve the environment is also enhanced. When the income grows high, people tend to think beyond their basic needs. They look forward for better surroundings – better air, water, land, health facilities, and better institutions for higher education. In these conditions, environmental conservation takes the priorities not only for the individuals of the society but also for the policy makers. If the basic level of living - food, shelter, and clothing is achieved then government can also direct the finances for better technologies for environmental protection, higher education, health and infrastructural support. Enhanced economy with well informed and educated people will also encourage people into buying green products which may initially require a little higher investment but a quick payback with environmental and health benefits.

From the table 4.18 it is seen that the increase in EPI (macro) values with decrease in land population density in Indian Cities. This clearly identifies population control is a major driver for improving sustainability in a city. The cities with large land population density have been found to perform poorly on environmental fronts. In the current study, it has also been observed that cities with smaller administrative areas are easier to manage and hence perform better on all eight domains of sustainability index. Cities which have of less area show positive EPI (Macro) values. The Cities of i.e. Kolkata, Chennai, Pune and Hyderabad show negative EPI (City) values. However, due to better governance and quality of life, some cities are exceptions (Bengaluru, Ahmedabad and Delhi) show positive values in spite of their size. Geographically, when we weigh the EPI values by the factors of domain population in the cities, Bengaluru is found to be more sustainable followed by Mumbai and followed by Delhi. The cities of Pune, Kolkata and Chennai seem to be lagging behind as per the data analysis in the present study.

Overall, the cities such as Pune, Mumbai and Delhi have performed better on the infrastructure than the rest. On the other hand Chennai, Bengaluru and Ahmedabad are on the lower side. Rapid and unplanned economic development, (along with unprecedented rate of migration) is the main force in rendering the development unsustainable. However, it is important since it depicts a city's growth and monetary well-being.

A city's Gross Domestic Product (GDP) is one of the ways for measuring the size of its economy. Per capita Income often used as an indicator of standard of living in an economy. The indicator values show that the cities established during the British Rule (Kolkata, Mumbai, Chennai and Delhi) with established and flourishing trade and commerce still continue to have higher incomes, while cities that are relatively new hubs of IT sector (Bengaluru and Pune) are making remarkable gains.

Economy of the city is also linked to the employment patterns. Employment-to-population ratio is a statistical ratio that measures the proportion of the country's working-age population that is employed. The unemployment rate is the number of people unemployed in a city per unit working population. Having a high unemployment rate often means that an important cross section of the population in working age is unemployed and the economy is not able to produce enough jobs for the people. This generally has a negative effect on the GDP per capita of the city. The unemployment indicator shows that places like Pune and Bengaluru (with upcoming IT hubs) offer more employment opportunities and hence show lower unemployment rates. Overall, in terms of economic development Mumbai, Delhi and Bengaluru are performing well than the rest. However, the cities like Ahmedabad and Hyderabad have shown lower Sustainable performance in the Economic Index.

CHAPTER 5
APPLICATION OF SUSTAINABILITY INDICATORS AT MICRO LEVEL: A CASE STUDY OF SETTLEMENTS IN DELHI

5.1 SETTLEMENTS IN DELHI

Delhi's urban population almost grew double from 8.4 million in 1991 to 16.3 million in 2011. The net in-migration has contributed more to the tremendous population growth than the natural growth. The growth of urban population in Delhi over the past two decades as per the census information in given in the Table 5.1 below:

Table 5.1: Urban Population Growth in Delhi, 1991-2011

	Total Population (million)	**Urban Population (million)**	**% of Urban Population to Total Population**
1991	9420644	8471625	89.93
2001	13850507	12905780	93.18
2011	16753235	16333916	97.50

Source: Census of India, 1991-2011, Statistical Abstract of Delhi-2012

The urbanisation in Delhi is evident in the form of urban sprawl where the core area is experiencing less population growth than the periphery in the past two decades (Sivaramakrishnan, Kundu et al. 2005). The rural and urban composition of the land area of NCTD has undergone changes over the past few decades due to rapid urbanisation. According to the estimates of Directorate of Census Operations, Delhi the increase in the urban land component in the past two decades for NCT Delhi is given in Table 5.2 below:

Table 5.2: Urban land Composition NCT-Delhi (1991-2011)

	Total Area (sq.km)	**Urban Area (sq.km)**	**% of Urban Area to Total Area**
1991	1483	685.34	46.21
2001	1483	924.68	62.35
2011	1483	1113.65	75.09

Source: Census of India

As per Census 2011 estimates, 75 per cent of NCT Delhi is urbanised at present. It is estimated that the entire area under NCTD will be urbanised by 2021 (India 2007).

5.1.1 Settlement Typologies

The settlements are differentiated on the basis of tenure security, dwelling conditions, infrastructure status and the degree of planning intervention. As per MPD-2021, the settlement pattern in Delhi is broadly divided into the following typologies:

1. Planned Settlements- These are the outcome of planning initiatives, either by the Delhi Development Authority (DDA) or private agencies. Although the planned development of the city began as early as in 1960s, roughly around 24 per cent of the population actually lives in such planned settlements at present.

2. Unplanned Settlements-

   a) Unauthorised Colonies

   These settlements have developed primarily on agricultural land by illegal means and do not possess permission from planning, building and other regularising departments. The dwellings in these settlements have lesser degree of tenure security along with inadequate and sub-standard physical and social infrastructure. In 1993, there were 1,071 unauthorised colonies which are still in the process of regularisation. It is estimated that about 0.74 million people that is approximately more than 5percent of Delhi's inhabitants live in these kind of settlements (GoNCT Delhi, 2009). The Government of Delhi regularised 567 unauthorised colonies in 1977, and at present, a total of 1.76 million people live in this type of settlement that is roughly around 12 percent of Delhi's total population. The dwellings in these regularised urbanised settlements have the right to tenure and better infrastructure.

b) Urban Villages

These settlements were existent as rural villages within the limit of NCT Delhi.. After rapid urbanisation of Delhi they fell into urban areas and were renamed as "urban villages". These settlements though have a higher degree of tenure security but lack adequate social and physical infrastructure. When Delhi had its first master plan in 1962, about20 number of villages located within the urban area were declared as urban villages which has now grown up to 135 in number. A scheme to improve civic services in these villages was started by the Delhi Development Authority (DDA) during 1979-80 and then transferred to the Municipal Corporation of Delhi during 1987-88. The urban villages are home to around 0.88 million people that is approximately around 6 per cent of the city's total population.

c) Slum, Squatter Settlements and JJ clusters

These settlements are basically encroachments on public or private derelict land by poor migrants with no security of tenure. The dwellings in these settlements mostly comprise of temporary or kuttcha structures with non- existent infrastructure and amenities and extremely poor and unhygienic living conditions. At per census 2011, at present 10.65 percent of the total population of Delhi i.e. around 1.78 million people live in slums. There are few notified slum areas where the improvement schemes were undertaken by the Government in the form of tenure security and few basic infrastructural facilities like water supply and sewage connections. The resettlement schemes of these JJ clusters initiated in the 1970s by relocating squatters and slum households from the heart of the city to its periphery in order to improve their living conditions. The resettlements were mostly undertaken on the periphery and hardly involved any integrated mechanism of economic and social habitation (Schenk 2004).

Around 180,000 JJ cluster households were resettled by the DDA between 1975 and 1977 and 26 new JJ resettlement colonies were set up. Between 1979 and 1980, 44 JJ resettlement colonies were provided along with improved basic civic amenities. Between 1988 and 1991, the DDA transferred these settlements to the MCD. Presently all 44 JJ resettlement colonies have a piped water supply and sewerage system.

3. Special Area Settlements

These settlements in old Delhi have been designated by the master plan as 'Special Area' and include the walled city of Delhi-the Shahjahanabad, the walled city extension- Pahar Ganj, Sadar Bazar, Roshanara Road and their adjoining areas; and Karol bagh area. These settlements are characterised by a mix of different land uses and have similarities in compact and congested built form, narrow circulation space and low-rise high density developments, mainly accommodating residential, commercial- both retail or wholesale and industrial uses. The planning regulations for Special Area are different from other areas with focus on conservation and providing suitable framework for allowing mix use activities appropriate to the specific character of the area along with redevelopment of services, infrastructure amenities and parking facilities.

5.1.2 Selecting Settlements for Case Study at Micro Level

Delhi's explosive population growth and rapid urbanisation has led to a widening gap between the demand and supply of land, housing and allied infrastructure leading to the mushrooming of various unplanned settlements with inadequate infrastructure, poor living conditions and even various urban environmental problems in the planned settlements too.

The Master plan for Delhi addresses the various planning issues and gives broad guidelines for development and improvement at zonal level i.e. a macro scale. There is an urgent need to look into the various urban environmental issues at the neighbourhood or settlement level to incorporate the local inhabitants concerns, to address the site specific planning issues and for better implementation of local area schemes with bottom up approach. There have been recently few initiatives of Local

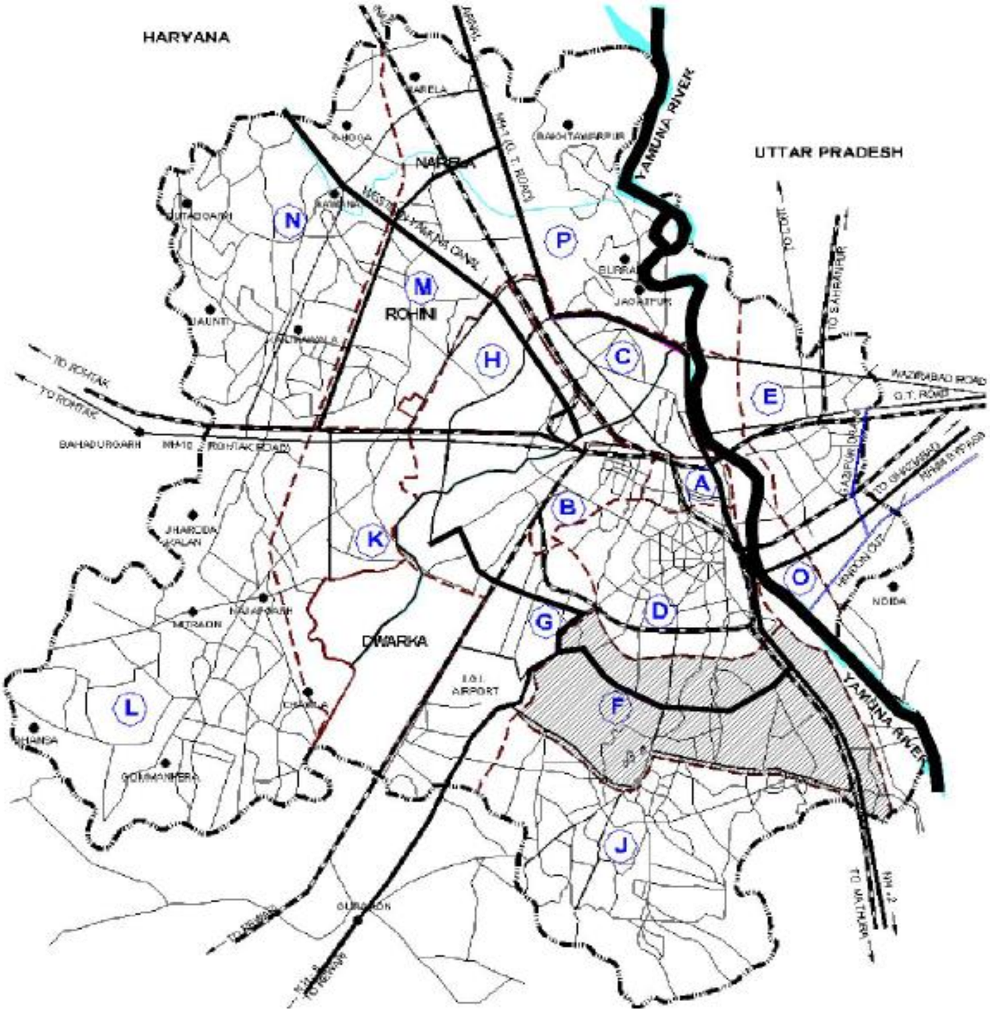
Area planning by Municipal Corporation of Delhi and urban design interventions by DUAC.

Three settlement areas, which can comprehensively represent both the planned and unplanned settlements in Delhi, have been chosen for the present study- CPWD Colony, a planned settlement by Government agency; Mohammadpur urban village and cluster of slums adjacent to Mohammadpur urban village. Each settlement possesses unique characteristics and calls for individual studies for environmental improvement and can become a prototype for further studies. The selected three settlement areas are closely located to each other at a very prime location in South Delhi are under a lot of developmental pressure. The closely located settlements have been chosen for the study for the sake of convenience of collection of data and information through primary field surveys. The present study mainly focuses on environmentally sustainable imperatives for improvement of these settlements in Delhi. In order to improve the environmental conditions of the various settlement types it is necessary to first asses their present environmental condition on various parameters at micro level involving the community/various stakeholders and then to devise an action strategy for in situ improvement and incorporation in the broader planning schemes.

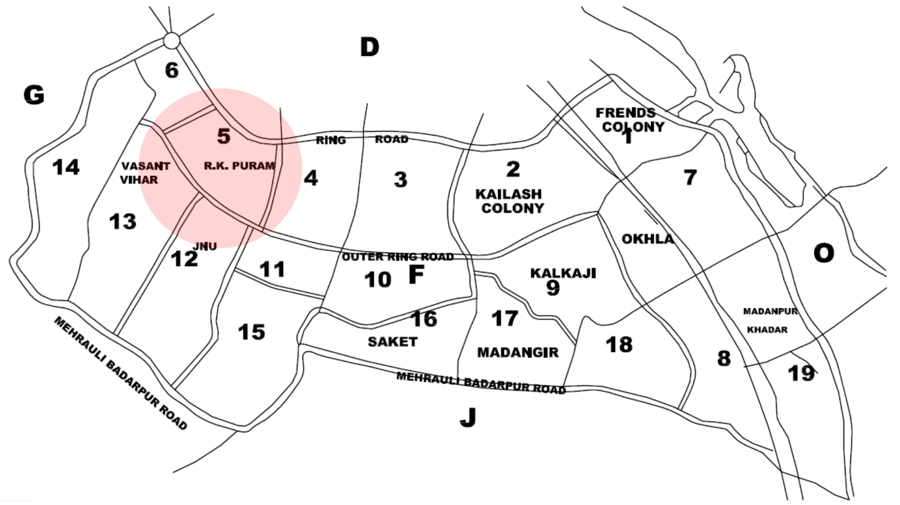
5.2 A BRIEF ABOUT THE SELECTED SETTLEMENTS IN DELHI

5.2.1 Location & Connectivity of the Settlements

The three selected settlements for the present study- CPWD Colony, Mohammadpur urban village and cluster of slums (Kumhar Basti, Adarsh Colony and Azad Basti) are located at a very prime position in south of Bhikaji Cama Place, a very important district centre, in the R.K. Puram Ward no 167 of MCD in south Delhi. The R.K. Puram ward comes in Zone F-5 in the Zonal Development Plan. The location of the three settlements in Zone F of Delhi is shown in the Maps 5.1 and 5.2 below:

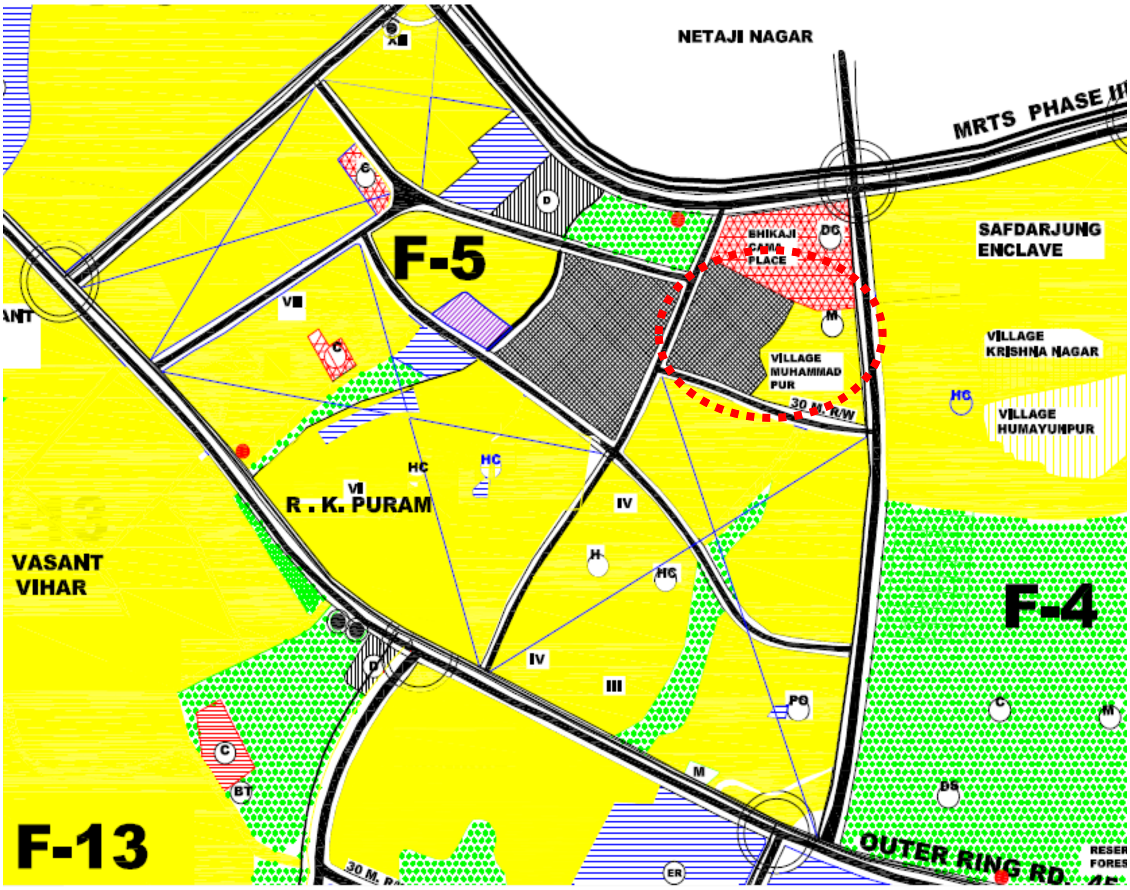


Map 5.1 Location of Zone-F on the map of Delhi
Source: MPD Delhi



Map 5.2 Key Map of Zone-F in Delhi
Source: Zonal Plan- F, Delhi

As per the zonal plan, shown in Map 5.3 below, the land occupied by the CPWD colony is residential, land under Mohammadpur urban village has been earmarked as a residential area with mixed-land use, whereas the land occupied by the cluster of slums is Government land earmarked for offices.



Map 5.3 Land use plan of Zone-F in Delhi
Source: Zonal Plan-F, Delhi

The main connectivity of the settlements is from Africa Avenue in the east. On the north of the settlements lies the Ring Road at a walking distance. The location is very well connected with public transport and lot of buses ply on both the routes. A metro station is proposed near Bhikaji Cama Place in phase 3 (Mukundpur-ShivVihar line), which will further increase the connectivity and real estate importance of the place.

Map 5.4 Aerial Image of the Study Area and its precincts
Source: Google Maps

5.2.2 A Brief Background of the Settlements

Mohammadpur village came into existence about 325 years ago when a few farmers who had their dwellings in the nearby Munirka village settled on the vacant land near Teen Burji Mosque, as they wanted to live closer to their agricultural land in the vicinity. With the acquisition of their land for urbanisation over the time, their village was given ‘Lal Dora’ status. The cluster of slums on the west of Mohammadpur urban village has been in existence for past 40 years encroached on the government land. The CPWD planned colony has also been in existence for approximately around 40 years.

5.2.3 Present Socio-Economic Structure

The Central Publics Works Department Housing Colony is covering an area of 4.21 ha. with a population of 1563 people approx. as per the RWA records. The residents of the colony are central government employees engaged in the central public works department and comprise mostly of middle and upper middle class population.

The Mohammadpur urban village is spread over an area of 8.36 ha with a population of 45523 people approximately as per the information gathered from village Pradhan and local councillor's office from the Delhi State Election Commissions Voting List. The village has undergone complete urbanisation in the past few decades with a complete change in the profile of people living here. It provides low-cost accommodation and employment opportunities in the vicinity to both the skilled and unskilled migrants and service population as the area has good access to public transport, high end residential areas and education and health services in the vicinity. A lot of small offices have also rented spaces here due to Bhikaji Cama Place (the CBD) in its vicinity and with the growth in economy and rising rentals has made the property owners financially very strong. All the streets inside the village have mixed land use with mainly convenience shops, barbers, photostat shops, mobile repair shops etc. The edge opposite Africa Avenue has mainly automobile and two wheeler repair shops apart from scrap dealers.

The records of Delhi Urban Shelter Improvement Board (DUSIB) suggest that the cluster of slums adjacent to Mohammadpur urban village comprises of 553 dwelling units with the following breakup:

- Azad Basti which has 96 Jhuggies
- Kumhar Basti which has 123 Jhuggies
- Adarsh Colony which has 334 Jhuggies

The above three squatter settlements have encroached an area of approximately 3.13 ha with a population of approximately 3515 people as per the estimates by DUSIB and pradhan of the squatter settlements. Many of the residents of these slums are employed in the nearby vicinity as domestic helps and in the offices mostly as peons with only 10 per cent of the people of these settlements below the poverty line. Many of the houses here are as high as 4 storeys. Most of the houses here have their own toilets and have been provided water and sewer connection by the Municipality.

Table 5.3: Comparative table of the various details of the chosen settlements of study

Sl. No.	DETAILS	MOHAMMADPUR VILLAGE	CPWD COLONY	SQUATTER SETTLEMENTS
1.	Area (ha) (Approximately)	8.36	4.21	3.13
2.	Population (Nos.) (Approximately)	45,523	1,563	3,515
3.	Density (Persons /Hectare) (Approximately)	5,446	372	1,124
4.	Households (Nos.) (Approximately)	7,283	334	654
5.	Household Size (Persons/Household) (Approximately)	6.25 ~ 6	4.68 ~ 5	5.38 ~ 5

Source: Voters List (DSEC), DUSIB / Author (from Primary Survey, Village Pradhan, Local Councillor, RWA

5.3 ENVIRONMENTAL PROFILE

The present environmental status of the three selected settlements (CPWD Colony, Mohammadpur urban village and Squatter Settlements) has been discussed under the following eight resource based domains identified in the previous chapters:

- Air
- Water
- Land
- Housing
- Infrastructure
- Energy
- Population
- Finance

In order to assess the present environmental status of the settlements apart from reconnaissance field survey, interaction with various stakeholders namely the residents, RWA's, village Pradhan, local councillor's office, various NGO's etc. a household survey was also conducted by the author.

Household survey was conducted on a sample size of approximately twenty per cent of the total households (HH) chosen randomly in each of the settlement as mentioned in the table below with the help of the survey format (Annexure IX):

Table 5.4 Survey statistics of the households of the three settlements

Details	Mohammadpur	CPWD Colony	Squatter Settlements
Total no .of HH	7283	334	654
Total no .of HH surveyed	1440	64	130
Total percentage of HH surveyed (Approximately)	20	20	20

Source: Author (from Primary Survey, Village Pradhan, Local Councillor, RWA)

5.3.1 Air

The household survey in 2014 and the reconnaissance field survey indicates that approximately 3 percent of the total surveyed households in the Mohammadpur urban village and around 8 per cent of the total surveyed households in the cluster of slums rely on kerosene and biomass for cooking and other domestic purposes like heating etc. Few residents of the village burn dung cakes daily for cooking and religious purposes. Apart from the households few small establishments like dhabhas, press walas etc. use coal as a cheap and easy alternative to a cleaner fuel like LPG.

Around 3 per cent of the households and establishments in the Mohammadpur urban village and less than 1 per cent households and establishments in the cluster of slums are using Diesel Generator (DG) sets as power back up without adhering to the recommended stack heights.

Plate 5.1: Dung cakes being dried for use later as Fuel
Source: Field Survey

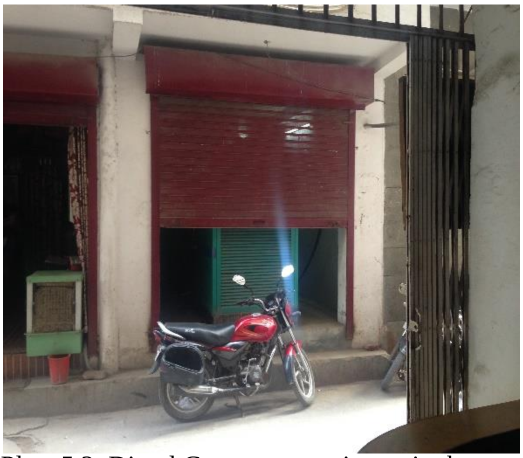


Plate 5.2: Diesel Generator sets in use in the Village without proper stack height
Source: Field Survey

On the village periphery, near the slums there are few informal car repair workshops which are releasing volatile organic compounds (VOC's) frequently in the air during re-painting of the vehicles. The welders and metal workshops in the fringes of the urban village and the squatter settlement also contribute to the air pollution. There are a few informal food joints (*dhabas*) in the squatter settlements which use coal for cooking thereby contributing to the air pollution.

Burning of solid waste in the morning by the municipal sweepers and cleaners has been observed as a regular feature in the open grounds on the periphery of the village adjoining the slums. These various activities contribute to the air pollution especially the particulate matter which poses a great threat to the health of the residents and the environment in the winter months when the air is dense and mixing height is low due to temperature inversion.

Moreover, the squatter settlement does not have proper metalled roads in the interiors and almost none of the internal roads have any plantation. Such un-metalled roads are close to 30 percent of the total road length of the settlement. In the urban village approximately 5 per cent of the total road length is not metalled and all most 90 percent of the interior roads are without plantation due to lack of availability of space Construction activities in the urban village and the squatter settlement contributes further to the suspended particulate matter in the air.

Plate 5.3 Burning of solid waste and dried leaves- a regular feature in the open space adjoining the Village
Source: Field Survey

Plate 5.4: Construction activities contributing to the SPM

Source: Field Survey

On the other hand all the households in the CPWD colony have CNG connections supplemented by LPG for cooking and do not use biomass or kerosene. Almost 14 percent of the households have power backups through battery operated inverters instead of diesel generators. The residents did not report of any incidences of burning of solid waste within the colony premises nor were such incidents observed during the tenure of the survey. All the internal roads in the colony are metalled with plantations on both the sides in almost 90 per cent of the total road length

Plate 5.5 Metalled roads with plantation on both sides in the CPWD Colony
Source: Field Survey

Plate 5.6 CNG connection in the CPWD colony

Source: Field Survey

5.3.2 Water

The house holds survey and the reconnaissance field survey indicates that all the households in the Mohammadpur urban village and the CPWD colony are connected to the municipal sewer line. However in the squatter settlements roughly around 75 per cent of the households have been connected to the municipal sewer and the rest of the households depend on either the community paid toilets or resort to defecation in the open grounds in the vicinity or the storm water drains, thus contributing to the land and water pollution. The incidences of water borne diseases are high in the squatter settlements due to unhygienic living conditions.

Plate 5.7: Community toilets in the Squatter Settlement
Source: Field Survey

Plate 5.8:Dumping of solid waste in the open by the slums and urban village
Source: Field Survey

Dumping of solid waste in open and in storm water drains is a regular feature in the village and the squatter settlement. The reason could be attributed to inadequate number and distribution of disposal bins in these areas.

In the CPWD colony there are adequate numbers of solid waste disposal bins and moreover because of the awareness of the residents and active campaigns of the RWA of the colony against random waste disposal they are not resorting to open dumping of solid waste. However few instances were reported and upon further investigating the reason it led to the conclusion that sometimes the domestic helps who were given the responsibility of dumping the household waste are resorting to dumping it either in the open or in storm water drains for the sake of their convenience and lack of awareness.

5.3.3 Land

The population of the Mohammadpur urban village at present is approximately around 45,523 persons estimated from the voters list and the information provided by the RWA, village panchayat and the local councilor’s office. The village area is approximately 8.36 Ha. The density of population in the urban village is around 5,446 persons per hectare.

The present population of the squatter settlements is approximately 3,515 persons estimated by the voters list and by consulting the NGOs working in the squatter settlement, the Pradhan’s office, and the local councilor’s office and by updating the list available with DUSIB. The area encroachment of the squatter settlement is around 3.13Ha.Hence the density of population in the squatter settlement is roughly around 1,124 persons per hectare.

The present population of the CPWD colony is approximately around 1,563 persons estimated by household survey and from the list available with the RWA .The area of the colony is approximately 4.21 Ha. The density of population in the CPWD colony is around 334 persons per hectare.

Optimal utilization of land is necessary to avoid overpopulation and the resulting overstressed infrastructure or under population and underutilization of the utility network and services. MPD housing strategy gives the net residential density norms in terms of category of dwelling unit sizes as i) EWS housing up to 30sq.m-600 DU/ha, ii) Category I above 30 sq.m to 40 sq.m-500 DU/ha, iii) category II above 40sq.m to 80 sq.m-250 DU/ha and iv) Category III-above 80 sq.m-175 DU/ha. Considering an average household size of 5 persons it roughly gives an idea of desired net population density range as 875 persons per hectare on the lower side to 3000 persons per hectare on the higher side. Based on this net population density range criteria CPWD colony has a very low density followed by squatter settlement. Whereas Mohammadpur urban village has a very high density compared to the taken threshold range.

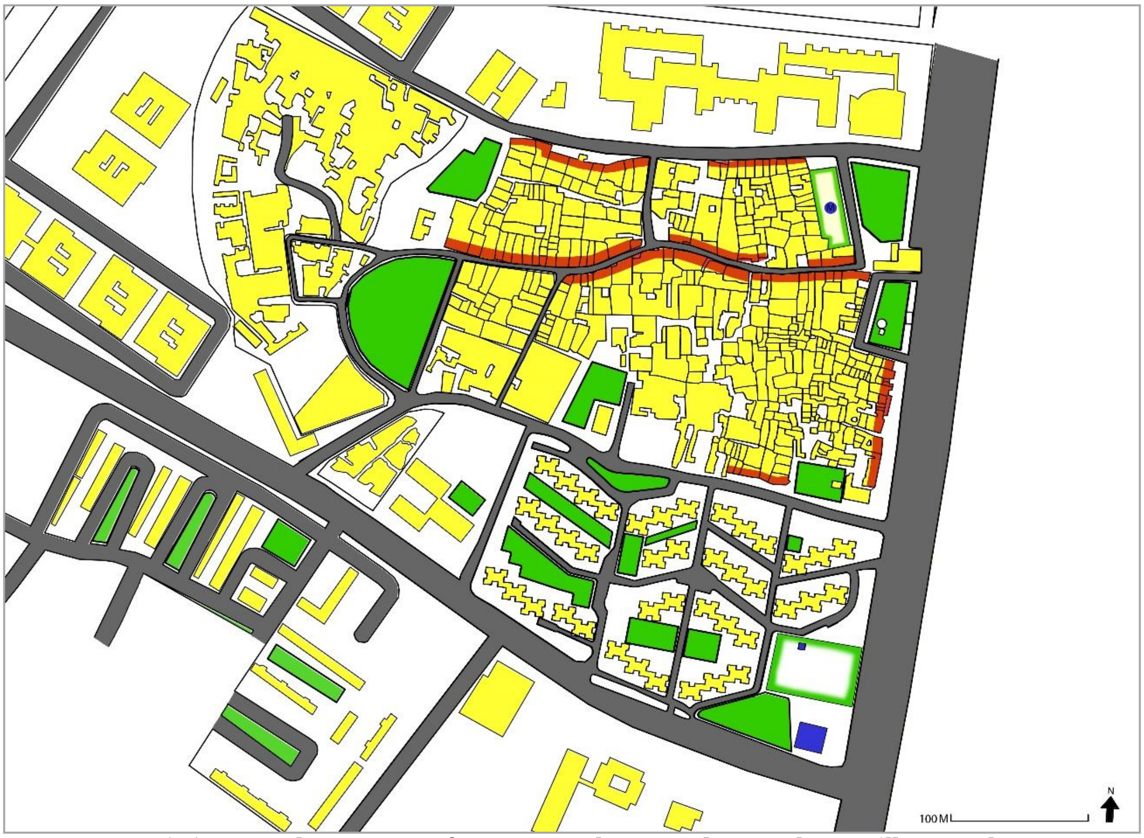
Floating population in a settlement also exerts pressure on the resources and the infrastructure. The exact estimates of the floating population in number could not be gathered from the local offices and hence a broad estimation has been done based on the number of establishments and commercial character of the settlements. In the CPWD colony it is mostly residential use and the domestic workers and people providing basic day to day services comprises the floating population which is low in number. In the urban village because of the prevalence of lot of commercial activities ranging from offices to other small services, the percentage of floating population is very high. In the squatter settlement there does not exist much of employment opportunities and the residing population works in either the village or the nearby residential areas during the day time and hence the floating population is very low in number.

The existing land use map of the three settlements with broad details of land under built up area, green areas, roads, paved and unpaved areas has been prepared from the aerial images and the information gathered from the field survey and is shown below in Map 5.5.

The provision of green space in a settlement is essential for the health of the inhabitants and overall environmental quality of the place. As per the aerial images and as shown in the land use map it has been estimated that in the CPWD colony roughly around 8.9

per cent of the total land area is under green mostly within the housing blocks and in the Mohammdapur urban village roughly 11.53 per cent of the total land is under green though mostly on the periphery of the settlement. On the other hand there are no proper green spaces in the squatter settlement. The per capita green space availability of the urban village approximately works out to 0.21 sq.m per person and that of the CPWD Colony works out to 2.49 sq.m. per person.

As per MPD residential standards, around 2.5 ha of green space shall be provided in the form of tot lots, housing area parks and neighborhood parks for a neighborhood of 10000 population size. Based on this the desired per capita green space for a neighborhood in Delhi works out to be around 2.5 sq.m. per person. Thus the per capita green space provision is satisfactory in the CPWD colony, insufficient in the urban village and almost nonexistent in the squatter settlement.



Map 5.5: Existing Land use map of CPWD Colony, Mohammadpur Village and Squatter Settlement

Source: Prepared by Author from Aerial images and Field Survey with help of the drawings existing Municipal Drawings

The increase in built up and paved areas and a consequent decrease in green and soft areas in urban settlements are leading to an increase in incidences of water logging and urban flooding during monsoons, as the storm water drains cannot handle the large volume of water generated in a very short time concentration during episodes of heavy and continuous rains. The surface run off coefficient of a plot of land gives an idea of the percentage of rainfall that becomes run off. Hence an attempt has been made to calculate composite run off rate (Refer Annexure V) of each plot of land under the three settlements based on the percentages of different types of surfaces to assess their vulnerability for water logging and flooding during monsoons.

Table 5.3 below gives the breakup of areas of different types of surfaces and the calculations of the composite run off coefficient rate of the three settlements

Table 5.5 Calculation of the 'Composite Run off Coefficient' of the three settlements

[*1] **Type of Surfaces**	**CPWD Colony** (Area in sq.m)	**Urban Village** (Area in sq.m)	**Slums** (Area in sq.m)	[*2] **Run-off Coefficients**	**CPWD Colony** (Run off rate)	**Urban Village** (Run off rate)	**Slums** (Run off rate)
Green cover (lawns, parks)	3783	9654	0	0.05-0.25 (0.15)	567.45	1448.1	0
Unpaved open spaces	24236	19793	12812	0.10-0.30 (0.20)	4847.2	3958.6	2562.4
Roads and pavements (asphalt, concrete)	7885	8229	1537	0.85-0.90 (0.87)	6859.95	7159.23	1337.19
Roof	6185	45984	17016	0.70-.95 (0.82)	5071.7	37706.88	13953.12
Total	42089	83660	31365		17346.3	50272.81	17852.71
[*3]Composite Run off Coefficient (%)					41.21	60.09	56.92

[*1] Area computed from the existing Land use map
[*2] Run off Coefficients taken from Rangwala, 2012
[*3] For Composite Run off Coefficient Rate Calculations refer Annexure V

Source: Computed by Author

The findings from the above table and the normalisation values as mentioned in Annexure V indicates that the CPWD colony with composite surface run off coefficient rate of 41 per cent is at medium risk of flooding whereas Mohammadpur urban village and the squatter settlement with composite surface run coefficient rate of 60 percent and 57 percent respectively are at high risk of flooding due to more paved surfaces and less of green areas.

An increase in more number of impervious surfaces decreases the evapotranspiration rate and contributes to overall increase in the heat island effect. An attempt has been made in the Table 5.6 below to calculate the impervious surface ratio to total land area of each settlement to do an assessment of the contribution to heat island effect (Refer Annexure VI for normalisation values and calculation details)

Table 5.6 Calculation of the 'Impervious Surface Ratio' of the three settlements

	CPWD Colony (Area in sq.m)	**Urban Village** (Area in sq.m)	**Slums** (Area in sq.m)
Total land area	42089	83660	31365
Roads and pavements (asphalt, concrete)	7885	8229	1537
Roof	6185	45984	17016
Total Impervious surfaces	14070	54213	18553
[*1]Impervious Surface Ratio (%)	33.43	64.80	59.15
[*1] For Impervious Surface Ratio Calculations refer Annexure VI			

Source: Computed by Author

The findings from the above table and the normalisation values as mentioned in Annexure VI indicates that the CPWD colony with impervious surface ratio of 33 per cent is at medium risk contribution to heat island effect whereas Mohammadpur urban village and the squatter settlement with impervious surface ratio of 65 percent and 59 percent respectively are at high risk contribution to heat island effect due to more built and paved surfaces and less of green areas.

Another criterion for assessment of the contribution to the risk of heat island effect is the calculation of the effective albedo value (refer Annexure VII) of different surface types in the plot of land under each settlement. The calculation of the effective albedo value of different surface types in the three settlements is given in the Table5.7 below:

Table 5.7: Calculation of the 'Effective Albedo (%)' of the three settlements

*1 **Type of Surfaces**	**CPWD Colony** (Area in sq.m)	**Urban Village** (Area in sq.m)	**Slums** (Area in sq.m)	*2 **Albedo Values**	**CPWD Colony** (Albedo of surfaces)	**Urban Village** (Albedo of surfaces)	**Slums** (Albedo of surfaces)
Green cover (Gardens, lawns, parks)	3783	9654	0	0.25-0.30 (0.28)	1059.24	2703.12	0
Unpaved open spaces	24236	19793	12812	0.17	4120.12	3364.81	2178.04
Roads and pavements (asphalt, concrete)	7885	8229	1537	0.13-0.20 (0.16)	1261.6	1316.64	245.92
Roof	6185	45984	17016	0.10-0.35 (0.23)	1422.55	10576.32	3913.68
Total	42089	83660	31365		7863.51	17960.89	6337.64
*3 **Effective Albedo (%)**					18.68	21.47	20.21

*1 Area computed from the existing Land use map
*2 Source: Akbari et.al, Taha et.al
*3 For Effective Albedo (%) Calculations refer Annexure VII

Source: Computed by Author

The findings from the above table and the normalization values as mentioned in Annexure VII indicates that the CPWD colony and squatter settlement with effective albedo of 19 per cent and 20 percent are at medium risk of contribution to heat island effect whereas Mohammadpur urban village with effective albedo of 21.5 percent is at low risk of contribution to heat island effect. The low albedo values can be attribute to more of asphalt paved roads in CPWD colony and high albedo values in Mohammadpur urban village can be attributed to more concrete paved roads in the interior of the settlement.

Apart from the above parameters a reconnaissance survey was done to see if any contamination of land is taking place by dumping of any hazardous wastes or chemicals. No such activity was seen in the three settlements during the survey though the residents of the urban village and the squatter settlement reported occurrence of such incidents occasionally by car workshops and other small scale industries using oils, paints etc. functioning on the periphery of the village and the slums.

5.3.4 Housing

It has been estimated from the voters list, RWAs, village Pradhan and the councilor's office that the population of around 45,523 persons in the Mohammadpur urban village comprises of around 7283 households inhabiting roughly around1823 houses. The housing availability roughly works out to be 40 houses per 1000 population. Almost all the houses in the village are 'pucca' though approximately only 60 per cent of the houses have proper natural lighting and ventilation. The average house hold size in the village works out to be around 6.25 persons per household. This figure is on the higher side in comparison to the average household size of 4.68 persons in Delhi. The figure clearly indicates the fact that there are many native families having joint household sharing the same kitchen. Apart from this there are many institutional households like messes, boardings, students and working people's hostels where a group of people are sharing the same kitchen.

The population of the squatter settlements is estimated to be around 3,515 persons with nearly 654 households inhabiting around 551 houses. The housing availability works out to be around 16 houses per 1000 population. Approximately 25 percent of the dwelling units are kuccha and roughly around only 10 per cent of the housing stock has access to proper natural lighting and ventilation in the interiors. The average household size in the squatter settlements is around 5.38 persons per household.

There are a total of 328 government flats in the CPWD colony out of which 9 are vacant. The population of the CPWD colony has been estimated at 1,563 persons with 334 households. The housing availability roughly works out to be around 200 houses per 1000 population. The colony has 100 per cent pucca houses with proper natural lighting and ventilation in the interiors, though almost 25 percent of the total numbers of houses are in bad condition due to lack of repair and maintenance for past many years. The average household size in the housing colony is around 4.68.

Plate 5.9:Houses in CPWD Colony
Source: Field Survey

Plate 5.10:A typical narrow street flanked by houses in the Urban village with insufficient natural light &ventilation
Source: Field Survey

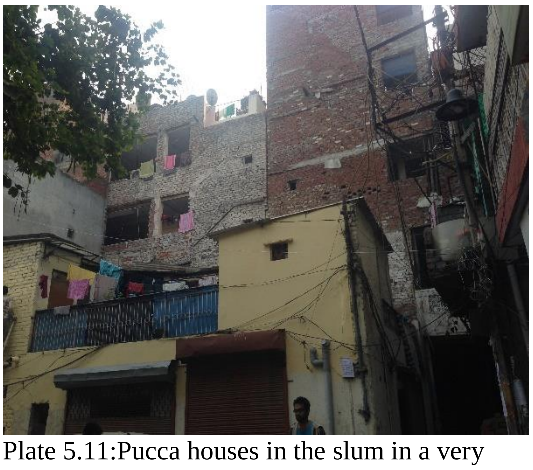


Plate 5.11:Pucca houses in the slum in a very congested form
Source: Field Survey

Plate 5.12:Kuttcha houses in the slum
Source: Field Survey

5.3.5 Infrastructure

The house hold survey of the settlements indicates all the households have water supply connection from DJB (Delhi Jal Board) in the urban village and CPWD colony. In the squatter settlements approximately 25 per cent of the households do not have access to proper water supply and water source within premises and depend on community taps or extract ground water through bore wells. The DJB water supply duration is for three and a half hours in the morning and two hours in the evening in the Mohammadpur village and the squatter settlement and around a total of 2 hours in the morning and one and half hours in the evening in the CPWD colony. Thus the water supply duration in the three settlements is almost at par with most of the residential areas in Delhi.

All the households in the Mohammadpur urban village and the CPWD colony are connected to the municipal sewer line and have proper toilet facilities within the houses. However in the squatter settlements only 75 per cent of the households have been connected to the municipal sewer and have toilet facilities within their premises and the rest of the households depends on either the community paid toilets or resort to open defecation.

Solid waste collection is on daily basis in Mohammadpur urban village and CPWD colony but not in the squatter settlements; however segregation at source is not in an organised manner in either of them. The collected solid waste is frequently openly dumped at the side of the streets or in the open grounds in the village and in the slums by the cleaning staff '*safai karamcharis'* as they do not want to make the effort of transporting it to the nearest dalao. However such open dumping of the solid waste is rarely taking place in the CPWD colony. Segregation of waste is mostly seen at the dalaos mainly by scrap dealers.

For collection of the solid waste and further transportation there is one dalao in the CPWD colony, three dalaos in the Mohammadpur urban village and none for the squatter settlement. As per MPD residential standards one dalao of an area of 0.02 ha shall be provided for every 10000 population. Considering the standard the number of dalaos is sufficient in the CPWD colony and falling short in the Mohammadpur urban village.

Plate5.13:Dalao in the CPWD Colony
Source: Field Survey

Plate 5.14: Dalao in the Mohammadpur Village
Source: Field Survey

5.3.6 Energy

The household survey of the settlements indicates all the households have authorised metred electrical connections in the urban village and CPWD colony. In the squatter settlement 13 percent of the households don't have any authorised metred electrical connection.

The number of households having LPG connections is cent percent in the Mohammadpur urban village. The households in the CPWD colony have piped natural gas connections which they use predominantly for cooking. In the squatter settlements the number of households that have LPG connections is around 75percent and the rest resort to using bio mass or kerosene for cooking.

None of the households in the Mohammadpur urban village, squatter settlement and the CPWD colony which have provisions of rain water harvesting or waste water recycling nor any of the settlements have these facilities at the community level. Access to public transport access points, daily public services and convenience shops are available for all the three settlements within a range of 500 metres due to the central and prime location of the settlements within the city.

5.3.7 Population

The house hold survey of the settlements indicates that the literate percentage of people is almost 98 percent in the CPWD Colony which is followed by 91 percent in the Mohammadpur urban village and 77 percent in the Squatter Settlements.

In terms of access to basic health facilities all the settlements have in the vicinity of less than 500 m of their location, which is the clinic and nursing home situated in the Mohammadpur urban village serving all the three settlements.

As far as the diseases among the children below 5 years are concerned the survey reveals that the incidences occur very rarely in CPWD Colony, occasionally in Mohammadpur urban village and very frequently in the Squatter Settlements.
The health of infants and children is majorly based on the adherence to all mandatory vaccinations till the age of five which lays the strong foundation for a disease free and healthy society.

In this regard full compliance is found in the CPWD Colony and in the Mohammadpur urban village 94 percent of the surveyed households have complied to all the vaccinations and in the Squatter settlements the compliance is 87 percent which is the least compliant.

The average age of the household is a fair indicator of the potential work force. In the survey of the households for the average age of the household in the CPWD Colony it is 41 years, for the Mohammadpur urban village the average age of the household is 45 years and it is 32 years for the Squatter Settlement.

The average income per household gives us a fair measure of the affordability and standard of living of the people there the average monthly household income in the CPWD colony is Rs 59,542 and in Mohammadpur urban village is Rs 38,256 and in the squatter settlement is Rs 14,456.

5.3.8 Finance

The household survey of the of the settlements indicates that the rate of income growth since past one year in the CPWD Colony has been 10.68 %, in the Mohammadpur urban village the rate has been 6.56% and in the Squatter Settlement 3.25%.Most of the people who are employed in the private sector and the informal sector and are daily wage earners.

The average monthly expenditure per household in the CPWD Colony in the past one year has been Rs 35,135, for the Mohammadpur urban village the average monthly expenditure per household has been Rs 25,832 and for the Squatter settlement it's been Rs 11,241.

The average monthly expenditure on electricity consumption per house holding the last one year is Rs 2318 for the CPWD Colony; the amount is Rs 1621 for the Mohammadpur urban village and for the Squatter Settlement the amount is Rs 638.

The percentage of population employed in CPWD Colony is 41.4 percent, in the Mohammadpur urban village it is 37.5 percent and in the Squatter Settlement it is 25.6 percent.

5.3.9 Present Environmental Profile

The summary of the present environmental status of the three settlements as discussed in detail above under the resource based domains- air, water, land, housing, infrastructure, energy, population and finance has been summarised in the Table 5.8 below.

An attempt has been made to quantify few indicators in percentages on a scale of 0-100 percent or 0-10 per cent wherever feasible, from household survey, an analysis of land use plan and aerial images. For few indicators where the quantitative assessment was not viable a qualitative assessment has been done on the Likert Scale based on the stakeholders perception, information from local offices duly supported by reconnaissance survey. Using the Likert scale the parameters have been tabulated either on the basis of frequency (never/rarely/occasionally/frequently/very frequently) quantity (none/very few/few/many/abundant) and potential (very high, high,medium,low,verylow).

Table 5.8 Present Environmental Profile of the Three Settlements in Delhi at Micro level

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
AIR Maintaining air quality and reducing pressure on the atmosphere	HH using biomass or kerosene for cooking/other domestic purpose (%) (Source: Primary Survey, 2014)	0	3	8
	HH /establishments using DG sets (%) (Source: Primary Survey, 2014)	0	3	< 1
	Establishments /small scale industries/workshops causing emissions (none/very few/few/many/abundant) (Source: Primary Survey, 2014)	None	Few	Very Few
	Emissions from burning of solid waste/dry leaves (daily/ frequently/ occasionally/ rarely/never) (Source: Primary Survey, 2014)	Rarely	Daily	Daily
	% of paved road length / area of total road (Source: Primary Survey, 2014 + Aerial Images)	100	95	70
	% of road length with road-side green/plantation (Source: Primary Survey, 2014 + Aerial Images)	90	10	0

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
WATER	Households with municipal sewage connection (%) (Source: DJB/Primary Survey, 2014)	100	100	75
	Open dumping of solid waste/ dumping in storm water drains (daily/frequently/occasionally/ rarely/never) (Source: Primary Survey, 2014)	Rarely	Daily	Daily
	Contamination of storm water runoff(agricultural fields,/landfills/chemical working sites/others) (daily/ frequently/occasionally/ rarely/never) (Source: Primary Survey, 2014)	Rarely	Daily	Daily
	Incidences of water borne diseases (very frequently/ frequently/occasionally/ rarely/ never) (Source: Local Office/Primary Survey, 2014)	Rarely	Rarely	Frequently

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
LAND	Population Density (person/ Ha) (Very High, High, Medium, Low, Very Low) (Source: Local office/Primary Survey,2014/Aerial Images)	372	5446	1124
	% of Floating Population (Very High, High, Medium, Low, Very Low) (Source: Primary Survey, 2014)	Low	3	Very Low
	Per Capita Green Space (sq.m/person) (Source: Land use Plan/Primary Survey, 2014/Aerial Images)	2.49	0.21	0
	Composite Surface runoff rate based on the percentage of different types of surfaces (%) (Very High, High, Medium, Low, Very Low) (Source: Land use Plan/Primary Survey/Aerial Images)	41 Medium	60 High	57 High

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
LAND (Contd.)	Impervious surface ratio to the total land area (%) (Very High, High, Medium, Low, Very Low) (Source: Land use Plan/Primary Survey, 2014/Aerial Images)	33 Medium	65 High	59 High
	Measurement of Albedo of different surfaces by their area percentages (%) (Very High, High, Medium, Low, Very Low) (Source: Land use Plan/Primary Survey, 2014/Aerial Images)	19 Medium	21.5 Low	20 Medium
	Contamination of land- dumping of hazardous waste/chemicals (very frequently/frequently/occasionally/ rarely /never) (Source: Primary Survey, 2014)	Never	Occasionally	Occasionally

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
HOUSING	Housing availability (No. of houses/1000 population) (Source: Local offices/Primary Survey, 2014)	219	40	16
	Average Household size (no.) (Source: Primary Survey, 2014)	4.68	6.25	5.38
	Share of population living in pucca (durable) houses (%) (Source: Primary Survey, 2014)	100	100	75
	Share of population living in houses with proper natural light and ventilation (%) (Source: Primary Survey, 2014)	100	60	10

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
INFRASTRUCTURE	Households with potable municipal water supply service (%) (Source: DJB/Primary Survey, 2014)	100	100	75
	Households with source of water within premises (%) (Source: DJB/Primary Survey, 2014)	100	100	75
	Piped water supply reliability (no. of hours of supply /day) (Source: DJB/Primary Survey, 2014)	3.5	5.5	5.5
	Households with municipal sewage connection (%) (Source: DJB/ Primary Survey, 2014)	100	100	75
	Households with access to proper toilet facilities within premises (%) (Source: DJB/ Primary Survey, 2014)	100	100	75

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
INFRASTRUCTURE (Contd.)	Quantity of industrial/hospital/hazardous waste generation (Very High, High, Medium, Low, Very Low) (Source: Primary Survey, 2014)	Very Low	Medium	Medium
	Frequency of solid waste collection (daily, alternate days/thrice a week/twice a week/weekly) (Source: Primary Survey, 2014)	Daily	Daily	Twice a week
	Open dumping of solid waste (daily/frequently/occasionally/ rarely/never) (Source: Primary Survey, 2014)	Rarely	Occasionally	Daily
	Sufficiency of dalaos for solid waste dumping(no.) (Source: Primary Survey, 2014)	1	3	0

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
ENERGY	Households with electricity connection (%) (Source: Primary Survey, 2014)	100	100	87
	Households with LPG /CNG connection (%) (Source: Primary Survey, 2014)	100	100	79
	Households with motorised vehicles (petrol/ diesel consumption) (%) (Source: Primary Survey, 2014)	85	72	34
	Households using renewable source of energy - solar energy, biogas (%) (Source: Primary Survey, 2014)	0	0	0
	HH with Rain water harvesting provision (%) (Source: Primary Survey, 2014)	0	0	0
	HH with waste water recycling Provision (%) (Source: Primary Survey, 2014)	0	0	0
	Access to public services and transport stops within walking distance(m) (less than 500m/ 500m-800m/ 800m-1km / >1km) (Source: Primary Survey, 2014)	500	500	500

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
POPULATION	Literacy Rate (%) (Source: Primary Survey, 2014)	98	91	77
	Access to basic health facilities in the vicinity (m) (less than 500m/ 500m-750m/ 750m-1km / >1km) (Source: Primary Survey, 2014)	<500	<500	<500
	Incidences of diseases among children below 5 years of age (very frequently/occasionally/ rarely/very rarely/never). (Source: Primary Survey, 2014)	Very Rarely	Occasionally	Very Frequently
	Adhered to all mandatory and major vaccinations till the age of 5 years as per WHO. (%) (Source: Primary Survey, 2014)	100	94	87
	Average age of people. (%)(Source: Primary Survey, 2014)	41	45	32
	Average Monthly Income per HH (Source: Primary Survey, 2014)	59,542	38,256	14,456

DOMAIN	MICRO INDICATORS	CPWD Colony	Mohammadpur Urban Village	Squatter Settlements
FINANCE	Income Growth Rate (%). (Source: Primary Survey, 2014)	10.68	06.56	03.25
	Average monthly expenditure per Household (Rs./Month) (Source: Primary Survey, 2014)	35,135	25,832	11,241
	Monthly Expenditure Electricity consumption (Average Monthly Household Electricity bill) (Source: Primary Survey, 2014)	2318	1621	638
	Percentage of Population Employed (%) (Source: Primary Survey, 2014)	41.4	37.5	25.6

Source: Compiled by Author from Primary Survey

5.4 APPLICATION OF ENVIRONMENTAL PERFORMANCE INDEX (MICRO)

Based on the methodology discussed in the previous section, the data (quantitative and qualitative) of the selected indicators were collected. A score was assigned, a 'Comparative Indicator Value' (CIV) to each indicator through a Likert Scale i.e. the environmental performance of each indicator under the identified domains was assessed on a sustainability scale of 1 to 5 where 1 score was attributed to the worst case scenario or performance and 5 score has been attributed to the best case scenario or performance. The Likert sale has been used for quantitative assessment of the indicators. This scale can be used to ascribe a quantitative value to a qualitative data, in statistical analysis to make it amenable. A numerical value is assigned to each potential choice and a mean figure for all the responses is computed at the end of the evaluation or survey (Kapshe, 2000).

In the process of measuring the Environmental Performance of a Settlement, domains and indicators play an important role. In the process of arriving at an index, selection of suitable indicators and fixing their number experts and planners were interviewed and their opinion was collected for finding weights (Refer **Annexure VIII**) to be assigned to each domain.

The Environmental Performance Index (Micro) for each domain of the settlement is derived by averaging the CIV computed for each of the indicators in the domain and multiplying it with the weightages given by experts as described in the process in the previous point.

EPI (CIV_{Air}) =Average CIV scores ($A_1, A_2, \ldots, A_n$) X weightages given by experts

Where A_1, A_2 and A_n are the various indicators under the domain of air.

The Environmental Performance Index (Micro) for each settlement is calculated by summing up the EPI of each domain and getting the final score.

Settlement EPI (Micro) = ∑ {EPI (Air) + EPI (Water) + …………+ EPI (Popn.) +EPI (Economy)}

Based on the individual Environmental Performance Index (Micro) for each settlement the Scores are arranged in a descending order. The settlement obtaining the highest EPI (Micro) Score is assigned the first ranking and the one with the least score the last ranking. The domain wise EPI (Micro) has been tabulated below

Table 5.9 Domain wise 'Environmental Performance Index' of the Three Settlements in Delhi (Calculations)

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	[*1]CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
AIR	HH using biomass or kerosene for cooking/other domestic purpose (%)	0	5	3	4	8	2	Range of 0-10% divided in 5 equal divisions and the highest score given to the least use of biomass
	HH/establishments using DG sets (%)	0	5	3	4	< 1	5	Range of 0-10% divided in 5 equal divisions and the highest score given to the least use of DG sets
	Establishments /small scale industries/workshops causing emissions (none/very few/few/many/abundant)	None	5	Few	3	Very Few	4	A score of 1-5 , where the highest score given to the settlement having least number of units causing air emissions

[*1] **CIV-** Comparative Indicator Value, where indicators are assigned score on a scale of 1 to 5, where 1 score is attributed to the worst performance and 5 score is attributed to the best performance

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
AIR (Contd.)	Emissions from burning of solid waste/dry leaves (daily/ frequently/ occasionally/ rarely/never)	Rarely	4	Daily	1	Daily	1	A score of 1-5 , where the highest score given to the least incidences of solid waste burning
	% of paved road length/ area of total road	100	5	95	5	70	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum % of paved road length
	% of road length with road-side green/plantation	90	5	10	1	0	1	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum % of road length with plantation
	Environmental Performance Index (Air)		**39.63**		**20.50**		**23.23**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
WATER	Households with municipal sewage connection (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum % of sewage connectivity.
	Open dumping of solid waste/ dumping in storm water drains (daily/frequently/occasionally/ rarely/never)	Rarely	4	Daily	1	Daily	1	A score of 1-5 , where the highest score given to the least incidences of solid waste dumping in open
	Contamination of storm water runoff(agricultural fields,/landfills/chemical working sites/others) (daily/ frequently/occasionally/ rarely/never)	Rarely	4	Daily	1	Daily	1	A score of 1-5 , where the highest score given to the least incidences of contamination of storm water runoff
	Incidences of water borne diseases (very frequently/ frequently/occasionally/ rarely/ never)	Rarely	4	Rarely	4	Frequently	2	A score of 1-5 , where the highest score given to the least incidences of water borne diseases
	Environmental Performance Index (Water)		**33.15**		**21.45**		**15.60**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
LAND	Population Density (person/ Ha) (Very High, High, Medium, Low, Very Low)	372 Very Low	5	5446 Very High	1	1124 Low	4	As derived from MPD DU/ha criteria (<875p/ha, 875-1250p/ha, 1250-2500p/ha, 2500-3000p/ha, >3000p/ha) A score of 1-5 , where the highest score given to the least population density
	Floating Population (Very High, High, Medium, Low, Very Low)	Low	4	Very High	1	Very Low	5	A score of 1-5 , where the highest score given to the least pressure from the floating population
	Per Capita Green Space (sq.m/person)	2.49	5	0.21	1	0	1	As derived from MPD green space criteria $\geq$2.5 sq.m/ person. Range of 0-2.5 divided in 5 equal divisions and the highest score given to the maximum per capita green space

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
LAND (Contd.)	Composite Surface runoff rate based on the percentage of different types of surfaces (%) (Very High, High, Medium, Low, Very Low)	41 Medium	3	60 High	2	57 High	2	Refer Annexure V for normalisation values A score of 1-5 , where the highest score given to the least risk of urban flooding
	Impervious surface ratio to the total land area (%) (Very High, High, Medium, Low, Very Low)	33 Medium	3	65 High	2	59 High	2	Refer Annexure VI for normalisation values. A score of 1-5 , where the highest score given to the least risk of urban heat island effect
	Measurement of Albedo of different surfaces by their area percentages (%) (Very High, High, Medium, Low, Very Low)	19 Medium	3	21.5 Low	4	20 Medium	3	Refer Annexure VII for normalisation values A score of 1-5 , where the highest score given to the least risk of urban heat island effect
	Contamination of land- dumping of hazardous waste/chemicals (very frequently/frequently/ occasionally/rarely/never)	Never	5	Occasionally	3	Occasionally	3	A score of 1-5 , where the highest score given to no incidences of contamination of land
	Environmental Performance Index (Land)		**27.60**		**13.80**		**19.71**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
HOUSING	Housing availability (No. of houses/1000 population)	219	5	40	1	16	1	Range of 0-250 divided in 5 equal divisions and the highest score given to the maximum housing availability
	Average Household size(no.)	4.68	3	6.25	4	5.38	3	Range of 0-10 divided in 5 equal divisions and the highest score given to the minimum household size
	Share of population living in pucca (durable) houses (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum percentage of pucca houses
	Share of population living in houses with proper natural light and ventilation (%)	100	5	60	3	10	1	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum percentage of houses having proper natural lighting and ventilation
	Environmental Performance Index (Housing)		**32.85**		**23.73**		**16.43**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
INFRAST-RUCTURE	Households with potable municipal water supply service (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum municipal water connections
	Households with source of water within premises (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum households having water source within the premises
	Piped water supply reliability (no. of hours of supply /day)	3.5	3	5.5	5	5.5	5	Range of 0-6 divided in 5 equal divisions and the highest score given to the maximum number of hours of water supply
	Households with municipal sewage connection (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum sewage connections

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
INFRAST-RUCTURE (Contd.)	Households with access to proper toilet facilities within premises (%)	100	5	100	5	75	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum households having toilets within the premises
	Handling of industrial / hospital / hazardous waste generated (Very Good, Good, Satisfactory, Poor, Very Poor)	Very Good	5	Satisfactory	3	Satisfactory	3	A score of 1-5 , where the highest score given to the best handling of any hazardous or hospital waste
	Frequency of solid waste collection (daily, alternate days/thrice a week/twice a week/weekly)	Daily	5	Daily	5	Twice a week	2	A score of 1-5 , where the highest score given to the daily collection of solid waste
	Open dumping of solid waste (daily/frequently/occasionally/ rarely/never)	Rarely	4	Occasionally	3	Daily	1	A score of 1-5 , where the highest score given to the least open dumping of solid waste
	Sufficiency of dalaos for solid waste dumping(no.)	1	5	3	3	0	1	A score of 1-5 , where the highest score given to the maximum percentage of sufficiency of the number of dalaos
	Environmental Performance Index (Infrastructure)		**31.73**		**29.47**		**21.16**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
ENERGY	Households with electricity connection (%)	100	5	100	5	87	5	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum electricity connections
	Households with LPG /CNG connection (%)	100	5	100	5	79	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum LPG/CNG connections
	Households with motorised vehicles (petrol/ diesel consumption) (%)	85	1	72	2	34	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the least ownership of private motorised vehicles
	Households using renewable source of energy - solar energy, biogas (%)	0	1	0	1	0	1	A score of 1-5 , where the highest score given to the maximum usage of renewable sources of energy by households

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
ENERGY (Contd.)	HH with Rain water harvesting provision (%)	0	1	0	1	0	1	A score of 1-5 , where the highest score given to the maximum percentage of RWH provision
	HH with waste water recycling Provision (%)	0	1	0	1	0	1	A score of 1-5 , where the highest score given to the maximum percentage of waste water recycling provision
	Access to public services and transport stops within walking distance(m) (less than 500m/ 500m-800m/ 800m-1km / >1km)	Within 500m	5	Within 500m	5	Within 500m	5	A score of 1-5 , where the highest score given to proximity of public services within 500 m distance
	Environmental Performance Index (Energy)		**19.27**		**20.29**		**21.30**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
POPULATION	% of literates with respect to the total population	98	5	85	5	78	4	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum % of literates.
	Access to basic health facilities in the vicinity (less than 500m/ 500m-750m/ 750m-1km / >1km)	100	5	100	5	100	5	A score of 1-5 , where the highest score given to the closest basic health facilities In the vicinity as per the given ranges.
	Incidences of diseases among children below 5 years of age (very frequently/occasionally/ rarely/very rarely/never).	Very Rarely	4	Occasionally	2	Very Frequently	1	A score of 1-5 , where the highest score given to the least incidences of diseases among children below 5 years of age

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
POPULATION (Contd.)	Adhered to all mandatory and major vaccinations till the age of 5 years. (%)	90	5	10	1	0	1	Range of 0-100% divided in 5 equal divisions and the highest score given to the maximum % of adherence to all mandatory and major vaccinations till the age of 5 years
	Average age of people.	41	2	45	1	32	5	A score of 1-5 , where the highest score given to the minimum average age.
	Average Monthly Income per Household (in Rs)	59,542	5	38,256	3	14,456	1	A score of 1-5, where the highest score given to the maximum average monthly income per household.
	Environmental Performance Index (Popn.)		**32.93**		**21.53**		**21.53**	

DOMAIN	MICRO INDICATORS	CPWD Colony (Values)	CIV	Mohammadpur Urban Village (Values)	CIV	Squatter Settlements (Values)	CIV	Scoring Criteria
FINANCE	Income Growth Rate (%).	98	5	85	5	78	4	A score of 1-5, where the highest score given to the highest percentage of literates.
	Per capita monthly expenditure (Rs./Month)	35,135	5	25,832	4	11,241	3	A score of 1-5, where the highest score given to the highest per capita expenditure
	Expenditure on electricity consumption (Household electricity bill / month)	2318	5	1621	1	638	1	Range of 0-100% divided in 5 equal divisions and the highest score given to highest expenditure
	Percentage of Population Employed (%)	41.4	3	37.5	2	25.6	2	Range of 0-100% divided in 5 equal divisions and the highest score given to highest percentage of population employed.
	Environmental Performance Index (Finance)		**40.80**		**27.20**		**22.67**	

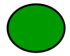
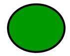
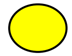
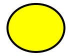
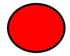
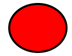
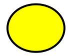
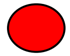
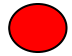
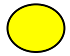
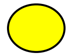
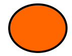
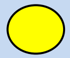
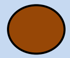
Table 5.10: Domain wise Tabulated Environmental Performance Index and Rank of the Three Settlements in Delhi

DOMAIN	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
EPI Air	39.63	20.50	23.23
EPI Water	33.15	21.45	15.60
EPI Land	27.60	13.80	19.71
EPI Housing	32.85	23.73	16.43
EPI Infrastructure	31.73	29.47	21.16
EPI Energy	19.27	20.29	21.30
EPI Population	32.93	21.53	21.53
EPI Finance	40.80	27.20	22.67
Total Environmental Performance Index (Micro)	257.97	177.96	161.63
Rank	1	2	3

Table 5.11: Environmental Performance Index of the Three Settlements in Delhi (Color Index)

Red	**> 0≤ 1** **CRITICAL ZONE**	Orange	**> 1≤ 2** **VERY HIGH RISK ZONE**	Brown	**>2≤3** **HIGH RISK ZONE**	Yellow	**>3≤4** **MEDIUM RISK ZONE**	Green	**>4≤5** **LOW RISK ZONE**

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
AIR	HH using biomass or kerosene for cooking/other domestic purpose (%)	Green	Yellow	Orange
	HH/establishments using DG sets (%)	Green	Yellow	Green
	Establishments /small scale industries/workshops causing emissions (none/very few/few/many/abundant)	Green	Brown	Yellow
	Emissions from burning of solid waste/dry leaves (daily/ frequently/ occasionally/ rarely/never)	Yellow	Red	Red
	% of paved road length/ area of total road	Green	Green	Yellow
	% of road length with road-side green/plantation	Green	Red	Red
	Environmental Performance Index (Air)	Green	Brown	Brown

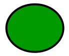
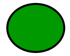
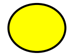
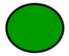
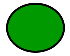
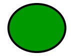
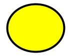
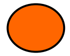
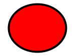
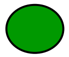
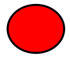
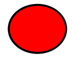
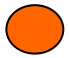
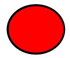
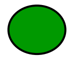
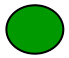
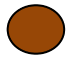
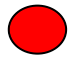
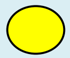
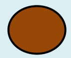
DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
WATER	Households with municipal sewage connection (%)			
	Open dumping of solid waste/ dumping in storm water drains (daily/frequently/occasionally/ rarely/never)			
	Contamination of storm water runoff (agricultural fields,/landfills/chemical working sites/others) (daily/ frequently/occasionally/ rarely/never)			
	Incidences of water borne diseases (very frequently/ frequently/occasionally/ rarely/never)			
	Environmental Performance Index (Water)			

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
LAND	Population Density (person/ Ha) (Very High, High, Medium, Low, Very Low)			
	% of Floating Population (Very High, High, Medium, Low, Very Low)			
	Per Capita Green Space (sq.m/person)			
	Composite Surface runoff rate based on the percentage of different types of surfaces (%) (Very High, High, Medium, Low, Very Low)			
	Impervious surface ratio to the total land area (%) (Very High, High, Medium, Low, Very Low)			
	Measurement of Albedo of different surfaces by their area percentages (%) (Very High, High, Medium, Low, Very Low)			
	Contamination of land- dumping of hazardous waste/chemicals (very frequently/frequently/occasionally/ rarely/never)			
	Environmental Performance Index (Land)			

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
HOUSING	Housing availability (No. of houses/1000 population)	🟢	🔴	🔴
	Average Household size(no.)	🟤	🟡	🟤
	Share of population living in pucca (durable) houses (%)	🟢	🟢	🟡
	Share of population living in houses with proper natural light and ventilation (%)	🟢	🟤	🔴
	Environmental Performance Index (Housing)	🟡	🟤	🟠

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
INFRASTRUCTURE	Households with potable municipal water supply service (%)			
	Households with source of water within premises (%)			
	Piped water supply reliability (no. of hours of supply /day)			
	Households with municipal sewage connection (%)			
	Households with access to proper toilet facilities within premises (%)			
	Handling of industrial / hospital / hazardous waste generated (Very Good, Good, Satisfactory, Poor, Very Poor)			
	Frequency of solid waste collection (daily, alternate days/thrice a week/twice a week/weekly)			
	Open dumping of solid waste (daily/frequently/occasionally/ rarely/never)			
	Sufficiency of dalaos for solid waste dumping(no.)			
	Environmental Performance Index (Infrastructure)			

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
ENERGY	Households with electricity connection (%)	🟢	🟢	🟢
	Households with LPG /CNG connection (%)	🟢	🟢	🟡
	Households with motorised vehicles (petrol/ diesel consumption) (%)	🔴	🟠	🟡
	Households using renewable source of energy - solar energy, biogas (%)	🔴	🔴	🔴
	HH with Rain water harvesting provision (%)	🔴	🔴	🔴
	HH with waste water recycling Provision (%)	🔴	🔴	🔴
	Access to public services and transport stops within walking distance(m) (less than 500m/ 500m-800m/ 800m-1km / >1km)	🟢	🟢	🟢
	Environmental Performance Index (Energy)	🟠	🟠	🟤

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
POPULATION	Literates with respect to the total population (%)			
	Access to basic health facilities in the vicinity (less than 500m/ 500m-750m/ 750m-1km / >1km)			
	Incidences of diseases among children below 5 years of age (very frequently/occasionally/ rarely/very rarely/never).			
	Adhered to all mandatory and major vaccinations till the age of 5 years. (%)			
	Average age of people.			
	Average Monthly Income per Household (in Rs)			
	Environmental Performance Index (Population)			

DOMAIN	MICRO INDICATORS	CPWD Colony (CIV)	Mohammadpur Urban Village (CIV)	Squatter Settlements (CIV)
FINANCE	Income Growth Rate (%).			
	Per capita monthly expenditure (Rs./Month)			
	Expenditure on electricity consumption (Household electricity bill / month)			
	Percentage of Population Employed (%)			
	Environmental Performance Index (Finance)			

Source: Author

5.5 ENVIRONMENTAL PERFORMANCE ANALYSIS OF THE SELECTED SETTLEMENTS (BASED ON PRIMARY DATA)

This section presents the analysis of each of the 8 domains i.e., air, water, land, energy, housing, infrastructure, population (labour) and; capital resource: finance (capital).The selected 32 indicators under the eight domains have been fed with data collected through the field surveys and Z-scores have been computed for relative comparison of the settlements (Table 5.10). The critical analysis of various indicators has been carried out to understand its causes and implications in the different settlements. Differences have been observed both in terms of socio-economic development and environmental degradation of the settlements. The selected settlements were compared for their comparative performance using the EPI (Micro) under each of the domains.

The environmental performance of the selected three settlements on the indicator households using biomass or kerosene for cooking/other domestic purpose, the performance of the CPWD Colony is the best as none of the households are using biomass or kerosene for cooking or for other domestic purpose.

In Mohammadpur urban village 3 percent of the surveyed households are dependent on biomass and kerosene especially for cooking. The reason for this can be traced back to the fact that the elder people feel that food is much tastier and healthy when cooked with biomass (especially cow dung) on a traditional chulah. The women folk are of the opinion that cooking in challah causes a lot of smoke and soot; it leads to frequent respiratory problem (mostly asthma and chronic bronchitis). Burning of cow dung cakes (*locally known as upla)* in the evening which has a religious significance for many of the households as they feel that it purifies the air and the surrounding and keeps mosquitoes away by acting as a mosquito repellent. An increasing body of evidence has linked exposure to indoor pollutants with increased rates of respiratory morbidity and mortality. Women and children exposed to high indoor PM concentrations have significantly increased rates of acute respiratory infections and women cooking over biomass fires for extensive periods have an enhanced risk of chronic obstructive pulmonary disease (COPD) and lung cancer (I.S.Mudway,2005)
In the squatter settlement almost 8 percent of the households use non-LPG fuels including coal, wood, crop residue, kerosene and cow dung cakes for cooking/other

domestic purpose. The reason for use in the Squatter settlement is to do more with cost and affordability.

This is despite the fact that Delhi was declared ‘kerosene-free’ in June 2014, the reality in thousands of households across the city is different. Under the scheme that was launched in August 2012, below-poverty-line (BPL) households were supposed to get LPG cylinders free of charge – with oil companies and the government splitting the cost. But, since many of the intended beneficiaries lack Ration and BPL cards – the documents needed to apply for the scheme – they have been unable to get the free cylinders. (Centre for Science and Environment, 2015).

In terms of the usage of diesel generator sets the CPWD colony gets the best score as none of the households use it and all the households have battery operated inverters. In the Mohammadpur urban village about 3percent of the households use DG sets which not only cause air pollution but also noise pollution. This noise pollution mostly due to the non-muffling of the sound at source and air pollution due to non-compliance to the recommended stack height. In the Squatter Settlements less than 1 percent of the surveyed households use diesel generator sets mostly during power cuts. In the recent years the power supply for the state has improved and power outages have reduced .The NGT and the CPCB have started taking steps in this direction by laying down stringent guidelines for the use of diesel generators and encouraging tapping into the potential of renewable energy sources.

Upon recognising a fact that genset is a source of air and noise pollution in urban India, the emission standards for diesel gensets (up to 800 kilowatt) were notified on17.05.2002 which have been revisited and revised on 11.12.2013.It has been decided to fix the life of genset i.e. 15 years for residential and commercial purpose and 16 years for agricultural purpose would help in controlling air and noise pollution due to use of gensets, since, it is a difficult proposition to monitor noise and emission levels at par with the PUC certificate system, as applicable for in-use vehicles but a detailed framework in that regard needs to be chalked out (CPCB,2013).

In terms of the establishments, small scale industries and workshops causing emissions in the three selected settlements. There are no such entities present in the CPWD colony making it the best among the three. The squatter settlement is next as it has a few informal eating joints (*dhaba*) which are using coal for cooking which contributes to the air pollution. The Mohammadpur urban village has a few car repair garages (engaged in car painting) and a few welding shops which release VOC and pollutants into the air.

In all welding processes, various types of air pollutants are generated. Air pollutants created by welding include fumes and gases…. Exposure to excessive levels of fume and gases can cause different adverse health effects on workers. Since a large number of workers are exposed to welding emissions and also the generated pollutants have negative impacts on environment. (Golbabeia and Khadem, 2015)

As far as VOC's are concerned they are a major cause for formation of smog by reacting with ozone in the atmosphere. The main reason behind these car repair garages (engaged in car painting) and a few welding shops being present in the urban village is that these places are not bound by building bye- laws and strict construction norms and regulations, as regulated under the Delhi Municipal Act as they are in the Lal Dora area. There is an urgent need for these specific establishments to be relocated from residential to industrial areas and the informal joints to switch to LPG as a fuel choice.

As far as emissions from the burning of solid waste and dry leaves are concerned the incidences are rare in the CPWD colony and occur daily in the urban village and the squatter settlements. Burning of solid waste in the morning by the municipal sweepers and cleaners has been observed as a regular feature in the open grounds on the periphery of the village adjoining the slums. These various activities contribute to the air pollution especially the particulate matter which poses a great threat to the health of the residents and the environment more so in the winter months when the air is dense and mixing height is low due to temperature inversion. This happens mainly as the sweepers, the shopkeepers and sometimes the residents do not want to make the effort of collecting and disposing in the designated bins and dalaos because of their distance. Instead they choose to burn them as it saves them all the effort. The people are ignorant and unaware of the existing laws and those who chose to ignore it, ignoring the fact the pollution that it causes. This situation on ground is also a reflection of the attitude of the civic bodies, who are yet to notify and implement the municipal solid waste management bye-laws.

Almost all the internal roads in the CPWD colony are metalled with plantations on both the sides. Moreover, the squatter settlement does not have proper metalled roads in the interiors and almost none of the internal roads have any plantation. Such un-metalled roads are close to 30 percent of the total road length of the settlement. In the urban village approximately 5 per cent of the total road length is not metalled and all most 90 percent of the interior roads are without plantation due to lack of availability of space. Construction activities in the urban village and the squatter settlement contributes further to the suspended particulate matter in the air. Since the CPWD colony is a planned and developed settlement hence the entire infrastructure including roads well laid out. However, in the Mohammadpur urban village and the squatter settlements (since they are more organic) the development has been incremental and haphazard. The legal status of the squatter settlements being a grey area results in clear apathy of the civic agencies towards their development (as they do not pay any tax to the civic bodies).

The household survey and the reconnaissance field survey indicates that all the households in the Mohammadpur urban village and the CPWD colony are connected to the municipal sewer line. However in the squatter settlements roughly around 75 per cent of the households have been connected to the municipal sewer (not all are legal) and the rest of the households depend on either the community paid toilets or resort to defecation in the open grounds in the vicinity or the storm water drains, thus contributing to the land and water pollution. The incidences of water borne diseases are high in the squatter settlements due to unhygienic living conditions. In the rainy season when water logging occurs in the settlement the illegally connected sewer lines overflow and mix with the water supply lines causing contamination of the drinking water which often results in frequent instances of waterborne diseases.

Dumping of solid waste in open and in storm water drains is a regular feature in the village and the squatter settlement. The reason could be attributed to inadequate number and distribution of disposal bins in these areas. However in the CPWD colony there are adequate numbers of solid waste disposal bins and moreover because of the educational awareness of the residents and active campaigns of the RWA of the colony against random waste disposal they are not resorting to open dumping of solid waste. However few instances were reported and upon further investigating the reason it led to the conclusion that sometimes the domestic helps who were given the responsibility of dumping the household waste are resorting to dumping it either in the open or in storm water drains for the sake of their convenience.

Based on this net population density range criteria CPWD colony has a very low density followed by squatter settlement. Whereas Mohammadpur urban village has a very high density compared to the taken threshold range.

Floating population in a settlement also exerts pressure on the resources and the infrastructure. The exact estimates of the floating population in number could not be gathered from the local offices and hence a broad estimation has been done based on the number of establishments and commercial character of the settlements. In the CPWD colony it is mostly residential use and the domestic workers and people providing basic day to day services comprises the floating population which is low in number. In the urban village because of the prevalence of lot of commercial activities ranging from offices to other small services, the percentage of floating population is very high. This is primarily due to the fact that this place is not bound by bye- laws and strict construction norms and regulations, as regulated under the Delhi Municipal Act as they are in the Lal Dora area. Being in the close vicinity of the CBD area (Bhikaji Cama Place) most of the supporting services for the CBD is catered to by the shops and establishments here. The rentals in this area are not as high as in the CBD area making it an attractive proposition for the shops and establishments of supporting and secondary nature to take up space on rentals. In the squatter settlement there does not exist much of employment opportunities and the residing population works in either the village or the nearby residential areas during the day time and hence the floating population is very low in number mostly comprising of labours from the nearby construction sites and workforce from nearby offices who come for cheap and affordable food in the squatter settlement.

The provision of green space in a settlement is essential for the health of the inhabitants and overall environmental quality of the place. The per capita green space availability of the urban village approximately works out to be around 0.21 sq.m. per person and that of the CPWD Colony is 2.49 sq.m. per person. While there are no green space available in the squatter settlement.

As per the provisions of MPD residential standards, around 2.5 ha of green space per 1000 population, the green space provision is satisfactory in the CPWD colony, insufficient in the urban village and almost nonexistent in the squatter settlement. The green space in the Mohammadpur urban village exist on paper most of the green space has been encroached and serve as car parking for the residents as there is a dearth of car parking provision due to lack of proper designated space and increase in the number of motor vehicles in the past few decades.

The CPWD colony has medium impervious surface ratio as compared to squatter settlement and Mohammadpur urban village. The Mohammadpur urban village with the highest impervious surface and less of green areas is at high risk of flooding due to an increase in incidences of water logging and urban flooding during monsoons, as the storm water drains cannot handle the large volume of water generated in a very short time concentration during episodes of heavy and continuous rains.

This holds true for Heat island effect too. The CPWD colony with impervious surface ratio of 33 per cent is at medium risk contribution to heat island effect whereas Mohammadpur urban village and the squatter settlement with impervious surface ratio of 65 percent and 59 percent respectively are at high risk contribution to heat island effect. An increase in more number of impervious surfaces decreases the evapotranspiration rate and contributes to overall increase in the heat island effect.

The main factors contributing to this can be mainly attributed to the increase in the rampant construction with high embodied energy materials and significant decrease in the green cover.

The next parameter which was contamination of land taking place by dumping of any hazardous wastes or chemicals. No such activity was seen in the three settlements during the survey though the residents of the urban village and the squatter settlement reported occurrence of such incidents occasionally by car workshops and other small scale industries using oils, paints etc. functioning on the periphery of the village and the squatter settlements. This was mainly due to the fact that these places are free from building bye- laws and strict construction norms and regulations, as regulated under the Delhi Municipal Act as they are in the Lal Dora area.

The housing availability in the Mohammadpur urban village roughly works out to be 40 houses per 1000 population. Almost all the houses in the urban village are 'pucca' though approximately only 60 per cent of the houses have proper natural lighting and ventilation. The settlement originally was based on layout which consisted of G or G + 1 structures with courtyards, hence the houses and the street sections and widths were sufficient for proper light and ventilation. But with the current redevelopment on the plots the courtyards which were the natural source of light and ventilation have ceased to exist in the buildings. The G + 3 developments with encroachments have made it difficult for light to penetrate on to the streets. The population of the squatter settlements is estimated to be around 3,515 persons with nearly 654 households inhabiting around 551 houses. The housing availability works out to be around 16 houses per 1000 population. Approximately 25 percent of the dwelling units are kuccha and roughly around only 10 per cent of the housing stock has access to proper natural lighting and ventilation in the interiors. The average household size in the squatter settlements is around 5.38 persons per household. The haphazard nature of development, with high density has created a very unhygienic condition for the settlement. These settlements are like ticking time bombs in case any disasters, as most of the materials used for the makeshift constructions are highly inflammable in nature. It would be difficult to evacuate or carry out relief and rescue operations due to narrow lanes. There is an urgent need to have preparedness and plans ready for these settlements in case any disaster strikes.

There are a total of 328 government flats in the CPWD colony out of which 9 are vacant. The population of the CPWD colony has been estimated at 1,563 persons with 334 households. The housing availability roughly works out to be around 200 houses per 1000 population. The colony has 100 per cent pucca houses with proper natural lighting and ventilation in the interiors, though almost 25 percent of the total numbers of houses are in bad condition due to lack of repair and maintenance for past many years. The average household size in the housing colony is around 4.68.

In the infrastructure attribute of the selected settlements especially in the aspect of municipal supply of water , source of water within premise, duration of water supply, municipal sewage connection, toilet facilities within the premise and solid waste management both the CPWD Colony and Mohammadpur urban village perform quite well and have scored almost cent percent. Only the squatter settlements have lagged in all the aspects this is mainly due to the fact that their legal status is not recognised by the civic agencies as they are non- notified slums. Some of the population in the settlement has to face a lot of hardships in this regard as the water supply and the sanitation facilities are not available and accessible to all. The public conveniences that have been set up for the rest are not maintained and have fallen to disuse. .

The household survey of the settlements indicates all the households have authorised metred electrical connections in the urban village and CPWD colony. In the squatter settlement 13 percent of the households do not have any authorised metred electrical connection. The number of households having LPG connections is cent percent in the Mohammadpur urban village. The households in the CPWD colony have piped CNG connections which they use predominantly for cooking. In the squatter settlements the number of households that have LPG connections is around 75percent and the rest resort to using bio mass or kerosene for cooking. This is mainly due to the fact that most of the people cannot afford the LPG cylinders and those who can don't have required identity proofs to secure a connection.

None of the households in the Mohammadpur urban village, Squatter Settlement and the CPWD colony which have provisions of rain water harvesting or waste water recycling nor any of the settlements have these facilities at the community level. Access to public transport access points, daily public services and convenience shops are available for all the three settlements within a range of 500 metres due to the central and prime location of the settlements within the city. In the household motor vehicle ownership aspect the CPWD colony has the highest household motor vehicle ownership (85 percent) followed by Mohammadpur urban village (73 percent) and lastly by Squatter settlement (34 percent).The access to easy loans and in the recent years have seen a growth in the ownership over the past decade in the village .This has led to the issues of available parking space of vehicles especially in the urban village as the houses do not have required parking. Hence, the vehicles are now either parked in the open green spaces of the village or the main arterial road of the village which have now become the make shift parking spaces. This has resulted in regular traffic snarls on these roads. Alternate parking arrangements (multilevel car parking) options need to be explored immediately to be able to decongest this place.

The literate percentage of people is almost 98 percent in the CPWD Colony which is followed by 91 percent in the Mohammadpur urban village and 77 percent in the Squatter Settlements. The low level of literacy in the squatter settlement is mainly due to the fact that many of the elderly people (mostly women) who have migrated with their families from the village are not educated and seemed not keen on becoming literate. In the Mohammadpur urban village the elderly females belonging to the native families who were in their seventies and eighties were found to be illiterate. Though some adult literacy programs were started but they have failed mostly due to non-participation by the people who found no incentive in doing so.

In terms of access to basic health facilities all the settlements have in the vicinity of less than 500 m of their location, which is the clinic and nursing home situated in the Mohammadpur urban village serving all the three settlements.

As far as the diseases among the children below 5 years are concerned the survey reveals that the incidences occur very rarely in CPWD Colony, occasionally in Mohammadpur urban village and very frequently in the Squatter Settlements. The frequency of diseases among the children below 5 years is a direct outcome of the living conditions that the child is exposed to which is the worst in the Squatter Settlements out of the three settlements. Apart from that in terms of water and sanitation also the performance of the squatter settlements is also poor which is why the frequency of diseases amongst the children below five years is the highest.

The health of infants and children to a large extent depends on the adherence to all mandatory vaccinations till the age of five which lays the strong foundation for a disease free and healthy society. In this regard full compliance is found in the CPWD Colony, in the Mohammadpur urban village 94 percent of the surveyed households have complied to all the vaccinations and in the Squatter Settlements the compliance is 87 percent which is the least compliant. Inspite of all-around efforts by the civic agencies the numbers are not as per the expectation as the people here are ignorant and often don't follow their vaccine schedule .Many people are found to resort to quacks for treatment , though medical facility is available close by.

The average age of the household is a fair indicator of the work force and disposable income. In the survey of the households for the average age of the household in the CPWD Colony it is 41 years, for the Mohammadpur urban village the average age of the household is 45 years and it is 32 years for the Squatter Settlements. Though the work force is younger in the squatter settlement but many of them are unemployed or don't have a regular job. Unlike in the Mohammadpur urban village where the average age of the household is higher but the employment levels are higher too.

The average income per household gives us a fair measure of the affordability, standard of living and disposable income of the people there the average household income in the CPWD colony is almost one and a half times that of Mohammadpur urban village and almost four times that of the Squatter settlement. However the disparity of income is found to be highest in the Mohammadpur urban village where a stark difference is noticed in the income of the native landlords and the migrant tenants.

5.6 INTERPRETATION OF RESULTS

The radar diagram in Figure 5.1 shows the composite environmental performance index of the three settlements namely CPWD Colony, Mohammadpur urban village and the adjacent squatter settlement in Delhi on a sustainability scale of '1 to 5', where '1' score has been assigned to the worst performance under a domain and '5' score has been assigned to the best performance under a domain.

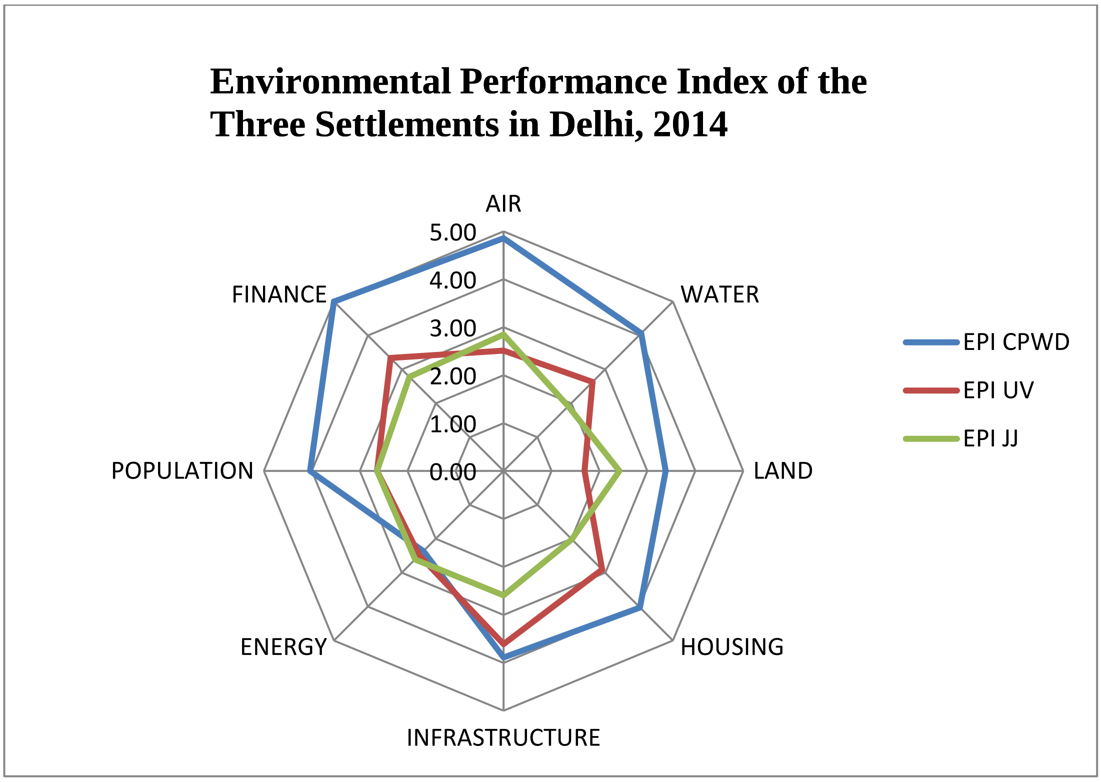


Figure 5.1: Environmental Performance Index of the Three Settlements in Delhi under the eight domains , 2014
Source: Author

The CPWD colony is performing best on the sustainability scale with respect to the parameters of ‘air’, ‘water’ ,‘housing’ , ‘population’ and ‘finance’; good on the parameters of ‘land’ and ‘infrastructure’. However it is performing fairly medium on the parameter of ‘energy’ as there are no energy conservation measures being followed neither at the household or the neighbourhood level and needs intervention.

The Mohammadpur urban village colony is performing fairly medium on the sustainability scale with respect to the parameter of ‘infrastructure’ and ‘finance’, low satisfactory on the other parameters of ‘housing’, ‘water’, ‘air’ ,‘energy’ and ‘population’. However it is performing poor on the parameter of ‘land’ which can be attributed to very high population density and dense built-up area.

The squatter settlement is performing low satisfactory on the sustainability scale with respect to the parameters of ‘infrastructure’, ‘energy’, ‘air’ ,‘land’, ‘population’ and ‘finance,. It is performing poor on the parameters of ‘housing’ and ‘water’ which can be attributed to poor condition of built form without sufficient natural lighting and ventilation, a quarter of the built form is in kutchha from or as shanties, open dumping in storm water drain and frequent incidences of water borne disease due to unhygienic living conditions.

The environmental problems of the three settlements are very much related to the way their urban form has taken shape governed by the socio-economic profile of the residents. Apart from addressing the broad urban environmental issues each settlement need context specific action plans for environmental improvement and quality of life which shall be elaborated in the next chapter.

CHAPTER 6
CONCLUSIONS

The research work is aimed at exploring measures for ensuring environmentally sustainable urban settlements in India. The potential use of sustainability indicators as a tool to assess current sustainability status, to highlight critical aspects, to make judicious resource allocation and to arrive at informed decisions is identified for urban settlements in India. The major concerns that led to the research initiative, generic conclusions drawn from the study and the recommended policy measures are presented in the following section:

6.1 GENERIC & SPECIFIC CONCERNS

- The world's urban population is expected to increase by 68 per cent by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050 with the highest growth rates in the developing world, which will be responsible for 95 percent of the world's urban population growth. The urban population of the developing world is projected to increase from 2.7 billion in 2011 to roughly around 5.3 billion by 2050; where Asia alone will accommodate 63 percent of the world's urban population (UN-DESA, 2011; UN-HABITAT, 2008).

- The world's urban population is not distributed evenly among cities of different sizes. Cities of one million and more inhabitants accounts for about 40 per cent of the world urban population in 2011 and is projected to account for 47 per cent of the world urban population by 2025. As per UN-DESA, 2011 projections future urban population will be increasingly concentrated in large cities of one million or more inhabitants with megacities of at least ten million inhabitants experiencing the largest percentage increase (UN-DESA, 2011).

- India with a total population of 1210.2 million, (Census 2011), is the second most populous country in the world after China and 377.1 million i.e. 31.16 per cent of its total population is living in urban areas. As per census 2011, there are 53 cities with million plus population, which are the major urban centers in the country, accommodating 160.7 million persons accounting for 42.6 percent of the total urban population. The distribution of population in India is highly skewed as three megacities at present accommodate about a quarter of total urban population, due to polarization of economic opportunities and thus creating a situation, which is reasonably complex, and pose sustainable planning problems. (Planning Commission, Government of India).

- As per the population growth trends, by 2051, India will be the most populous country in the world with a population of 1700 million, of which 820 million i.e. around 48 per cent of the total population will live in urban settlements. By 2051, it is estimated that there will be around 85 cities with million plus population and 15 megacities with more than 10 million population (Kshirsagar, 2010).

- As per UNEP, 2012 estimates, at present the urban areas account for 50 percent of all waste, generate 60-80 percent of all greenhouse gas emissions and consume 75 percent of natural resources and yet occupy only 3 percent of the Earth's surface. The concentration of population in particular areas have a particularly damaging effect on environment once critical pollution thresholds are exceeded. The alarming population growth is increasingly resulting in urban sprawl, mounting stress on infrastructure, creation of slums, a widening rich–poor divide, deteriorating quality of urban services, depletion of non-renewable resources and increased environmental pollution and energy use.

- There is a pressing need that the city planners and policy makers focus on to what extent the urbanisation could be permitted, so that either the impact on the environment stays within sustainable limits or there is a possibility of replenishing resources and recovering from impact on environment within a reasonable time frame. The city planners and policy makers need a set of tools to arrive at a sequence of logical actions which could help them in making judicious resource allocation and informed decisions for continual improvement of human settlements.

- The global concern regarding rapid urbanisation and environmental degradation, has led to lot of initiatives in the field of sustainable urban development in the past two decades around the world, which gained major impetus after the *Brundtland Commission*s Report 'Our Common Future' in 1987. Though the various initiatives associated with urban environmental planning have taken a formal shape in last few decades mostly in the developed world, in the developing countries, especially India, these efforts have helped mostly in raising awareness about the future urban development challenges and environmental crisis. India has been a regular participant in various international environmental conferences and is committed to follow many global commitments towards solving the urban development and environmental issues. However till now there is lack of concerted efforts in the country in this direction.

- The tackling of urban sustainability issues on the local ground requires a different perspective as the urbanisation and environmental problems are different in scale and focus in the developing countries. While on one end the developed world is concerned about the environmental issues of global warming, conservation of natural resources etc., the developing world is struggling with providing the basic needs of shelter, safe drinking water, toilet facilities and other necessary infrastructural facilities to its citizens.

- In the Indian context incorporation of urban environmental sustainability concept in the physical planning of urban settlements in India requires special attention. The physical planning of cities and towns in India is dominated by 'Master Plan Approach', which is focussed on land use and often ignores many important socio-economic and environmental aspects (Devas, 1993). There is inadequacy of research relating to the spatial planning of the cities and towns in India as the first few Five Year Plans after independence focussed on country level macro-economic planning and development dominated by top-down approach (Kundu, 2001).

6.2 GENERIC CONCLUSIONS AND FINDINGS

- ✓ The pathway taken by urban development over the next few decades will play a crucial role in the trajectory of fundamental health and wellbeing of the human species and all life on earth. The need of the hour is environmentally sustainable urban development for the protection of the natural environment and livable pollution free built environment. Environmental sustainability is one of the eight international Millennium Development Goals (MDGs) that were established following the Millennium Summit of the United Nations in 2000.

- ✓ The 'Agenda 21'adopted at Earth Summit in 1992 recognised the importance of development of sustainability indicators, across one or all of its various dimensions-social, economic and environmental, by countries as well as international organisations, to make informed decisions at all levels concerning sustainable urban development. A lot of efforts have been made in this direction in the past two decades around the world not only by developed countries and international bodies but by many developing countries too. A review of the IISD Compendium, the most comprehensive database to date to keep track of Sustainability Indicators efforts shows 836 entries worldwide (IISD, 2007) with none of the Indian cities in the list which deserves an attention .

- ✓ Each nation or city is unique in its geographic location, cultural and social values, economic condition, national goals and policies and thus a universal set of indicators which can be applied globally does not make any sense; though several agencies and countries across the world have already worked towards formulating indicators of sustainable development at various levels and provide relevant guidance; the final framework needs to address the urban sustainability issues in the Indian context.

- ✓ Sustainable city planning in India, a geographically vast, culturally diverse and second most populated country in the world represents an overarching challenge. The first major problem lies in identifying a group of indicators which can be applied throughout the country in varied urban areas irrespective of the diverse socio-economic, regional and environmental issues. The other major issue is the availability of data at the local level that can truly represent the ground realities.

- ✓ An effective urban environmental improvement plan or policy should be an outcome of dynamic interaction of ground reality, expert's opinion and people's perception. Both the top-down approach and bottom-up approach are important for effective planning at macro level- national/city level and implementation at micro level – local or neighbourhood level (Banerjee et al., 1982; Richardson, 1982; Mathur 1984).

- ✓ Thus in order to incorporate urban environmental sustainability concept in the physical planning of urban settlements in India there is a dire need to develop a set of simple and effective sustainable development indicators at various levels. Apart from broader indicator sets at national or city level, there is also a need of developing comprehensive micro-level urban ecosystem sustainability assessment indicators to overcome the hindrance of data availability and to ensure community participation.
- ✓ The careful framing, monitoring and interpreting of the indicators at various levels would help the urban areas to assess the present state of the sustainability, highlight critical aspect of the socio-economic-environmental status of the system, raise public awareness about environment and to devise future action plans or policies to ensure inter-generation and intra-generation equity.

- ✓ The data collection done at small neighbourhood or community level can be aggregated to the local level to generate sufficient and reliable data bank to make comparison at the local level feasible and provide implementable inputs to the local area environmental and developmental action plans. The collated data at the local level may further be aggregated at the regional or state or national level in a meaningful manner, wherever possible, and can be used to translate the information in national level planning and development policies. This method would ensure sustainable ecosystems and a bottom-up approach in formulation of national level policies.

- ✓ Experiences of few cities provide some important lessons for improved urban governance. These lessons are: (a) Build credibility of local government through improved administration; (b) Make initial efforts in a few critical areas that are "visible" and affect daily lives of most residents; (c) Changes have to come from within the system, not forced by state or national government; (d) Demonstration effects are important and more cities will learn from few success stories; (e) Dissemination and networking of local governments is crucial; (f) State and national governments may not always support the initiation of changes, but will yield only when citizen support is received; and (g) Responsive administration for citizen grievances is essential. The strategy for improved governance should include enablement, participation, and capacity building. (Mehta, D. 2006)

6.2 FINDINGS/CONCLUSIONS BASED ON THE RESEARCH

6.3.1 Macro Level Findings and Way Ahead

The analysis of the sustainability (environment, social and economic) of eight metropolitan cities in India under the broad domains based on the essential **natural resources:** air, water, land, energy; **built in resources:** housing, infrastructure; **human resource:** population and; **capital resource:** finance reveals the following findings:

- ❖ Under the National Air Monitoring Programme (NAMP) and National Air Quality Index (AQI), air quality is measured at different monitoring stations across the selected cities in the study under the parameters SO_2, NO_2 and PM_{10}. The air indicator values on the expected lines show that the cities with less industrial activity and less number of vehicle ownership are comparatively better-off in terms of air quality when compared to the other cities. However when compared to the permissible limits of NO_2, SO_2 and PM_{10} most of the cities have alarmingly high PM_{10} values. Cities like Pune and Ahmedabad having large percentage of two-stroke vehicles and diesel fed public transport system score poorly in terms of SO_2. Residual crop burning and construction activities lead to an increase the PM_{10}

levels apart from the high vehicle ownership as is the case with Delhi. The NO_2 levels are higher in the cities of Delhi and Kolkata, where the public transport fleet is being run on CNG or due to mushrooming of roadside eateries that burn coal and wood for fuel. The increase in the vehicle ownership continues to be a cause of worry across all the cities in spite of the fact that all efforts are being made to increase the efficiency of the public transport systems through buses and metros, which clearly points to the failure of the system to address the issues of proper last mile connectivity of the public at large. Coastal cities like Chennai and Kolkata are influenced by the sea breeze effect and hence show lesser air pollution levels over longer duration of time.

In the recent past the National Green Tribunal (NGT) has started taking pro-active measures in addressing environmental issues related to air quality across the country by serving strict mandates and directives to the central and various state governments and their agencies to reduce pollution from multiple-sources. There is an ardent need to create a robust, efficient, intelligent and clean (fuel) public transport system with last mile connectivity. There is a need to establish regional coordination mechanisms and integrated environmental management through a Clean Air Programme which shall monitor the air quality at the National level.

- City-wise water quality data is being collected and compiled by Central Pollution Control Board. The water quality indicator adopted in the study is based on average violations of different water quality parameters in different cities in their respective water sources. The single biggest reason for water pollution in India is urbanisation at an uncontrolled rate. The rate of urbanisation has only gone up at a fast pace in the last decade or so, but even then it has left an indelible mark on India's aquatic resources. This has led to several environmental issues in the long term like paucity in water supply, generation and collection of wastewater to name a few. The treatment and disposal of wastewater has also been a major issue in this regard. The areas near rivers have seen plenty of towns and cities come up and this has also contributed to the growing intensity of problems. Uncontrolled urbanisation in these areas has also led to generation of sewage water. In the urban areas water is used for both industrial and domestic purposes from waterbodies such as rivers, lakes, streams, wells, and ponds. Worst still, 80 percent of the water that we use for our domestic purposes is passed out in the form of wastewater. In most of the cases, highly urbanized and industrialized cities fail in treating the sewage and effluents satisfactorily before discharging into the water sources (mostly rivers) due to lack of adequate infrastructure. As a result these cities score poorly in terms of DO and high in terms of BOD which depict deterioration of surface water quality and clearly points to tremendous pollution of surface-level freshwater. This is true for almost all the cities covered in this study. In few cities, like Delhi the volume of water available in the city stretch is low due to diversion for other purposes and further ads to the problem of pollution.

SPCB's and CPCB need to take more proactive measures for strict compliance on discharge of treated sewage and effluents into the water source through efficient and effective infrastructure. Decentralised waste water system and waste water recycling options at neighbourhood levels should be explored extensively on a large scale through various partnership models.

- The cities like Chennai and Hyderabad with higher population growth rate and density show more utilisation of land and hence display pressure on land resources. As per UDPFI guidelines 2014, Ministry of Urban Development, Government of India the suggested gross population density for a settlement size of a metropolitan city is 125-175 persons per hectare and three out of eight studied cities exceed the desirable density. Fast urbanisation, occupation opportunities and migrating population are the prime reasons behind fast growth in population and density of all the studied metropolitan cities.

  Importance of green spaces in cities is recognised as an important source of recreation, social interaction and health. It also plays a vital role in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development of a city. The current National Forest Policy (MoEF, 1988) aims at maintaining a minimum of 33 percent of country's geographical area under forest and tree cover. It is observed that the cities with well-planned areas like Delhi which have dedicated and earmarked open spaces have better per capita green than the rest. However, with growth and development activities the green covers in these cities are facing pressure. The depletion of green cover increase the urban vulnerability to climate change, deterioration in air quality, generation of urban heat islands (UHIs), and acute water shortage.

The need of the hour is formulation of strong economic reform policies for creating decentralised employment opportunities in tier II cities to check huge migration to the major metropolitan cities and to reduce the pressure on land and infrastructure. Also formulation and implementation of policies that promotes urban greens, public private partnership models for afforestation and plantations in catchment areas to rejuvenate water bodies to protect the urban green cover (woodlands, wetlands, parks, gardens, avenue plantations and block plantations). The urban greens need to be managed as urban forest ecosystems to enhance optimal urban forest cover and to nurture and sustain urban health, clean air and many other related benefits both direct and indirect in nature for the urban settlements.

- Housing and housing amenities are major indicators to gauge human well-being of a country. Any person in the house, the basic civic amenities available to the household etc. will depict the overall socio-economic progress of the society. Housing is an important aspect in the assessing the overall growth and development of city. Housing is regarded as an 'engine of economic growth' and can give a big push to the economy through its strong 'backward' and 'forward' linkages with about 250 ancillary industries. Housing investment has inter-industry linkages and investment in housing/construction sector has strong multiplier effects on generation of income and employment in the economy (Study IIM Ahmedabad, 2000).

Housing availability in some of the cities is below the national average of 208 houses per thousand populations. In Mumbai the housing availability is the lowest at 60.2 followed by Kolkata at 93, Hyderabad has 138.8 followed by Chennai at 152.2. The same order exists in terms of the percentage of population in the slums. Mumbai has the highest with 41.9 percent followed by Kolkata 29.6 percent; Hyderabad has around 29.57 percent followed by Chennai at 28.5 percent against a national average of 17.36 percent. In terms of share of houseless population Delhi has the highest percentage 2.66 followed by Kolkata 0.49 percent, Chennai comes next with 0.36 percent and last is Mumbai with 0.3 percent these cities are well above the national average of 0.25 percent.

An unit increase in the financial expenditure on the construction sector would generate additional income in the economy as a whole, which would be almost five times as high as the direct income generated within the construction sector itself. Further, investment in housing has an employer multiplier effect of almost eight times. This indicates that an additional unit of final expenditure in construction sector induces an overall employment generation in the economy by an extent that is eight times the direct employment generated in the construction sector itself. (Ministry of Housing and Urban Poverty Alleviation, 2013).

Recognising the importance of housing in the country as a basic human need, it has been one of the incentives to promote housing on both, the demand and supply sides. Since independence, a large number of schemes have been launched under different names, but the focus continues to be on housing for the poor. The core of all the housing initiatives is to concentrate efforts on improvement of the housing conditions of industrial workers/ economically weaker sections and of low-income groups, through housing schemes, involving an element of subsidy ranging between twenty percent to fifty percent. All the housing programmes have resulted in the positive growth in the total housing stock, which has increased from 13.30 million units in 1961 to 78.48 million units in 2011.

The total urban housing shortage in the country in 2012 recorded a decline from 24.71 million at the beginning of 11th Plan to 18.78 million in the beginning of the 12th Plan. It is worth noting that 96 per cent of this shortage pertains to the economically weaker sections and the lower income groups of the society. The urban housing shortage during the 12th Five Plan period (2012-2017) may even come lower if the rate of growth in housing stock continues to be higher than the growth in number of Households in the 12th Five Year Plan, as observed in the last decade. Assuming the business as usual scenario and also continuation of the strategic intervention both at State & Central level, housing shortage may actually go down as per the official estimates by the MoHUPA (Planning Commission, 2012).

Various programme related to housing have been launched in the past including the recent programmes for housing the poor which includes: Two Million Housing Programme, Valmiki Ambedkar Awas Yojana (VAMBAY), Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Interest Subsidy for Housing the Urban Poor (ISHUP), Affordable Housing in Partnership (AHIP) Scheme, and interest subvention and Habitat Policy (NUHHP)' in 2007 with the challenging goal of 'Affordable Housing for All' and to advocate the aims and areas of action with which to progress towards it. Innovative approaches advocated by the NUHHP-2007 include the reservation of 10-15 percent of land or 20-25 percent Floor Space Index (FSI)/Floor Area Ratio (FAR) under private sector development for EWS and LIG housing, either by regulation in new developments in expansion areas of Development Rights (TDRs) to accelerate private investment in the provision of houses for the poor.

The initiatives under active consideration of the Ministry of Housing & Urban Poverty Alleviation (MoHUPA) in the recent past include Review of National Urban Land Policy, Real Estate Regulation Act (RERA), Model Legal Framework for assigning Property Rights to Slum Dwellers and Housing Start-Up Index (HSUI) .The other efforts taken towards affordable housing is to establish Housing Micro-Finance Institutions for the housing needs of poor in the informal sector. In cities there is a lack of availability of land at affordable prices. This is explained in terms of lack of 'legal' space or tenure security in the existing slums; absence of implementation of reservation of land for EWS / LIG housing and informal sector activities in Master Plans for cities, spiralling urban land prices that have soared on the adoption of land as a resource raising policy by states and municipalities. Another key constraint to affordable housing to the urban poor is the lack of adequate credit flow to the segment at affordable interest rates for the construction of the low-income houses which is critically important for the poor if they are not to be squeezed out of the formal housing market. Availability of rental housing for new migrants from rural areas and small towns seeking jobs in cities is another important issue which often leads to setting up of slums and squatter settlements.

The issue of housing needs to be addressed with focus on affordable housing. The affordable housing stock needs to be increased by ensuring adequate credit flow at affordable interest rates for the construction of the houses especially for the low-income group. Secured land tenure and rights need to be given to the weaker sections of the society where slums and squatter settlements exist ,innovative financing models and PPP models of development need to be encouraged to ensure that low-income housing issue is well addressed and also ensure access to the basic services for them along with shelter.

- Growing population pressures have put mounting stress on the infrastructure requirements. Four out of eight class I cities (Chennai, Bangalore, Hyderabad and Ahmedabad) taken up in the study do not meet the national average of per capita water supply of 179 lpcd in class I cities. However, as per the census data 2011, all the selected cities exceed the national average of urban India in terms of percentage of households having potable water supply, percentage of households having source of water within premises and percentage of households having sewage connection. Also, six out of eight class I cities (except Mumbai and Pune) exceed the national urban average in terms of percentage of households having access to toilet facilities within premises.

The issue of basic services need to be addressed not only through the creation of new assets but also upgrading and management of existing assets.

In order to bring about improvements in delivery of basic urban services, apart from investment of funds through various financing models, there is a need to develop National Benchmarks. This will provide standardised framework for performance monitoring and evaluation against agreed targets, finally resulting in achievement of service level benchmarks in respect of basic services like water supply, sewerage, solid waste management and storm water drainage. This will help in shifting focus from asset creation to outcomes.

- ❖ As per CPCB Report, 2010-2011 per capita solid waste generation is within the range of average per capita waste generation in Urban India at 0.5 kg/capita/day in six out of eight class I cities (except Chennai and Ahmedabad). The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a city. Cities with high GDP and population growth rate generate more waste per person compared to other cities. The differences in the MSW characteristics indicate the effect of urbanisation and development. In urban areas, the major fraction of MSW is compostable materials (40–60%) and inert (30– 50%). The relative percentage of organic waste in MSW is generally increasing with the decreasing socio-economic status. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amount of MSW generated daily in metropolitan cities. Unscientific disposal causes an adverse impact on all components of the environment and human health. The present scenario of waste treatment in India is not very encouraging; the lack of resources such as financing, infrastructure, suitable planning and data, and leadership, are the main barriers in MSW Management. The increase of service demands combined with the lack of resources for municipalities are putting a huge strain on the existing MSWM systems. The global expansion of urban slums with absent or deficient water, sewage and solid waste collection systems translate into a broad range of health and sanitation issues in all the major metropolitan cities.

CPCB, SPCB's and the concerned civic bodies need to take more proactive measures for a strict check on generation, proper segregation, handling and disposal of Municipal Solid Waste. Proper Management of solid waste at neighbourhood levels should be explored extensively on a large scale along with recycling options with proper support and incentives of the government Agencies.

- As per census 2011 all the selected class I cities either meet or exceed the national urban average in terms of percentage of households having electricity connection and LPG connection. However, except the city of Hyderabad, all the other seven cities meet the urban national average of households using renewable source of energy. Also, only in the city of Mumbai and Kolkata, private ownership of motorised vehicles by the households is less than the national average. The other six cities exceed the national average in terms of percentage of households owning motorised vehicles.

  There is a need to further strengthen the energy distribution system and ensure that the benefits reach the real beneficiaries through effective and efficient mechanisms.
  There is a need to rationalise the energy tariffs proportionate to the usage. The renewable power options need to explored and promoted on a large scale through subsidies, exemption, accelerated depreciation and tax holidays. There is a need to look at provision of renewable purchase obligation for solar power in the National Tariff Policy. Off grid power generation options (e.g. Biomass, Roof – top Solar panels, etc.) need to be encouraged. Policies regarding vehicle ownership needs to be looked into.

- The growth rate of population is an important parameter to assess the pressures on the existing resources and facilities. Higher rates of population growth and land population density can therefore have negative impact on sustainable development. Population data for the years 2011 and 2001 from the Census reveals that four cities out of the eight studied have lower population growth rates than the rest which can be attributed to high densities of population and perhaps to higher literacy rates, deflection of migrating population to other close by tier II cities due to reasonable opportunities in the rural hinterland.

The growth rate of population needs to be controlled by improving the literacy and education levels coupled with increasing the empowerment of the women folk. Creation of reasonable employment and other opportunities along with development of the region especially in the tier II cities and rural hinterland may discourage migration.

- Literacy is a human right, a road towards empowerment and a means for social and human development. Educational opportunities and employability prospects to a large extent depends on literacy. Literacy plays a significant role in eradicating poverty, reducing child mortality, curbing population growth, achieving gender equality and thereby ensuring sustainable development, peace and democracy. Literacy leads to better family planning which in turn reduces the natural population growth rate of the cities. Higher literacy rates in cities have been correlated with lower poverty rates with better choices of energy use and improved air quality.

  Literacy rates have improved significantly in the last decade from 64 percent to 74 percent. The numbers of children who do not get education especially in the rural areas are still high. The government has made a law that every child under the age of 14 should get free education; the problem of illiteracy is still at large. The literacy gap between the male and female has reduced in the past decade from 21percent to 16percent but a lot is left to be desired.

  The spread of education changes the outlook of people. They prefer to delay marriage and adopt small family norms. Educated women are health conscious and avoid frequent pregnancies and thus help in lowering birth rate. Many of our cities are moving from a condition of high birth and death rates, to a condition of low birth and death rates which leads to a slow rate of growth of population which is referred to as the ‘Demographic Transition’. The high population growth rates are due to high birth rate and fast declining death rates due to better sanitation and health facilities. However, the capacities to absorb increasing manpower are much less. Furthermore, the process of economic development tends to be more capital intensive under modern technological conditions, and hence, has less potential of employment generation in the short term. Since the total size of the population is already large, there is urgency for speedy achievement of demographic transition from high birth rate to low birth rate resulting in lower population growth.

The inter relationship between poverty and environment has been recognised by the World Health Organisation as a major cause and probability of poor health in these Cities. Health facilities are one of the most important components which indicate development on the social fronts. The data for availability of the total number of beds per 1000 population in a region gives an idea of the state of primary health care facilities in different cities. The indicator shows that relatively smaller cities have shown higher number of beds per 1000 population than the bigger ones. Data for life expectancy (at birth) has been collected from MoHFW (2011) and added as an indicator of health status and facilities in the city. The indicator shows that life expectancy is low in cities which have a strong socio-economic disparity.

Facilities such as housing, transportation, health care, and education become inadequate. The worst symptoms of congestion in every aspect of living conditions are manifested in the urban areas. In our country, a situation of "over urbanisation" prevails which puts unbearable strain on urban amenities. Overcrowded houses, slums and unsanitary localities, traffic congestion and crowded hospitals have become common features in the developing countries. But today's developing countries are experiencing a much faster growth in their population under conditions different than those faced by the developed countries. Thus they are faced with huge problems of imparting education, employment, urban development and environmental degradation.

The literacy rate in India is a matter of concern but many Government and NGO initiatives through various ads, campaigns and programs have helped to spread awareness amongst people about the importance of literacy. The strict rules for female equality rights have brought down the difference between the genders in literacy. The numbers of children who do not get education especially in the rural areas are still high. The government has made a law that every child under the age of 14 should get access to free education, the problem of illiteracy still remains. The essence and role of education articulated in our National Policy on Education (NPE), continues to be relevant even today. It states that education is essential for all and is fundamental to our all-round development. Education develops manpower for different levels of the economy and is also the platform on which research and development flourish to take nation towards self-reliance. In sum, education is a unique investment in the present and the future for the growth and development of the nation.

6.3.2 Micro Level Findings

- The metro cities in India are a mix of planned settlements, old walled city areas, unauthorized colonies, urban villages, slums and JJ clusters and differs basically on tenure security, dwelling conditions, infrastructure status and the degree of planning intervention.

- Field survey of the various settlements at micro level throw light on various factors contributing to air pollution, particulate matter and noise pollution.

  A small percentage of households in the metro cities mainly in the urban villages and squatter settlements are dependent on biomass or kerosene for cooking/other domestic purpose either due to affordability, ignorance, and age old followed traditions or lack of documents to avail the government schemes for free or subsidised LPG cylinders. The use of DG sets, emission of volatile organic compounds by small scale industries and workshops in the residential areas generate air and noise pollution. There is an urgent need for these specific establishments to be relocated from residential to industrial areas and the informal food joints and road side eateries (dhabas) to switch to LPG as a fuel choice.

The National Green Tribunal and the CPCB have taken steps in this direction by laying down strict guidelines and rules for the use of diesel generators and encouraging the use of renewable energy sources.

The government has started making it easier for the economically weaker section of the society to avail the schemes for free or subsidised LPG cylinders by the linking of Aadhar with their accounts and transferring the subsidy directly in them. The government has also started promoting the use of renewable energy by giving incentives and subsidising the renewable energy options however the choice is still not popular and a lot needs to be done for the benefits to reach the masses at large especially the economically weaker section of the society.

- Un-metalled roads, lack of plantation contributes to the suspended particulate matter in the air, recent redevelopment schemes for various projects have led to widespread felling of full grown trees and they have been compensated by planting of saplings at a place away from the project area which doesn't address the issue of reducing urban green. Often the saplings are forgotten once the project is complete and post - project assessment and evaluation of the plantation is not done and most of these plantations have been unsuccessful.

  The civic bodies must take active measures to avoid or minimise felling of trees in all development projects. They must encourage the option of replanting the tree to the extent possible. If at all saplings are to be planted, it must be done in the close proximity of the project and not at a remote location.

- Burning of solid waste by the municipal sweepers, shopkeepers and sometimes the residents causes air pollution particularly the particulate matter pollution. This happens as people do not want to make the effort of collecting and disposing in the designated bins and dalaos. The levels of awareness amongst certain sections of the population being low, makes them are ignorant and unaware of the existing laws. The ones who are chose to ignore it, well aware of the pollution that it causes and the health hazard it poses to the entire population of the city. It also contributes to the greenhouse gas emissions and the global warming.

The urban local bodies (ULB's) need to notify and implement the municipal solid waste management bye-laws on the ground .They need to create awareness and educate the citizens through mass media and impose deterrent measures on failure to comply with them. For effective MSWM, waste segregation at source should be encouraged in order to allow much more efficient value extraction and recycling. Efforts should be made to set up efficient and cost effective decentralised waste management systems through a sustainable financing model to ensure a better MSWM.

- Field survey of the settlements at micro level also elaborate on reasons of water pollution and land pollution. A large percentage of households in the squatter settlements in the cities have either been connected to the municipal sewer illegally and the rest of the households depend on either the community paid toilets or resort to defecation in the open grounds in the vicinity or the storm water drains, thus contributing to the land and water pollution and incidences of water borne diseases. Dumping of solid waste in open and in storm water drains is a regular feature in the village and the squatter settlement. This happens as people do not want to make the effort of collecting and disposing in the designated bins and dalaos. The reason could also be attributed to inadequate number and distribution of disposal bins in these areas.

The government and the municipal bodies under various schemes e.g. Swachh Bharat Mission etc. are trying to make efforts to address the problem of open defecation by constructing toilets both at household and at community levels and the overall cleanliness of the area through increasing the frequency of the

solid waste collection of the area but a lot needs to change in terms of the behaviour and attitude of the people.

- Contamination of land also happens by dumping of hazardous wastes/chemicals by car workshops and other small scale industries using oils, paints etc. functioning on the periphery of the urban villages/ squatter settlements.

  Provision of adequate infrastructure and educational awareness of the residents through active campaigns of the NGOs, RWA of the colony can be effective against open defecation and random waste disposal causing land and water pollution.

  The responsible agencies also need to ensure that the guidelines laid down for waste management especially bio hazardous and medical waste are adhered to. Incentive based disposal of hazardous wastes like batteries, etc. need to be implemented to see effective compliance for protection of the environment in urban areas.

- Settlements in the city like the urban villages and old areas in the walled city exhibits stress on infrastructure and resources due to pressure of floating population. These settlements because of low rentals become mushrooming ground of varied commercial activities ranging from offices to other small services, as it is free from building bye- laws and strict construction norms and regulations, as regulated under the Municipal Acts.

  Many old settlements, urban villages, unauthorised settlements and squatter settlements have very high impervious surface due to less of green areas which decrease the evapo-transpiration rate and contribute to overall increase in the heat island effect. These settlements are also at high risk of flooding due to an increase in incidences of water logging and urban flooding during monsoons. Due to high impervious surface ratio it generates a large volume of water in a very short time concentration during episodes of heavy and continuous rains, which the storm water drainage systems are not equipped to handle.

Most of the settlements have no provisions of rain water harvesting, ground water recharging or waste water recycling at the household or at the community level. Effective measures for rainwater harvesting management must be put in place to address the issue of depleting ground water and urban flooding.

- Haphazard nature of development, with high density creates unhygienic condition for the settlement. Development is characterised by less housing availability, bigger household size, improper light and ventilation due to illegal construction and encroachments. These settlements are potential hazards in case any disaster strikes, as most of the materials used for the makeshift constructions are highly inflammable in nature. It would be difficult to evacuate or carry out relief and rescue operations due to narrow lanes which impede the accessibility.

  There is an urgent need to have preparedness and plans ready for these settlements in case any disaster strikes. Reforms in the building bye laws with proper setbacks need to be notified and implemented strictly.

- The access to easy financing and disposable income in the recent years has seen a growth in the ownership of vehicles over the past decade. This has led to the issues of available parking space of vehicles as many houses do not have required parking. Green spaces in settlements get encroached for creating parking spaces. Hence, the vehicles are now either parked in the open green spaces or the main arterial roads. This has resulted in regular traffic congestions on these roads.

  Alternate parking arrangements (multilevel car parking) options need to be explored immediately to be able to decongest the settlements. Parking proofs may be checked before allowing any individual to own a vehicle.

- **Squatter settlements** lack on the infrastructure aspect - municipal supply of water , source of water within premise, duration of water supply, municipal sewage connection, toilet facilities within the premise and solid waste management due to the fact that their legal status is not recognised by the civic agencies as they are under the non- notified category of slums. Some of the population in the settlement has to face a lot of hardships in this regard as the water supply and the sanitation facilities are not available and accessible to all. The public conveniences that have been set up for the rest are not maintained and have fallen to disuse. In terms of water and sanitation the performance of the squatter settlements is very poor which is why the frequency of diseases amongst the children is quite high. In-spite of all-around efforts by the civic agencies the numbers are not as per the expectation as the people here are ignorant and often don't follow their vaccine schedule. Many people are found to resort to quacks for treatment, though medical facility is available close by.

In the squatter settlement quite a number of the households don't have any authorised metered electrical connection. In the squatter settlements the number of households that have LPG connections is around 75 percent and the rest resort to using bio mass or kerosene for cooking. This is mainly due to the fact that most of the people cannot afford the LPG cylinders and there are some who do not have required identity proofs/documents to secure a connection.

The civic agencies have to ensure that the basic infrastructural services like water supply, sanitation and storm water drainage are provided to the inhabitants of the squatter settlements at low or subsidised cost.

It is required to ensure that awareness and education about the available health facilities are given to the people. People should be encouraged to use mainstream health facilities and treatment which should be available to them free of cost or at low cost. These services will ensure better quality of life for the population especially in the squatter settlement.

- ❖ The low level of literacy in the squatter settlement is mainly due to the fact that many of the elderly people (mostly women) who have migrated with their families from the village are not educated and seemed not keen on becoming literate.

Alternate and parallel literacy programs for educating the adults and the individuals who could not complete formal education due to various reasons can be organised and more individuals could be encouraged to complete their education according to their ability.

6.4 ACTION AGENDA

To incorporate environmental sustainability in the Spatial Planning process of Development Plans in a decentralised system of governance, through formulation of sustainability indicators which will strengthen the data collection and provide useful inputs at different stage of planning, monitoring and review of development plans and policies

STRATEGIC ACTIONS

1. Formulation of Multi-level Sustainability Indicators

- Core indicators-common set of indicators with available data at broader level and with experts opinion; and
- Additional indicators- specific set of indicators relevant to a local area and with public participation

2. Data Collection

The data collection done at small neighbourhood or community level can be aggregated to the local level which may be further be collated at the regional or state or national level in a meaningful manner, wherever possible, and can be used to translate the information for plan preparation and policies.

3. Assessment of the State of the Environment

An assessment of the state of the environment at the local level and broader level through the data collected on the identified indicators and comparing with the national standards or threshold values

4. Assessment of Needs, Critical Areas & Priority Settings

Prioritising the areas that needs to be addressed based on criticality and the urgency of need of intervention

5. Plan Preparation & Policy Decisions

Incorporation of the critical areas and prioritised needs in spatial plans at macro and micro level and in broad policy decisions and guidelines

6. Implementation of the Plans

Implementation of the plans in time bound phases.

7. Review of the Plan Implementation and Raising Environmental Awareness

A repeated assessment of the state of the environment on the selected indicators to keep a track of the changes in the environment , to do a performance review of the plan implementation and environmental policies and to inform the general public about the state of the environment and raise awareness.

8. Updating the Action Plans and Environmental Policies

Based on the review of the plan implementation incorporation of changes shall be done in the further action plans and future environmental policies.

9. Introduction of Environmental Performance based Incentive System

Eligibility and allocation of funds and resources by the government at the state, city and the local level shall be based on the environmental performance.

The incentive based allocation of funds will make the municipal bodies responsive to the environmental issues.

This very study may further be elaborated in terms of reviewing different types of cities and towns as classified by the Census by Government of India against the set of pertinent indicators as was envisaged in Agenda21.

Similarly a comparative study of urban settlements and towns of various scales over the country through the Environmental Performance Index (EPI) may be taken up.

6.5 A FINAL WORD

An Environmentally Sustainable Urban Development focusses on natural and built resource dynamics and to achieve the sustainable development of urban settlements following three major goals have been identified in the research work:

a) Ecological resilience of the Natural environment- To preserve balance of the natural resources and the restoration and renewal capacity of the natural ecosystem.
b) Sustainable development of the Built Environment - Energy efficient settlements with adequate and secure housing and efficient infrastructure.
c) Improved Quality of Life – Socially and economically strong settlements with adequate opportunities for personal growth, health, psychological well-being, economic rewards and overall satisfaction in life.

The research work is a modest effort in formulating environmental sustainability indicators at macro and micro level in the Indian context to assess the present state of the environment, to keep track of the changes in the environment and to do a performance review of the environmental policies from time to time. At the macro level it will provide necessary inputs to the planners and policy makers to facilitate decision making and at the micro level it can help in creating awareness among the citizens and thus helping them make informed choices. Also it will ensure improved accountability and efficient delivery from the service providers to the ensure sustainability with bottom up approach.

The formulated set of indicators have been pilot tested for assessment of environmental performance of the eight most populous cities in India having more than five million plus population at macro level. At the micro level, three different types of settlements in Delhi differentiated on the basis of tenure security, dwelling conditions, infrastructure status and the degree of planning intervention have been selected for pilot testing the formulated indicator set.

The research also emphasizes that there does not exist any universal and finite set of indicators. It is strongly recommended to replicate the designed sustainability indicator tool for assessment of environmental performance of urban settlements at various scales incorporating the desired modifications as per the local context and data availability or other limitations

ANNEXURE- I

NATIONAL AMBIENT AIR QUALITY STANDARDS BY CPCB

Air Quality Assessment

The air quality of different cities/ towns has been compared with the respective NAAQS. The air quality has been categorized into four broad categories based on an Exceedance Factor (the ratio of annual mean concentration of a pollutant with that of a respective standard). The Exceedance Factor (EF) is calculated as follows:

Exceedance Factor = Observed annual mean concentration of criteria pollutant
Annual standard for the respective pollutant and area class

The four air quality categories are:

Critical pollution (C) :	when EF is > 1.5:
High pollution (H) :	when the EF is between 1.0 - < 1.5:
Moderate pollution(M) :	when the EF is between 0.5- <1.0: and
Low pollution (L) :	when EF is < 0.5:

It is obvious from the above categorization, that the location in either of the first two categories are actually not meeting the standards, although, with varying magnitude. Those, falling in the third categories are meeting the standards as of now but likely to exceed the standards in future if pollution continues to increase and is not controlled. However, the locations in Low pollution category have rather clean air quality and such areas are to be maintained at low pollution level by way of adopting preventive and control measure of air pollution. The table below gives the **pollution level classification**

Pollution level	Annual mean concentration range (µg/m^3) Industrial, Residential, Rural & others areas		
	SO_2	NO2	PM10
Low (L)	0-25	0-20	0-30
Moderate (M)	26-50	21-40	31-60
High (H)	51-75	41-60	61-90
Critical (C)	>75	>60	>90

ANNEXURE- II

WATER QUALITY STANDARDS BY CPCB

Designated Best-Use	**Class of water**	**Criteria**
Drinking Water Sources without conventional treatment but after disinfection	**A**	Total Coliforms (TC) Organism MPN/100ml shall be 50 or less; pH between 6.5 and 8.5; Dissolved Oxygen (DO) 6mg/l or more; Biochemical Oxygen Demand (BOD)5 days 20°C 2mg/l or less
Outdoor bathing (Organised)	**B**	TC Organism MPN/100ml shall be 500 or less; pH between 6.5 and 8.5; DO 5mg/l or more; BOD 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	**C**	TC organism MPN/100ml shall be 5000 or less; pH between 6 to 9; DO 4mg/l or more; BOD 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	**D**	pH between 6.5 and 8.5; DO 4mg/l or more; free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, Controlled waste disposal	**E**	pH between 6.0 to 8.5; Electrical conductivity at 25°C micro mhos/cm Max.2250; SAR Max. 26; Boron Max, 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

ANNEXURE- III

DEVELOPED AREA AVERAGE GROSS DENSITIES

UDPFI, MoUD GUIDELINES

The land use distribution norms depend upon gross population densities. Gross density can be defined as a units-per-acre density measurement that includes in the calculation - "the land occupied by commercial,industrial,public,semi-public, recreation and other uses along with residential uses." While net density can be defined as "unit-per-acre density measurement that includes in the calculation only land occupied by residential uses"

Density is expressed in terms of persons per hectares in the table below. These are suggestive population densities as per the settlement size.

Persons per hectare (pph) in		
Settlement Type	**Plain Areas**	**Hill Areas**
Small Towns	75-125	45-75
Medium Town	100-150	60-90
Large Cities	100-150	60-90
Metropolitan Cities	125-175	100-150
Megapolis	More than 200	--

Source: Revised based on UDPFI Guidelines

ANNEXURE- IV

ESTIMATION OF WATER REQUIREMENT

CPHHEO MANUAL, MoUD

Estimation of water requirement for metro cities as per Central Public Health and Environmental Engineering Organization, Ministry of Urban Development, manual on water supply is given in the table below:

As per CPHHEO Manual, rate of domestic water supply for metro cities is 150 lpcd at consumers point, and allowing 15% losses in distribution at production point	172 lpcd
Industrial, commercial, community needs @ 45000 liters / ha / day	47 lpcd
Special uses, embassies, floating population, hotels, airports, railway stations etc.	52 lpcd
Fire protection @ 1% of total demand	3 lpcd
Total	274 lpcd
Approx	60 GPCD

ANNEXURE V

CALCULATION OF COMPOSITE SURFACE RUNOFF COEFFICIENT

Surface runoff rate for a parcel of land can be calculated by ‘composite runoff coefficient’ formula. The runoff coefficient (C) is defined as the percentage of rainfall that becomes runoff.

‘Composite runoff coefficient is generated by multiplying each surface type by its surface run off coefficient and then dividing the sum of these results by the total area of the parcel of land, as shown below:

$$\text{Composite Surface Runoff Coefficient } (C_{comp}) = \frac{\Sigma\,(C_{individual\ area})\,(A_{individual\ area})}{(A_{total\ area})}$$

Where $C_{individual\ area}$ is the runoff coefficient of each surface type, $A_{individual\ area}$ is the area of each surface type within parcel, and $A_{total\ area}$ is the total parcel area.

The Normalisation values for surface runoff rate ratio adapted from Markart et al. (2006) to arrive at the potential risk of urban flooding and water logging is given in the table below.

Surface Runoff rate Ratio (%)	**Risk of Urban Flooding**
<10	VERY LOW
11-30	LOW RISK
31-50	MEDIUM
51-75	HIGH
75<	VERY HIGH

ANNEXURE VI

CALCULATION OF IMPERVIOUS SURFACE RATIO

The impervious surface ratio of a parcel of land can be calculated by dividing the total impervious surfaces by the total area of the parcel of land as shown below:

$$\text{Impervious Surface Ratio (ISR)} = \frac{IA_{total}}{A_{total\ area}} \times 100$$

Where: IA_{total} is the total impervious area within a parcel of land; $A_{total\ area}$ is the total parcel area.

The Normalisation values for impervious surface ratio percentage adapted from U.S. Environmental Protection Agency (1993) study to arrive at the potential evapotranspiration rate and the risk of urban heat island effect is given in the table below.

Impervious Surface Ratio (%)	**Evapotranspiration Rate (%)**	**Risk of Urban Heat Island Effect**
0 (Natural Ground cover)	40	VERY LOW
1-15	39	LOW
16-43	37	MEDIUM
44-88	33	HIGH
89-100	30	VERY HIGH

ANNEXURE VII

CALCULATION OF EFFECTIVE ALBEDO PERCENTAGE

The "effective albedo" of different surface multiplying each surface type by its albedo value and then dividing the sum of the results by the total area of the parcel of land as shown below:

Effective Albedo (EA) = $\Sigma (A_i * \alpha_i)$
ΣA_i

Where: A_i is the area of each surface type within the parcel of land and α_i is the albedo value of each surface type.

The Normalisation values for effective albedo percentage of urban surfaces as adapted from Oke et. al (1978) to arrive at the potential risk of urban heat island effect is given in the table below

Effective Albedo (%)	**Risk of Urban Heat Island Effect**
27<	VERY LOW
21.4-27	LOW
15.7-21.4	MEDIUM
10-15.7	HIGH
<10	VERY HIGH

ANNEXURE VIII

Questionnaire for Expert Opinion

Environmental Performance of Urban Settlements /Cities

Dear Sir,

The concept of measuring the holistic Environmental Performance was introduced by UNCED in 1992 as a part of 'Agenda 21'.This approach is based on resource based domain of OECD Indicator set and the evaluation of the Environment should be based on all the parameters of Sustainable Development. "The city should strive to provide:

1. A clean, safe physical environment of high quality (including housing quality)
2. An ecosystem that is stable now and sustainable in long term.
3. A strong mutually supportive and non –exploitive community.
4. A high degree of participation and control by the public over the decisions affecting their lives, health and wellbeing.
5. The meeting of basic needs (for clean air, healthy food, clean water, shelter, proper infrastructure, health care facilities and equal work opportunities) for all the city's people.
6. An optimum level of appropriate public health and sick care service accessible to all.
7. A diverse, vital and innovative economy.

Objective of this research is to make the Environmental Performance as basis for assessing the sustainability of the Urban Settlements /Cities. The study aspect related to this indicator based approach to measuring the Environmental Performance of Urban Settlements /Cities shall help in assessing priorities and possibilities of sustainable settlement/city development. In this study the Environmental Performance for the sustainability of the city through the chosen indicators is addressed from the view point planners and environmentalist and application is at the city level

Therefor please list down all those factors which contribute in improving the Environmental performance of an Urban Settlement in India. It is also requested to you to assess importance of various listed domains (aspects) .The contribution of various aspects (domains) could be identified considering qualities as described by OECD for evaluating the Environmental Performance of the Urban Settlement.

This information provided by you for this purpose shall be kept confidential and it will be used for research purpose only.

Shuvojit Sarkar (Ph.D. Scholar)
Department of Architecture
Jadavpur University, Kolkata-32

Please assign marks (weightage) to the following major aspects (Domains) related to the Environmental Performance of Urban Settlements. The aspect, which contributes more towards environment, shall get more marks/more weightage on a scale of 1-10 (including decimals up to two places), considering 10 as maximum importance and 1as minimum importance. Please indicate your assessment by putting values against each domain.

Aspect (Domain)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Remarks**
AIR SO_2 concentration ,NO_2 concentration PM_{10} concentration											
WATER Average DO concentration, Average BOD concentration, Total Coliform concentration											
LAND Population density , Green spaces/person											
HOUSING Housing availability, Average household size, Share of households with one room, Share of population living in pucca, Share of population living in slums, Share of population as Pavement dwellers											
INFRASTRUCTURE Water supply per capita, Households with potable water supply service, Households with source of water within premises, Households with sewage connection, Households with access to proper toilet facilities within premises, Solid waste generation											
ENERGY Households with electricity, Households with LPG connection, Households using renewable source of energy, Households with motorised vehicles											
POPULATION Literacy Rate , Health facility, Infant Mortality Rate , Average Life Expectancy, Households below poverty line											
FINANCE City GDP, Per capita Income, Employment Rate											

Suggestions/Remarks:

Name: Designation: Sign:

Weightages derived through expert opinion (25 experts):

Domain	Air	Water	Land	Infrastructure	Energy	Housing	Population	Finance
Avg. Weightage	8.20	7.80	6.90	7.30	6.80	7.10	7.60	6.80

ANNEXURE IX

Survey Questionnaire

Assessment of Environmental Performance of Urban Settlements / Neighbourhood

Dear Sir,

The concept of measuring the holistic Environmental Performance was introduced by UNCED in 1992 as a part of 'Agenda 21'.This approach is based on resource based domain of OECD Indicator set and the evaluation of the Environment should be based on all the parameters of Sustainable Development.

"The city should strive to provide:

1. A clean, safe physical environment of high quality (including housing quality)
2. An ecosystem that is stable now and sustainable in long term.
3. A strong mutually supportive and non –exploitive community.
4. A high degree of participation and control by the public over the decisions affecting their lives, health and wellbeing.
5. The meeting of basic needs (for clean air, healthy food, clean water, shelter, proper infrastructure, health care facilities and equal work opportunities) for all the city's people.
6. An optimum level of appropriate public health and sick care service accessible to all.
7. A diverse, vital and innovative economy with equitable distribution of resources.

Objective of this research is to make the Environmental Performance as basis for assessing the sustainability of the Urban Settlement. The study aspect related to this indicator based approach to measuring the Environmental Performance of Urban Settlement shall help in assessing priorities and possibilities of sustainable settlement development. In this study the Environmental Performance for the sustainability of the settlement through the chosen indicators is addressed from the view point of individuals and application is at the settlement level

Therefor please list down all those factors which contribute in improving the Environmental performance of the Urban Settlement and can help in assessing the present environmental status of the settlement.

This information provided by you for this purpose shall be kept confidential and it will be used for research purpose only.

Shuvojit Sarkar (Ph.D. Scholar)

Department of Architecture

Jadavpur University, Kolkata-32

SURVEY FORMAT for ENVIRONMENTALLY SUSTAINABLE IMPERATIVES FOR URBAN SETTLEMENTS IN INDIA : **Shuvojit Sarkar**

RESPONDENT NAME :	Age:	**HOUSE NO.**		**LOCATION:**	
Household Size:	Male:	Female:	Adult: Minor:	No.of Literates:	Avg. Age of HH.
Fuel used for cooking?	Biomass Kerosene	Wood	Coal Reason: Affordability ID Subsidy	LPG CNG	Electricity
WATER					
Water Connection?	Yes	No			
Municipal?	Yes	No	Metered	Yes	No
Water Point	Inside	Outside			
Hours of Water Supply	Morning	Afternoon	Evening	Night	
Quality of Supplied Water	Colour	Odour	Taste	Hardness	RO/Filter
Dependency on Other Sources	Boring	Tankers	RO/Filter	Community Taps	Bottled/Others
Water Borne Diseases in Past 1 Year?	Never	Rarely	Occasionally	Frequently	Very Frequently
SEWAGE and DRAINAGE					
Toilets Within House?	YES	NO			
Sewage Disposal	Municipal Connection	Septic Tank	Pit	Open	
Sewer Problems If Any	Back Flow	Choking	Contamination With Drinking Water		
Drainage of Surface Water/Rain Water	Yes	No	Surface Drainage	Under Ground Drainage	
SOLID WASTE					
Solid Waste Collection House	Yes	No	No of Days In a Week		
Solid Waste Collection Community	Yes	No	No of Days In a Week		
Solid Waste Segregation	Yes	No	No of Days In a Week		
Burning of Waste/Bio mass causing emission Daily	Yes	Frequently	Occasionally	Rarely	Never
Solid Waste Disposal in open	Open	Bins	Dalaos (Vats)		
HOUSING					
Housing Stock	Pucca/Masonry	Kuccha	Proper Ventilation and Light	Yes	No
Housing Stock Condition	Good	Bad	Dilapidated		
OTHER INITIATIVES/EMPLOYMENT/FINANCIAL/ HEALTH			Distance (in km) to the nearest Health Facility	Adhered to all vaccinations till age of 5. Y N	
Electricity Avg. Electricity Bill/Month	Metered	Non Metered	Average Units in a Month	DG Sets	Inverter
Vehicles ownership and Nos Yes No	Cycle	Scooter	Motor Cycle	Car	Others
Fuel Type used for Vehicle	Diesel	Petrol	CNG	Electric	
Rain Water Harvesting	Yes	No	If Yes HH Community	Avg. Monthly Income	
Waste Water Treatment/Recycling	Yes	No	If Yes HH Community	Avg. Monthly Expense	
Alt. /Renewable Energy Initiatives	Yes	No	If Yes HH Community	No.of employed HH member	
Surveyor:	Signature:		Date:		

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