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S. Mahendra Dev
Sudhakar Yedla *Editors*

Cities and Sustainability

Issues and Strategic Pathways

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Editors

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Foreword

"Is urbanization an opportunity or a challenge?"

Opinion is divided. For some it is an opportunity and for some a challenge. Urbanization, for me, is an opportunity. The government of the day also sees in it an opportunity rather than a challenge. The Prime Minister of India has made known his vision on this aspect.

I do acknowledge there are challenges and perhaps aplenty. Nonetheless, it has been the endeavour of the government to convert all those challenges into opportunities and take the country's development to greater levels. It will not be long before the country witnesses positive transformation. I see the book *Cities and Sustainability – Issues and Strategic Pathways* as one showcasing the challenges of urbanization and illustrating ways and means to turn them into opportunities.

Cities or towns are undeniably the growth engines and contribute a lion's share to the GDP compared to villages. Cities provide the enabling conditions for individuals and communities to achieve their full potential. They do provide better opportunities for education, health, employment, entertainment and, resultantly, better human development and better standards of living. Cities have better access to basic public services compared to rural areas.

Going forward, urbanization is an inevitable process. It is estimated that 40.6% of India's population will live in urban areas by 2030. It is no wonder if two-thirds of India will get the urban tag by 2050!

Undeniable is the fact that civic infrastructure in most of the cities and towns in India has reached a point of saturation. It is crumbling. Municipal bodies are ill-equipped to handle the huge influx of migrant population. Urban transport, urban housing, solid waste management, essential services delivery, livelihood and security are among the major challenges to cities/towns and to their sustainability. The question that agitates a sane mind, therefore, is whether an unchecked, unplanned, unscientific and unsustainable urbanization is allowed to take place at the cost of human existence itself.

The issue that brings itself to the fore thus is *sustainability*. To accommodate the increasing population, cities have to grow not only in terms of size, horizontal or vertical, but also in terms of opportunities to people for economic activity. Infrastructure thus becomes a prerequisite for growth. Infrastructure augmentation requires resources, natural as well as man-made, which are scarce and many of them non-renewable.

A city can grow on a sustainable basis only if there are opportunities for economic activity, education, health care, entertainment and a wide range of such services for residents. There is need to manage city's growth in a manner that is more sustainable in terms of environment and more inclusive in economic and social terms. While sustainable patterns of urbanization would need to be supplemented, unsustainable ones need to be supplanted with smarter, more inclusive and sustainable patterns as we move towards accelerated urbanization.

This calls for thoughtful actions and strategic planning, harnessing new technologies for low-carbon paths and investments in critical areas such as housing, sanitation, energy, transport and other infrastructure to ensure preventive environmental management and social cohesion. This requires innovative planning, effective governance, dependable funding and a strong association between the sciences of planning and policy. Urban governance, management and planning should be so crafted as to effectively deal with the challenges of urbanization.

The vision of smart cities is that these cities would offer employment and decent living options to all residents. These cities would provide sustainable economic, social and physical infrastructure such as 24×7 electric supply, water supply sanitation, clean air, quality education, health care, security, entertainment, ICT connectivity, and fast and efficient transport among other services. More than anything else, smart cities require smart leaders and smart people.

Our pursuit of inclusive and sustainable urbanization would become possible if we could narrow down the gaps in terms of social and physical infrastructure including our ability to provide housing, drinking water, sanitation, open public spaces, good roads, electricity, education and health services to all our new urban citizens while enhancing the environmental sustainability. Considering the mammoth financial requirements for sustainable urbanization, public-private partnerships have to play an important role.

It is gratifying to note that all the contributory authors of this book are persons of eminence in their professional stature. The valuable inputs of all the contributing authors would be of immense help to me, as Minister-in-Charge of Urban Development, Housing and Urban Poverty Alleviation, in understanding the urban challenges and reshaping urban policies. The book promises to hold the interest of the reader and will prove to be a good reading for urban planners and policy makers as also to the urban local bodies and city governments.

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Government of India, New Delhi, India,

M. Venkaiah Naidu

Preface

The Indira Gandhi Institute of Development (IGIDR) celebrated its silver jubilee in the year 2012–2013. Celebrating 25 years of its active presence in Indian policy making and its very meaningful contributions, the IGIDR organized a number of silver jubilee conferences on various themes wherein it played an active role. Having contributed immensely to policy making in cities (urban areas), energy and environment, the IGIDR organized a conference on a very important, contemporary and challenging theme – Cities and Sustainability. This conference held in October 2013 had a number of interesting presentations made by academics and policy makers representing Andhra Pradesh Industrial Infrastructure Development Corporation (APIIC), Australian National University (ANU), CDM Smith, GMR Institute, Indian Institute of Management (IIM), Indian Institute of Public Administration (IIPA), Indian Institute of Technology (IIT), International Council on Local Initiatives on Environment (ICLIE), IRG India Ltd., Mumbai Metropolitan Development Authority (MMRDA), National Environmental Engineering Research Institute (NEERI), National Institute of Technology (NIT), New Raipur Development Authority, The Energy Resources Institute (TERI), University of Minnesota, University of Mumbai and University of Ulsan. It had a wide and inclusive coverage of all stakeholders in ensuring sustainability in cities.

With a view to making the rich discussions and material presented in the conference available to a larger audience, the IGIDR has embarked on publishing this book, and the editors are thankful to Springer Publishers for agreeing to publish this important book which is also very timely.

Cities contribute significantly to the economic development of a country and thus experience tremendous growth spatially and economically. The pace at which the cities change outperforms that of provision of infrastructure as well as civic and other essential services. However, cities are the face of the national economy and need to be nurtured into “centres of sustainability” in order for them to continue with their contributions and also provide a “livable habitat” to the ever-increasing migrant population and the urban poor. A recent report of the Expert Group (chaired by Dr. C. Rangarajan) on poverty shows that in nearly half of the Indian states, the urban poverty ratio is more than that of rural poverty in 2011–2012. This portrays the significant presence of the urban poor and the need and challenge to serve them the basic needs. In order to achieve a strong base of sustainability, cities need to green their production process by integrating the material flows from various service and non-service entities, such as industrial clusters and municipal solid and electronic wastes. Reorienting cities towards "material cycle societies" holds the key for their move towards sustainability. It is important to correct their land use plan in a way to minimize the need to travel, which would eventually help in providing the citizens with "sustainable mobility" and a secure environment both in terms of clean environment and safer mobility.

Due to increased stress, the cities are subjected to various climate and non-climate risks, and it is important to have an integrated approach towards such calamities looming over these growth centres. Securing these cities for energy also reduces such risks and vulnerabilities and supports their growth unhindered. As the Asian cities are gearing up to develop their infrastructure, it is time for them to consider environmentally inclusive infrastructure planning and include innovative finance and institutional mechanisms to achieve such an inclusive growth.

This book, *Cities and Sustainability*, touches upon these important aspects of cities and provides useful insights and valuable suggestions towards fulfilling these important and indispensable targets.

This book aims to help the policy makers by identifying the key areas where more planning efforts could be focused in order to develop the cities into "centres of sustainability" and help them contribute more meaningfully to the national economy as well as provide more comfortable and inclusive living conditions to their citizens.

Mumbai, India

S. Mahendra Dev
Sudhakar Yedla

Acknowledgements

This edited volume is based on the IGIDR Silver Jubilee Conference on Cities and Sustainability held in October 2013. We thank the Reserve Bank of India for its generous support in organizing this conference.

The authors, who were also participants in the IGIDR Silver Jubilee Conference on Cities and Sustainability, have contributed significantly to this edited volume. We are grateful to their contributions, which make this book a valuable addition to the literature on policy making. The contributions of the anonymous reviewers in reviewing the individual chapters are invaluable in improving the material. Their support in bringing out this volume is duly acknowledged.

The support of the IGIDR administration and ancillary support staff in organizing the conference and in the preparation of this book is overwhelming, and we appreciate it highly. The support expended by Ms. Sandhya Garg, Ms. Shikha Juyal and Ms. Jayshree Borkar is duly acknowledged.

S. Mahendra Dev
Sudhakar Yedla

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Sudhakar Yedla holds a PhD in Environmental Engineering from the prestigious Indian Institute of Technology (IIT) Kharagpur, India. He has a Diploma in International Environmental Law and Certification in Environmental Economics and Development Policy from the World Bank Institute, Washington, DC, USA. His areas of expertise include urban environmental policy, climate change mitigation and sustainable mobility. Earlier he had served as a faculty member at the University of Ulsan, South Korea; Asian Institute of Technology, Thailand; and National Institute of Technology (NIT) Warangal. He had also served at the Institute of Global Environmental Strategies (IGES), Japan; at UNDP as GEF and SDG consultant; at UNESCAP as sustainable city consultant; and at UNEP, UN-FAO and Swedish International Development Cooperation Agency (Sida) as a Project Director for their regional initiative on climate change. He has published over 100 articles in international journals and books and is serving editorial boards of a number of international journals. At present, he is a Professor of Environmental Policy at the Indira Gandhi Institute of Development Research (IGIDR), Mumbai, India.

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Rangan Banerjee is the Forbes Marshall Chair Professor in the Department of Energy Science and Engineering and the Head of Centre for Technology Alternatives for Rural Areas, Indian Institute of Technology Bombay. He was responsible for creating a new Department of Energy Science and Engineering in 2007 and was its first Head of Department. He has also been the Dean of Research and Development. He has co-authored *Planning for Demand Side Management in the Electricity Sector* (Tata McGraw Hill, New Delhi), *Energy Cost in India vis-a-vis the World* (Indian Chemical Manufacturers Association, Mumbai) and *Engineering Education in India* (Macmillan Publishers, India). His areas of interest include energy management, modelling of energy systems, energy planning and policy, hydrogen energy and fuel cells.

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Chapter 1
Cities and the Sustainability Dimensions

Sudhakar Yedla

Abstract Cities are the epicenters of economic prosperity, and that makes them vulnerable to various stresses both of environment and social dimensions. However, due to their higher per capita incomes and improved systems and infrastructure, they are equally capable to respond to certain corrective and futuristic measures. For the urban systems to sustain, they need to have abundant supply of resources as well as improved systemic efficiency in using the resources available to them. This accounting to both internal and external sustainability would be possible only by embarking onto ecological efficiency in various segments of the urban system accounting to production and consumption. Therefore, the cities have to develop a combination of policies to address in tandem and realize ecologically efficient production, ecologically efficient landscaping, ecological friendly culture, ecologically efficient and secured services provision, and ecologically efficient sanitation system. These five components as part of eco-city would help cities not only for their environmental sustainability but also on social equity and economic prosperity.

1.1 Introduction

Asian region has been experiencing faster economic growth for the past few decades resulting in excessive environmental load. Having achieved higher economic growth rates, countries such as China and India look for inclusive growth which could last longer. Particularly, the societal and environmental inclusiveness is considered important to make the development more sustainable. Given the economic, social, and environmental relevance of urban areas, the way cities are planned, developed, and managed will have a major bearing on the sustainable development of the region. This is particularly relevant with Asia expected to have 50 % of its population living in urban area in the next few decades.

Urban centers are the growth centers for any country, and one of the main obstacles in exploiting the potential of urbanization is the lack of an integrated planning,

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which takes into consideration environmental and social aspects. This lack of integration is reflected in lack of integration of economic, environmental, and social aspects in policies and in institutions and across sectors. On the other hand, integrated and people-centered planning in cities like Curitiba (Brazil) and Bogotá (Colombia) has delivered substantial economic, environmental, and social benefits, while more recent eco-city development initiatives in Asia such as in Bangalore, India, as well as the proposed Dongtan City, and China are at the frontiers of applying sustainability concepts to urban areas.

In an attempt to find the limiting factors hindering the integrated and sustainable urban development in Asian and Pacific region, UNESCAP, in its recent works, has highlighted on lack of political support and widespread lack of awareness of sustainability concepts as applied to urban planning and infrastructure development (UNESCAP 2006a). Political support and inspired leadership have been among the reasons for the success stories of the cities cited above, as well as in other recent interventions, such as those in the cities of Seoul and Daegu, Republic of Korea (UNESCAP 2006b).

1.2 Potential of Cities

Geographical pattern of the world is on a rapid change. Both size and population of cities are on rise, and this pattern is being observed in Asia and the Pacific in the past few decades (Imura et al. 2005). Cities are the economic centers and possess high potential of employment generation. Most of the cities have higher per capita income than their respective national or regional average per capita. This coupled with lack of decentralized city planning and agrarian and other livelihood crisis results in raising rural-urban migration. It is expected that within the next few decades, fifty percent population in most populous countries like China and India would be living in urban agglomerations. It is for no dispute that Asian cities are fast growing both economically and geographically. UN-HABITAT had reported that majority of the World Mega cities would be from Asia in the near future (UN-HABITAT 2001). Thus, cities and their characteristics would define the regional dynamics.

Cities in this region have a particular characteristic of “intensity.” Targeting for annual growth rates of their economy in the range of 8–10 %, Asian countries have been stressing their cities beyond their capacity. As a result the big cities in this region are the areas with most severe environmental problems in the world. These problems include overpopulation, lack of city planning with scientific considerations, uncontrolled and unreasonable expansion of city boundaries, severe traffic congestion, and formation of fragile urban-rural fringe areas. With higher-growth objectives, cities attract a large number of factories, which are environmentally unfriendly. This jeopardizes the urban sustainability. The economic system in its conventional pattern considers various segments of urban ecology as independent entities and also considers industry as an exchangeable consumer of resources and producer of products without much links with the city. This has resulted in a linear production model with least ecological efficiency. Further, increasing per capita incomes due to the concentrated growth resulted in changing consumption patterns, which are ecologically unfriendly. Uncontrolled sprawling has been a root cause for the increased travel activity, and lack of infrastructure and eco-culture had resulted in excessive motorization and increased number of personal vehicles. Therefore, cities, which are the centers of economic activity and prosperity, have also been "centers of unsustainability."

With the increasing population on this finite planet with finite resources, we are not too far from a point where the endowment of natural resources can no longer be able to provide the life-supporting system for our economy and the society. Therefore, many international agencies as well as national governments have zeroed on an opinion that the present linear production system is not sustainable and should adopt "material cycle models." Given the importance of cities in our economy, strategies for sustainable urban development should be given priority in the overall sustainable development. This leads to various programs, viz., green cities, sustainable cities, industrial ecology, industrial symbiosis, eco-cities, etc. As the cities have been the centers of "unsustainable patterns of life," most of these green initiatives are centered on cities. While national and provincial governments have a role to play, it is the city governments who need to internalize the "green thinking" and "ecological principles" into their policy making, planning, and administration. In the economy of eco-cities, industry is interlinked with other industries and other segments of urban metabolism and is integrated in local and regional context which helps in achieving eco-efficiency. Therefore, the city administration has to play a key role of pivoting all the coordination required for eco-city development.

Cities, while they are the most exposed units to various problems, are equally equipped to handle solutions (Linan et al. 2004). As the countries and regions gear up for green and sustainability movements, they look at cities to implement those initiatives, which need trained human resources and technological and systemic support. Cities have conditions that are necessary to implement significant strategies for sustainable development. With abundant human resources and solid foundations of science and technology, cities have favorable conditions for carrying out sustainable development strategies oriented by knowledge and technology. Cities, which are the political, cultural, and educational centers, can play a critical role in demonstrating and promoting sustainable development strategies. With higher population densities and rich pool of resources, cities provide much brighter scope to achieve eco-efficiency. This in turn provides an opportunity to turn them into the "centers of sustainability." This argument is supported by UNFPA's report on "State of World Population 2007" (UNFPA 2007). With cities serving as the nodal points of economic prosperity, achieving eco-efficiency among them presents the most practical pathway for sustainable development. Therefore, sustainable urban development should get a priority while attempting sustainable development initiatives with particular focus on cities and urban agglomerations.

As they are stressed to their resource limits, cities have no way but to go through sustainable development phase, and it should be the ultimate goal of city development to achieve eco-efficiency. This goal should encompass various objectives, viz., harmonious increase of urban economic benefits, improved and modernized industrial structure, rational environment conservation, efficient utilization of resources, optimized city functions, ideal management of social services, and a higher standard of living. All these can be achieved if cities implement sustainable urban development strategies integrating all functional segments toward providing a superior living in an ecologically efficient way. When sustainability efforts are made in an administrative unit by means of utilizing and managing the local resources, setting up an ecologically sound institution and influencing people's behavior, such a unit is termed as eco-city. National or global sustainable development can become reality only when cities become ecologically efficient. The following section presents the concepts of eco-city and sustainable development in general.

1.3 Sustainability Science and Cities: The Basic Constructs

Ever since the environmentalism got into the existence, several definitions are given to sustainability. While some of them have limited the criteria of sustainability on maintaining ecosystems and natural resources, others considered social, economic, and ecological issues, well-being, and equity issues. In a generic presentation, sustainability is nothing but sustaining a system, may it be an institution or a human cluster. Considering these entities as operating systems, sustainability refers to sustaining these systems. There exists two ways of sustaining these systems. As in the case of systems approach, consider these systems as a black box, may it be an industrial production or an institution, and do not deal with it. Instead, deal with the external connections to the outer environment. This boils down to dealing with an input-output matrix. Therefore, a possible condition for sustainability of the systems is that the outer environment be able to supply the needed inputs on permanent basis and also accept its output. By its nature, this can be termed as external sustainability (Fleischer 2002). Based on this argument, if the environment can offer unlimited and the needed conditions, the system can sustain.

However, it is a well-known fact that economic growth is limited by two important aspects of the environment:

1. Finite nature of nonrenewable resources that environment can offer
2. Limited waste-receiving capacity of the environment (Turner et al. 1994)

Another dimension to the resources limit is that the rate of use of renewable resources cannot be greater than the rate of their regeneration. Therefore, unlimited and unrestricted support of input-output array from the environment is not a mere possibility. Thus, it is the human system (black box) that needs to adapt itself to the endowments of the natural environment. Therefore, targeting the criteria of external sustainability alone would not help sustain this system.

This leads toward examining the inside of the system. It is easy to understand that the rate of use of nonrenewable resources has to be limited so that its pace cannot be greater than the rate at which that source can be substituted by renewable source. It is easily understood as criteria for sustainability. But the individual decisions are influenced by many factors such as economic status, education level, social background, cultural background, etc. By creating incentives to use energy resources more judiciously, one can make this individual decision closer to the global interest. Attempting to improve the systemic efficiency by considering these conditions could be termed as internal conditions for sustainability.

Task of achieving sustainability needs to fulfill both external criteria of sustainability and meet different internal conditions within a system. In the literature, the internal system of human settlement is subdivided into three subsystems, namely, economics, environment, and social. While these subsystems do not lead to sustainability in themselves, their interaction results in sustainability (Camagni et al. 1998). The overlapping field between environment and social sets gives the environmental equity subset which talks about inter- and intragenerational equity issues. Interactions between economics and social sets and environment and economics sets result in distributive efficiency and long-term allocation efficiencies, respectively. These interactions are shown in Fig. 1.1. Camagni et al. (1998) argues that the interacting subsets result in various externalities, both positive and negative. A city or human settlement is considered sustainable only when its three subsystems interact in a way that the sum of positive externalities resulting from such interactions is larger than the negative externalities of their interaction. Thus, for any city or a human settlement to be sustainable, it must integrate the operations of its subsystems.

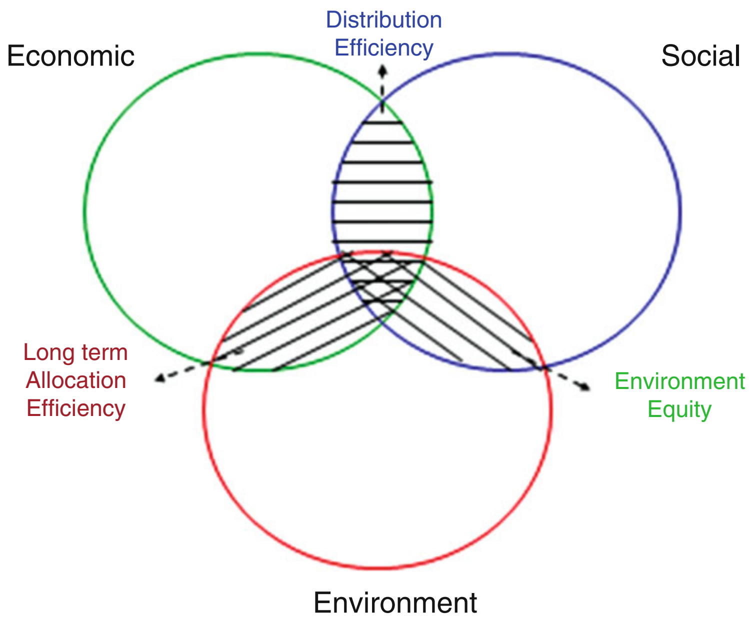

Fig. 1.1 Sustainability of the interaction of social systems (Source: developed by the author)

Different scholars choose different center points of the triangle of the three subsets, and it is interesting to see someone's central theme of sustainability may be an overlapping subset for some others. Therefore, definitions and the efforts toward sustainability depend on the subset triangle and the perceived interaction among them. Connecting the input-output matrix to the internal sustainability criteria shows the material flow goes through the city. A linear metabolism of cities is where the input is unrelated to the output which is thrown away as it comes out of the system. In contrast, circular metabolism uses every output as an input in another process (Girardet 1992). In order to handle these internal conditions of sustainability, literature had drawn on numerous classifications. However, there are issues common to all classification as explained in the next few paragraphs.

The above-discussed principles of sustainable development are generic in nature, and applying them to the society as a whole is not as practical. Therefore, it is initially applied to the cities and urban settlement. Roots of eco-city concepts are drawn from urban ecology. Urban ecology as a concept took shape during late 1970s of the nineteenth century and gathered real moment in the late 1980s with the publication of Register's Eco-city Berkeley (Register 1987), a visionary book on rebuilding of Berkeley. As defined by the first International Eco-city Conference held in Berkeley in year 2002, Eco-city is a "… living whole system, a natural and human-made unit having economically productive and ecologically efficient industry, systematically responsible and socially harmonious culture, and physically beautiful and functionally vivid landscape." Eco-cities are the places where living is made with least of human intervention that encompass all sectors, viz., mobility; energy; resources such as water, air, and soil; and social and ecological aspects as well. Mission of creating eco-cities follows ten principles as mentioned by Roseland (1997), which are extracted and presented below:

- Revise land-use priorities to create compact, diverse, safe, and vital mixed-use communities
- Revise transportation priorities to favor nonmotorized modes and transit over automobiles and to emphasize "access by proximity"
- Restore damaged urban environments
- Create decent, affordable, safe, convenient, and economically mixed housing
- Nurture social justice and create improved opportunities for women and other disadvantaged sections
- Support local agriculture, urban greening projects, and community gardening
- Promote recycling, innovative appropriate technology, and resource conservation while reducing pollution and hazardous wastes
- Work with business to support ecologically sound economic activity while discouraging pollution, waste, and the use and production of hazardous material
- Discourage excessive consumption of material goods
- Increase awareness of the local environment and bioregion

According to Roseland (1997), the major paradigms contributing toward eco-city concepts are appropriate technology, community economic development, social ecology, the green movement, bioregionalism, and sustainable development. The central theme of "appropriate technology" is that a technology should be designed to be able to be compatible with its local settings. "Community economic development" is a process by which communities can initiate and generate their own solutions to their common economic problems and thereby build long-term community capacity and foster the integration of economic, social, and environmental objectives. "Social ecology" is a study of both human and natural ecosystems and, in particular, of the social relation that affects the relation of the society with the nature as a whole. Social ecology goes beyond environmentalism insisting that protecting environment is not just sufficient but to create an ecological society in harmony with nature. It brings forth the considerations of social justice and equity linking them to the energy efficiency and appropriate technology issues. Among numerous definitions given for sustainability, the one given by the UN is the most accepted, which states that sustainability is nothing more than meeting the needs of the present without compromising the ability of future generations to meet their own needs. The paradigms explained above provide general direction for the application of such concepts to develop eco-cities all around the world.

With increasing attempts to apply these concepts in practice to structure/restructure cities toward sustainability, ecology-centered development of cities has taken different shape depending on the scale of operation. Eco-city relates to relatively small and limited areas within the urban agglomeration in absence of which it would be practically no-hope situation for the implementation of the conception. On the other hand, eco-city aims at a complex and holistic solutions in the selected area. Given the complexities in implementing, application of ecological principles is practically easier when tried with a small community and segments of the larger city. Developments of eco-towns and eco-industrial parks are such attempts, which are not eco-city movements in themselves but only a contributing part toward the development of an eco-city (GEC 2005). While eco-cities focus on overall urban planning and urban ecosystems, civil society and greening of cities, eco-towns focus on industrial systems, 3R, life cycle economics, etc. Eco-industrial parks focus only on industrial area, ISO 14001, and individual factories.

Development of eco-cites is a long and slow process. There exists other approach of end-of-pipe which is not only partial in nature but also applied only to "already damaged/polluted" entity. Another approach of linking environment to economy to avoid the formation of environment-damaging actions fails to encompass the maximization of resources utilization. In contrast, eco-city movement considers a spatially limited area and tries to create a livable and sustainable urban life by considering each element of urban life. As explained by Juergen and Rusong (2005), eco-city development is a healthy process toward sustainable development within the carrying capacity of local ecosystem through change of production mode, consumption behavior, and decision instrument based on ecological economics and systems engineering. Integration, demonstration, citizens' participation, and scientists and technician's catalyzing are the key instruments for the implementation of the eco-city plan (Juergen and Rusong 2005).

With sustainability concepts as foundation and the urban ecological principles providing the guidance, eco-city development requires an evolution of its

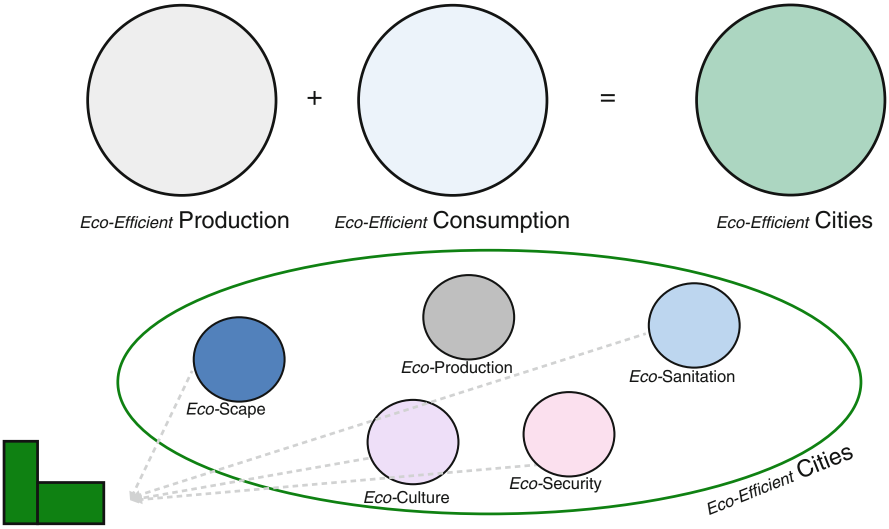

Fig. 1.2 Components of cities and their sustainability (Source: developed by the author)

components/units, which is a long and adaptive process based on the carrying capacity of the eco-systems. Juergen and Rusong (2005) have identified five such evolutionary components/goals to bring eco-city into practice. They are ecological sanitation, ecological security, eco-industry/ecological metabolism, eco-scape (eco-landscape), and eco-culture. Figure 1.2 presents these concepts.

Ecological sanitation provides citizens with a clean and healthy environment through encouragement of ecologically oriented, cost-affordable, and people-friendly eco-engineering for treatment and recycling of human wastes, sewage and garbage, reducing air pollution and noise, etc. *Ecological security* provides citizens with ecologically safe basic living conditions: clean and safe supply of water, food, service, housing, and disaster prevention. *Eco-industry/ecological metabolism* emphasizes on industrial transition from industry focusing on traditional products, to function-oriented and process-closed industry, through coupling of production, consumption, transportation, reduction, and regulation. *Eco-scape (eco-landscape)* emphasizes on alleviation of heat island, hydrological deterioration, greenhouse effects, and landscape patterns and processes. *Eco-culture:* Ecologically conscious man with ecologically sound and historically continuous culture grounded on the ecological principles of totality, harmony, recycling, and self-reliance. Eco-culture should be encouraged in eco-city development in the area of cognition (philosophy, science, education), paradigm or norm (religion, values, morality), behavior (production and consumption mode, customs), tangible cultural products (architecture, landscape, arts), and institution (organization, legislation, and policy making) (Juergen and Rusong 2005).

Achieving eco-efficiency and social inclusiveness is the most difficult task in eco-city development, which needs both scientific and administrative motivation to change people's lifestyle, production mode, and eco-consciousness.

1.4 Cities and Sustainability: Attempts and Lessons

Eco-cities are human settlements that respect the natural environment and use the least possible resources (by means of eco-networking in production process and changed consumption behavior) and keep waste and pollution to a minimum. Their economies are labor intensive, and buildings make good use of sun, wind, and rain. Food and goods are sourced locally, and transportation is limited to walking and cycling, with public transport for longer journeys. They encourage biodiversity by preserving natural habitats. Eco-cities offer their residents an excellent quality of life.

Based on concepts presented above, many countries have attempted to develop eco-cities, some with a great success. Such efforts are varying in degrees with some that have been comprehensive development strategies as in the case of Hannover Kronsberg, Germany. There are few more eco-cities being planned comprehensively such as Dongtan City, China and Masdar City, Abu Dhabi. Apart from such comprehensive projects, there exist numerous cases of eco-town and eco-industrial park development and also sustainable urban planning initiatives like Curitiba, Brazil. Though they do not qualify for an eco-city, they are certainly necessary steps toward achieving ecological sustainability of cities by addressing various segments of urban living. The following are such attempts made in various to achieve ecological efficiency in cities.

1.4.1 Dongtan Eco-City Project in China (Girardet 2004; Zhao and Girardet 2006)

Shanghai Industrial Investment Corporation has commissioned the world's first purpose-built eco-city – Dongtan. Built on Chongming Island in the Yangtze River Delta, Dongtan takes an area of 86 km^2 and houses 25,000 people and would have 500,000 people by 2030 (Girardet 2006). China, with 400 new cities planned to be developed in the next 20 years, aim to develop Dongtan Eco-city with a minimal ecological footprint which can be a template for future urban design. Its success would be crucial for Chinese city development program for the future.

Dongtan's design is based on the principle that all its citizens can be in close contact with green open spaces, lakes, and canals. It aims to ensure that people will take no more than 7 min to walk from any part of the city to a bus or tram stop. It aims to have buildings with high energy efficiency and largely powered by renewable energy – the wind, sun, and biomass. The city aims to create development with low energy consumption that is as close to carbon neutral as possible. Dongtan would produce its own energy from wind, solar, biofuel, and recycled city waste. Clean technologies such as hydrogen fuel cells would power public transport. A network of cycle and footpaths will help the city achieve close-to-zero vehicle emissions. Farmland within the Dongtan site will use organic farming methods to grow food. Most of Dongtan's waste output will be recycled and composted. It is expected to be a vibrant city with green "corridors" of public space ensuring a high quality of life for residents. The city is designed to attract employment across all social and economic demographics in the hope that people will choose to live and work there.

Dongtan will be pioneering eco-city that could become a template for sustainable urban development, in China itself and elsewhere in the world. It holds a promise of high-efficiency, small-footprint urban design.

1.4.2 Masdar Eco-City Project, Abu Dhabi

The first project as a result of the Masdar Initiative is a new six million square meter sustainable development that uses the traditional planning principals of a walled city, together with existing technologies, to achieve a carbon neutral, car-free, and zero waste community. The city is being built to highlight innovation in energy efficiency, sustainable practices, resource recycling, biodiversity, transportation, and green building standards. Every building in the city is being designed and constructed to provide a model for sustainable living and working. The city, estimated to cost $22bn and take 8 years for construction, is planned to house 50,000 people and 1,500 businesses. Masdar is an attempt to offer a sustainable urban blueprint for the future. Launched in 2007, it is an ambitious project providing a mixed-use, high-density city.

The principle of the Masdar development is a dense walled city to be constructed in an energy efficient two-stage phasing that relies on the creation of a large photovoltaic power plant, which later becomes the site for the city's second phase, allowing for urban growth. Masdar will be linked to surrounding communities, as well as the center of Abu Dhabi and the international airport, by a network of existing road and new rail and public transport routes. With a maximum distance of 200 m to the nearest transport link and amenities, this provides best conditions for walking and personalized use of public transport system. With expansion carefully planned, the surrounding land will contain wind, photovoltaic farms, research fields, and plantations, so that the city will be entirely self-sustaining. The city will have low-energy buildings, with natural air conditioning from wind towers. A solar-powered desalination plant is expected to provide water to the city. The city is designed in a way to use only a quarter of the power required for a similar-sized community, while its water needs are expected to be lower by 60 %. As a part of the plan, Abu Dhabi will become home to the world's largest hydrogen power plant.

There exist other attempts to develop eco-cities, though not in complete framework as in the case of Dongtan. The following are such efforts in different cities around the world.

1.4.3 Project Agastya: An Eco-City Initiative in Bangalore, India

Project Agastya is an initiative of a nongovernment organization (NGO). It is a citizens' voluntary initiative with active support, cooperation, and participation of the Central and Karnataka governments, the industry, educational and research organizations, NGOs, residential associations, community-based organizations, facilitators, experts, etc. for transforming Bangalore into a sustainable eco-city by 2025.

Project Agastya seeks to achieve this transformation through efficient participation of government, various stakeholders, and NGOs, and deployment of environmentally sound technologies. Several initiatives taken up by Project Agastya in the pursuit of its objectives are urban water resources management (including water conservation, stakeholder participation, pollution control, rain water conservation, etc.), integrated (solid) waste management, E-waste management, eco-tourism, urban planning/eco-cities, and integrated and sustainable energy management.

1.4.4 Yangzhou City: Attempts of Eco-City Planning

Under the program of Chinese Agenda 21, Yangzhou city has developed a plan for eco-city development with three main goals, viz., promote economic transformation from traditional economy into resource type, knowledge-type, and network-type sustainable economy with high efficiency; promote regional eco-environment development to create a good ecological basis for social and economic development; and promote the conversion from local people's traditional production, lifestyle, and values into environment-friendly, high-efficient resources, harmonious system, harmonious society, and eco-culture. Under the eco-city development plan, the city has developed the following short-term goals – create more employment opportunities, increase average education years; incubate large eco-industry groups and enterprises, higher GDP growth rate, recover abandoned mine areas and wetlands, set up natural conservation areas, purify rivers, and increase green space in the cities and towns. A series of capacity-building measures from institution, legislation, technology, education, finance, and safeguards have been made and put into implementation.

1.4.5 Curitiba, Brazil: Three Decades of Thoughtful City Planning

The city of Curitiba successfully demonstrates to the world on how to move toward sustainable systems by means of thoughtful city planning integrating sustainable transport considerations into business development, road infrastructure development, and local community development. In order to fulfill the goals of the master plan in providing access for all citizens, the main transport arteries were modified over time to give public transport the highest priority. Separating traffic types and establishing exclusive bus lanes on the city's predominant arteries helped to mold two defining characteristics of the city's transport system: a safe, reliable, and efficient bus service operating without the hazards and delays inherent to mixed-traffic bus service; and densification of development along the bus routes. Curitiba's busses carry 50 times more passengers than they did 20 years ago, but people spend only about 10 % of their yearly income on transport. As a result, despite the second highest per capita car ownership rate in Brazil (one car for every three people), Curitiba's gasoline use per capita is 30 % below that of eight comparable Brazilian cities. Other results include negligible emission levels, little congestion, and an extremely pleasant living environment. Curitiba boasts over 580 square feet of green space per inhabitant.

1.4.6 Other Green City Initiatives

Reykjavik, Iceland Reykjavik has been putting hydrogen busses on its streets, and, like the rest of the country, its heat and electricity come entirely from renewable geothermal and hydropower sources, and it is determined to become fossil-fuel-free by 2050.

Malmö, Sweden Known for its extensive parks and green space, Sweden's third largest city is a model of sustainable urban development. With the goal of making it to eco-city, several neighborhoods have already been transformed using innovative designs and are planning to become more socially, environmentally, and economically responsive.

London, England Under its Climate Change Action Plan, London will switch 25 % of its power to locally generated and more efficient sources, cut CO_2 emissions by 60 % within the next 20 years, and offer incentives to residents who improve the energy efficiency of their homes. The city has also set stiff taxes on personal transportation to limit congestion in the central city, hitting SUVs heavily and letting electric vehicles and hybrids off scot-free.

San Francisco, California, USA Nearly half the population takes public transit, walk, or bike each day, and over 17 % of the city is devoted to parks and green space. San Francisco has also been a leader in green building, with more than 70 projects registered under the US Green Building Council's LEED certification system. In 2001, San Francisco voters approved a $100 million bond initiative to finance solar panels, energy efficiency, and wind turbines for public facilities. The city has also banned nonrecyclable plastic bags and plastic kids' toys laced with questionable chemicals.

Bahía de Caráquez, Ecuador After it suffered severe damage from natural disasters in the late 1990s, the Bahía de Caráquez government and nongovernmental organizations working in the area forged a plan to rebuild the city to be more sustainable. Declared an "Ecological City" in 1999, it has since developed programs to protect biodiversity, revegetate denuded areas, and control erosion. The city, which is marketing itself as a destination for eco-tourists, has also begun composting organic waste from public markets and households and supporting organic agriculture and aquaculture.

Bogotá, Colombia Enrique Peñalosa, mayor from 1998 to 2001, used his time in office to create a highly efficient bus transit system, reconstruct sidewalks so that pedestrians could get around safely, build more than 180 miles of bike trails, and revitalize 1,200 city green spaces. He restricted car use on city streets during rush hour, cutting peak-hour traffic 40 %, and raised the gas tax. The city also started an annual "car-free day," and aims to eliminate personal car use during rush hour completely by 2015 (Wright 2001).

Kampala, Uganda This capital city is overcoming the challenges faced by many urban areas in developing countries. Originally built on seven hills, Kampala takes pride in its lush surroundings, but it is also plagued by big city ills of poverty and pollution. Faced with the "problem" of residents farming within city limits, the city passed a set of bylaws supporting urban agriculture that revolutionized not only the local food system but also the national one, inspiring the Ugandan government to adopt an urban–agriculture policy of its own. With plans to remove commuter taxis from the streets, establish a traffic congestion fee, and introduce a comprehensive bus service, Kampala is on its way to becoming a cleaner, safer, more sustainable place to live.

Eco-Towns in Japan Eco-town concepts originally focused on the individual systems related to 3R have now expanded to include eco-industrial parks and industrial symbiosis to focus on collective area within the urban setup. In addition to 3R (reduce, reuse, and recycle), eco-town concepts also involve green procurement, green consumerism, industrial ecology, extended producer responsibility, socially responsible investment, integrated waste management, green labeling, global reporting initiative, corporate social responsibility, EMS, and ISO 14001. In a nutshell, eco-town is a defined area where various eco-concepts can be developed and implemented. In Japan, eco-cities are originated through subsidies from various ministries such as Ministry of Economic, Trade and Industry (METI) and Ministry of Environment (MoE). Japan has one of the widest networks of eco-towns with strong legislation supporting the development of eco-towns. By March 2005, 23 cities were approved as eco-towns in Japan and received subsidies (GEC 2005). Eco-town projects in Japan include – Kawasaki, Kitakyushu, Iida, Oomuta, Sapporo, Chiba, Akita Prefecture, Uguisuzawa, Hokkaido, Hiroshima Prefecture, Kochi, Minamata, Yamaguchi Prefecture, Naoshima, Toyama, Aomori Prefecture, Hyogo Prefecture, Tokyo, Okayama Prefecture, Kamaishi town, Aichi Prefecture, and Suzuka. Eco-towns apply enterprise approach in achieving the optimal system of resources utilization with industrial cluster forming the core. It mostly concentrates on both sides of sustainable production as well as sustainable consumption by means of 3R principles and people participation.

1.5 Sustainability of Cities in Asia: A Review

Asia and the Pacific as a region is characterized by surging population, increasing urbanization and the proportionately increasing share of slum (informal settlements) population, increasing size of cities and so the travel distances and time, higher income disparities (as expressed by GINI coefficient), higher GDP growth rates, increasing travel activity with disproportionate development of infrastructure, excessive reliance on personalized cars resulting in huge green house gas emissions, increasing production with considerably inferior technologies, excessive utilization of resources with very least to almost no recycling, and, most importantly, lack of strong legislation at local level to handle various environmental and resources-related issue coexisting with lack of awareness among public and other key stakeholders (Imura et al. 2005). Providing basic civic and environmental services to growing urban agglomerations in the region presents a major challenge to the local policy makers, particularly in the case of informal human settlements. Lack of capacity to implement potential financial mechanisms such as PPP furthers the complexity of the situation (IGES 2005).

According to the forecast, the proportion of urban population would be more than 50 % in the next two decades. Due to this process, huge areas of former agricultural and natural land are being converted to build up areas and traffic ways. Share of area for industrial use would go up, and this additional requirement of land for industry may force them to the periphery of the cities giving rise to peri-urban areas. Peri-urban areas are the most vulnerable and fragile urban systems. To solve the current and upcoming ecological problems of the region's urbanization in their huge dimensions and complexity, single measures and scattered strategies on environmental protection are not sufficient. The transformation of the cities into eco-cities by a holistic approach is the need of the hour.

Along with the basic tenets of eco-city development as explained in the previous sections, following issues need attention while attempting to develop eco-cities in Asia and the Pacific:

From the discussion in the previous sections on sustainability concepts, it is clear that in order to achieve sustainable cities, one has to integrate the operation of its subsystems, viz., economic, environment, and social. Further, the individual attributes of these three legs forming a sustainability triangle determine the boundary of sustainability of the system. For instance, Moomaw (1996), using the same concept of sustainability, considered culture, economy, and environment as three corners of the sustainability triangle that enclose well-being, making it the central goal. This well-being could also be seen as a particular principle of social subsystem. While one considers economy, environment, and community as three corners with health as a central theme, sustainability could be an overlapping subset of environment and economy subsets. Therefore, it is essential to define the individual attributes of the subsystems of the sustainability triangle to reach the "desired dimension" of sustainability in Asia and the Pacific.

Asia and the Pacific as a region have a significant presence of peri-urban fringe areas. Development of eco-cities needs to internalize these fringe areas in order for it to be inclusive.

Poor systemic efficiency in civic services, low-end technology, and negligible recycling in production process present considerable scope for the implementation of *eco-efficiency* principles. A major share of the resources is wasted in the process of producing food, machines, vehicles, and infrastructure. It was reported that factor ten efficiency in the resource use needs to be targeted. Otherwise, a scarcity of resources would eventually lead to increase in the costs of production resulting from higher commodity prices. Eco-efficiency is often expressed as the creation of more value with fewer resources and less impact (UNESCAP 2006a).

Transportation system is highly inefficient in most of the Asian developing countries. Expansion of cities without proper city planning only adds to this problem. It gets more complex with the presence of slum population who are vulnerable to certain social implications of such unplanned system. Hence, improvements in travel behavior and traffic patterns need to get attention.

Many countries in this region suffer from poor governance and social inclusiveness. These two aspects play an important role in achieving eco-city development and hence need to be focused. Transparency and good governance along with multistakeholder participation are reported to be the success elements in various eco-town and eco-city initiatives around the world. With the presence of sections of varying social status, such social inclusiveness plays the key for successful development of eco-cities in Asia and the Pacific.

Change in individual consumption patterns is necessary by means of promoting environmental consciousness and 3R principles. Due to the presence of informal settlements, peri-urban fringe areas, and scattered industrial clusters, it is necessary to attempt eco-town development and make it a part of larger plan of eco-city development. With the vast nature of social strata and conditions, it may prove too complex to attempt a holistic execution. It is better to plan big and implement in parts. At the same time, piecemeal approach as it appears to be the case in many countries would not result in eco-living in urban agglomeration in this region.

Achieving eco-efficiency in industries plays a crucial role and development of eco-industrial parks, and promotion of industrial symbiosis plays an important role. Eco-industrial networking would help in making an eco-friendly production process. The decline of traditional industries and the dramatic change in industrial production patterns and global networking in the last two decades have opened new opportunities for ecological production. Clean production and ecological industry are key elements in comprehensive development toward an eco-city. In traditional economy, industry is mainly an exchangeable consumer of resources and a producer of products, which have not much to do with the city or region. In the economy of an eco-city, industry is interlinked with other industries and the location and is integrated in local and regional context which helps achieving eco-efficiency.

Promotion of cleaner production and eco-industry is appropriate measure to solve problems in the existing conglomerations in the region without total redevelopment and also to organize new eco-industrial parks with a well-balanced proximity of residential, working place, and other urban activities like shopping, education, recreation – avoiding the long commuter distances. They would also help integrate production, consumption in a comprehensive ecological-based economy. Developing eco-industrial projects needs time and a phase of orientation. Just like other high-tech development, particular setbacks cannot be completely avoided, and one has to work with a long-term perspective. Universally, the expectations of the authorities, entrepreneurs, planners, and public media in a rapid industrial and eco-industrial development are always higher. In Asia and the Pacific, with bigger challenges hanging over the heads, the temptation is high to trade long-term sustainable solutions for short-term results. The development of eco-city might take a little more time than conventional, resource-wasting urban development, but it will reward with sustainability. Eco-city and eco-industry development needs a strong, long-standing driving force, and a firm commitment for ecological living.

Ecological security is especially urgent for poor peri-urban areas in developing countries. Ecological security covers not only the tangible impacts on human health but also intangible or long-term impacts on human health and city's sustainability.

1.6 Policy Measures and Instruments for Promoting Ecological Efficiency of Cities

Development of eco-cities needs a systems approach where administration, eco-efficient industry, people's needs, culture, and eco-landscape are integrated. This implies a functional integration of these aspects which are presented as three segments, viz., "eco-industry," "eco-landscape," and "eco-culture." While eco-industry segment focuses on achieving resources conservation through industrial transformation and circular economy concepts, eco-landscape and eco-culture focuses on built environment and cultural aspects and consumption patterns, respectively (Juergen and Rusong 2005). Working toward eco-culture aspect is the most difficult part of developing eco-city. It needs both scientific and administrative motivation to change lifestyles and improve ecological consciousness. Promoting eco-city development needs a wide range of policy measures/strategies categorized into administrative, management, technological, and legislative.

Linan et al. (2004) have outlined a set of strategies to promote eco-city development. Such strategies include enhancing people's ecological consciousness and advocate and publicize ecological concept, drawing up of action plan to make the city development ecologically friendly, strengthening legislation for ecological society, establishing functional organizations that suit urban ecological development, developing and applying ecological technologies, and stressing on the inter-urban and interregional cooperation.

One of the important requirements for eco-city development is to "*internalize ecological principles*" in policy making and planning of city development. Ecology-centered strategies have to be made for cities, and priority development areas have to be designated. City of Curitiba in Brazil is one of those cities demonstrated on how to integrate ecological principles into urban planning and the corresponding benefits (ICLEI 1991, 1995). Movement toward eco-friendliness is at a very slow rate, and hence cities may have to develop a series of strategies to stimulate faster adaptation of ecological development. According to WBCSD, establishing framework conditions that foster innovation and transparency and that allow sharing of responsibility among stakeholders will amplify eco-efficiency for the entire economy and deliver progress toward sustainability (UNESCAP 2006a). Eco-planning of cities needs demonstration. In such an effort, China has initiated a movement for ecological demonstration districts involving the state environmental protection administration, research institutes, and local communities. The city of Dafeng in Jiangsu Province in China has started implementing eco-city strategy in 1986, and within 10 years time, its GDP has increased by 80 times while environmental quality remained at the same level of 1986. Such demonstration of eco-planning had resulted in greater dividends over long run with 82 cities and counties designated as "Ecological Demonstration Districts" by Chinese Government which implements eco-city planning strategies (Wang and Ye 2004). However, such demonstrations could have a negative effect as cities, by simply adopting the guidelines provided to them based on demonstration of pilots which may fail to achieve optimal solutions as their local conditions differ from the demonstration pilots. For the successful eco-city development, adaptation to local conditions holds the key. Therefore, to find a suitable path to sustainability of any particular city, local governments need to work with scientists to analyze current conditions and to adapt both domestic and international experiences to local conditions. City mayors and governors play a critical role in achieving such a development as demonstrated in the cities of Bogotá in Columbia and Curitiba in Brazil (ICLEI 1991; TCRP 2002).

However, eco-city planning suffers from serious lack of methodologies. Therefore, research needs to focus more on applying the methods and tools of industrial ecology to eco-city planning and methods of design for environment and to the design of eco-industrial parks (Lowe 2002).

Based on such demonstration pilots projects and research activities, it is possible to develop a set of indicators for the development of eco-town and eco-city. Such indicators classified as economic development indicators, environmental protection indicators, and social progress indicators (Wang and Ye 2004) can be used while devising an evaluation-based campaign such as sustainable development award or eco-city development award. Such approach was adopted by the National Eco-city Network in Japan to choose the winner of Japan's Eco-City contest where a questionnaire with 15 evaluation items and 80 questions was used to assess the degree of ecological efficiency attained in a city (municipality) (JSDN 2007).

Adaptation of ecological developmental plans for cities needs to be supported by law. Any action that is inconsistent with eco-development should be restricted by administrative and/or economic means, so that the plan will be implemented smoothly. Governments both at city and national level can stimulate progress of eco-city development by enacting legislative, financial, and technical measures to create the right incentives for innovation and changes in performance (UNESCAP 2006a).

By creating government agencies at all levels of city, regional, and national, a better execution of eco-policies can be achieved. These agencies will coordinate and monitor functions in different sectors, supervise implementation of eco-city strategy, and facilitate projects and plans.

Eco-city development needs strong participation from the private sector/business community, and hence the government needs to provide the business community with strong economic incentives and regulatory facilitation to build eco-cities. The government has to adapt such policies that encourage investment in eco-city development.

Eco-city development is an integrated and extremely complex network of activities. Policy making and administering them has to be based on consultative and coordination process. Key to achieve such a development is to have an institution spanning different administrative departments. It helps in effectively organizing, coordinating, and supervising the implementation of urban eco-development. Such institutions can as well help effectively publicize the eco-city development.

Eco-development process, unlike traditional development process where the developmental planning and implementation remain specific to the domain of application, interacts with various segments within and outside the city administrative boundaries. Therefore, it is essential to have strong intracity, intercity, and interregional cooperation to achieve eco-development. Such cooperation should be based on symbiotic principles and multi-stakeholder partnerships.

While cities make their efforts toward achieving eco-efficiency, national governments have to make a set of policies guiding the recourses utilization and environmental conservation. Most of the countries in this region have developed their national environmental policies/plans (extracted from multiple sources). However, they are all in most case centered on conventional environmental protection and resources conservation based on single R (recycle) principles. Having experienced mass production, mass consumption, and mass disposal, Japan and China have enacted various policies toward the development of circular economy based on 3R (reduce, reuse, and recycle) principles (MITI, Japan; Yong 2005). Though eco-town concepts are being considered, they are still at demonstration stages. Along with national environmental plans/strategies, various countries have varying degree of national legislation protecting various domains of environment, viz., water, air, and soils. However, no significant act/legislation was enacted for resources conservation and also to increase the recourses utilization efficiency. For the cities to implement the eco-efficiency in their development pathways, it is essential to have an integrated framework sufficiently backed up by national policies.

Eco-culture segment of eco-city development process is most important and complex. First step toward that is to make the public and decision makers aware of the benefits of eco-city. This helps decision makers change their ideas, attitudes, and behavior. Ecological consciousness is an essential element to realize eco-city development. At present, the eco-city development initiatives suffer from lack of awareness and public participation. Overcoming this barrier needs adequate education and training programs, capacity building and local skill development (Eco-city 2002). For such capacity development, multi-stakeholder partnership holds the key.

With cities focusing on growth and providing services to the ever growing populations, ecological balance often takes backseat. Due to lack of awareness of the benefits of ecological approaches and also lack of motivation, high-end city administration fails to place priority on environmental friendly growth of cities (green growth). A study conducted by UNESCAP had revealed that lack of political will is one of the major barriers for sustainable urban development. Active participation of high-end city administration such as mayors and governors plays a significant role in motivating the entire administration. In Curitiba, for instance, the mayor, Jaime Lerner, an architect and urban planner by background, was the main driver behind the social, ecological, and urban reforms that have made it a model city. Role of a champion and champion organization in implementing environmental friendly policies is well known, and there exists numerous examples around the world such as Bogotá, Curitiba, decentralized composting in Dhaka (ICLEI 1991; IGES 2007; TCRP 2002; Yedla 2007). Therefore, motivating such decision makers would be crucial in the development of eco-cities. One of the possible ways to motivate them is by establishing a regional award given away by a high-profile organization. Unlike research funds or infrastructure grants, this would provide high visibility which counts significantly for politicians and the leaders such as mayors and governors. This could even be a low-cost approach as their trickling down effect on successful implementation of eco-city would be significant.

Any effort to make cities sustainable should involve a matrix of policies aiming at addressing all the elements of eco-efficiency as described in previous sections (Yedla 2008).

This book attempts to address the sustainability issues of cities in the five-element ecological efficiency framework as presented above. Chapters 2, 3, and 4 addressed the issue of eco-production in cities. While the second and third chapters explain the principles of eco-industrial parks and their application and implementation in two contracting cities – Ulsan in South Korea and Chittagong in Bangladesh, the fourth chapter explains the concept of exclusive economic zoning in India cities and its practical application and the implications.

The ecologically efficient landscaping aiming mainly at transportation and mobility of people is addressed by Chaps. 5, 6, and 7. While there are issues at macro-level bothering the philosophical threads of urban transportation, the micro-level issues of rubbing efficiency to the mobility needs and means to improve "people's ability to move" are of equal importance in achieving ecologically efficient mobility. While fifth chapter presents the scenario of urban mobility in India and prescribes a few policies toward their improvement, Chap. 6 takes up the important issues and challenges at macro-level planning of city's mobility. Chapter 7 brings out the challenges that nonmotorized mode traveler face in India cities and prescribes possible ways to improve their ability to move "effectively" and "safely." Nonmotorized modes contribute more than 50 % of work trip and much larger the number for urban poor. Hence, promoting this environmental, resources, and people friendliness holds the key for making the urban mobility sustainable.

The cities need to have ecologically secured services made available to them. In order to fulfill this important requirement, the cities need to have improved resilience for natural as well as climate change-induced catastrophic events and vulnerabilities. Energy access plays another important element in making the cities more secured. Chapters 8 and 9 address these important issues of eco-security.

Cities with vulnerability to various imposing situations can be further crippled with poor sanitation and waste management systems. While inefficient management of municipal solid waste (garbage) can cause tremendous damage to the city's ability to handle excess precipitation (such as cloud bursts), the mismanaged corporate waste (E-waste) can cause significant social damage and resources depletion. Chapters 10 and 11 explain the issue of waste management, their present situation, and the way forward in order to achieve ecologically efficient ways of managing these important services. Chapter 12 presents the important dimension of air pollution in Indian metropolitan cities with a specific study on Kolkata.

Provision of infrastructure holds the key for all the components of ecological efficiency in cities. Non-inclusive designs of infrastructure can lock cities into unsustainable consumption patterns for the next couple of decades. Therefore, it is important to green the infrastructure and find more meaningful and inclusive means of financing the same. Chapters 13 and 14 present such efforts made by a number of India cities. With its comprehensive coverage of issues, this book is an attempt to promote sustainability in cities by bringing the issues to the fore and develop a matrix of policy measures toward their sustainability.

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Chapter 2
Role of Eco-production in Managing Energy and Environmental Sustainability in Cities: A Lesson from Ulsan Metropolis, South Korea

Hung-Suck Park and Shishir Kumar Behera

Abstract Currently, 1.6 billion people or 40 % of Asians live in cities and urban areas that generate a total GDP of 80 %. As the cities consume enormous amount of resources and energy, they eventually result in massive environmental pollution. A total of 15 industrial complexes in Ulsan city (the industrial capital of Korea) consume 85 % of the total energy and other resources producing 20 % of the total national export. Thus, efficient use of energy and resources in industrial park is essential to maintain economic and environmental sustainability in Ulsan. In this context, the Ulsan Eco-industrial Park (EIP) initiative plays a vital role in eco-productions that reduce impact on the environment through optimized utilization of energy and resources by establishing symbiotic relationships among industries in a mutually beneficial manner. In this chapter, the role of collective eco-production efforts through national EIP initiative has been demonstrated to manage the economic, environmental, and social sustainability in this industrial city. The viability of industrial symbiosis (IS) networks through the design and implementation of various policy instruments, through the presence of facilitators such as an EIP centers, and through enabling frameworks such as the research and development into business (R&DB) approach for retro-fitting the conventional industrial complexes into EIPs has been demonstrated.

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2.1 Introduction

The city of Ulsan in South Korea is located about 390 km from the southeast end of the capital city of Seoul. It was officially granted the status of a city by the national government in 1962. At that time, about 85,000 residents of the area were mainly depending on agriculture and fisheries for their livelihood and were staying in small villages. On January 27, 1962, Ulsan was designated as a specialized industrial district as part of the government's economic development plan to encourage the development of heavy industry. This original plan was aimed to increase the population of Ulsan to a half million people and establish the city as a regional center for industry and culture. Unfortunately, growth was focused narrowly on improving the economy and establishing heavy industries such as petrochemical, nonferrous metal, shipbuilding, and automotive companies. Little attention was paid to the state of the environment. Large amounts of emissions and pollutants were discharged from industrial complexes, causing damage to agricultural and marine products. As a consequence, seven districts consisting of 7,467 households had to be evacuated, and industries causing pollution were forced to compensate the residents for damages. These events led Ulsan being known nationally and globally as a heavily polluted city.

To address these problems, the government designated the Ulsan Mipo-Onsan industrial complexes as a special air pollution control area in 1986. The industrial complex was required to follow unprecedented strict environmental regulations, forcing companies to invest more in pollution prevention facilities and to organize environmental management plans. Furthermore, the adoption of Local Agenda 21 at the 1992 Rio Earth Summit encouraged better understanding of environmental responsibilities and promoted more sustainable environmental actions among the industries, nongovernment organizations, and citizens of Korea.

Based on the stage model (Yedla and Park 2009) that explains the evolution of environmental problems vis-à-vis economic development, dominant environmental issues of Ulsan city can be classified into poverty-related issues (1960s), production-related issues (1970s–1990s), and consumption-related issues (1990s–present) with respective environmental management strategies. Currently, Ulsan city is in transition to that of an eco-city by transforming industrial manufacturing system by eco-production concept through EIP program (Fig. 2.1).

This chapter describes the eco-production strategy adopted by the Ulsan national industrial complexes through Korean national EIP program. First, the Korean EIP program supported by national environmental policies for promoting circular economy in the country through the reuse of resources and energy and industrial policies for promoting eco-friendly industrial structures in the country is reviewed. Then, we demonstrate the viability of industrial symbiosis networks designed and implemented using policy instruments like national EIP programs, presence of facilitators such as EIP centers, and through enabling frameworks such as the R&DB approach that are observed to be critical factors for retro-fitting the conventional industrial complexes into EIPs.

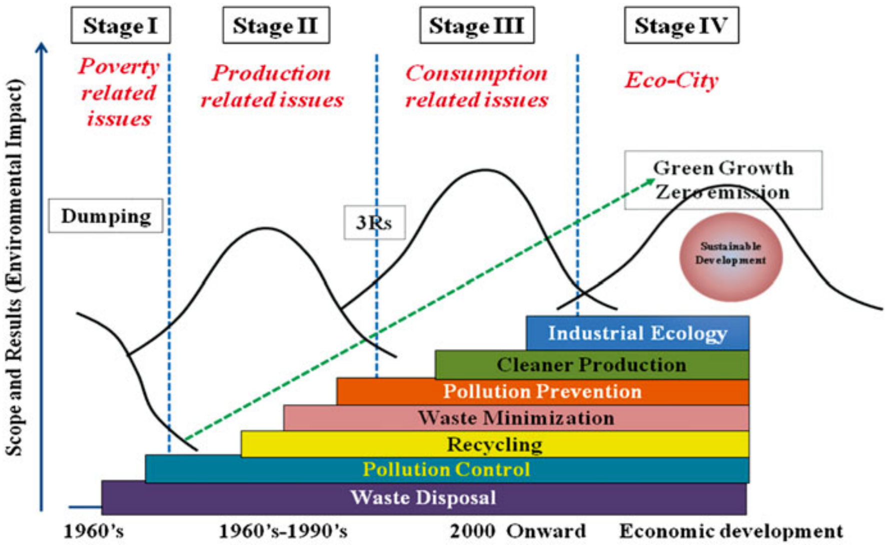

Fig. 2.1 Stage model that explains the evolution of environmental problems and countermeasures vis-à-vis economic development in Ulsan (Modified from Yedla and Park 2009)

2.2 National Policies Supporting EIP and Their Salient Features

2.2.1 Environmental Policies

The policies pertaining to sustainable environmental development focuses on fulfilling the goals of environmental conservation and developing an investment plan to improve the existing environmental infrastructures. The environmental policy entitled "Environmental Vision 21" strives to balance conservation and development within the scope of environmental capacity. The five principles that were proposed to enable their implementation are mentioned as follows: (1) principle of prevention, (2) principle of harmony and integrity, (3) principle of charging polluter and recipient, (4) principle of utilizing economic incentives, and (5) principle of opening information and getting residents involved. Further, this policy strengthened its initiatives in preserving the natural resources by implementing steps that consider the water, air, and soil environment. For the nationwide effective implementation of environmental policies, various reform measures are taken, wherein it is proposed to establish a green gross national product (GNP) and benchmark for sustainability to achieve eco-friendly development through the introduction of an environmental agreement, strengthening the regional environmental management systems (EMS) through standards, and promotion of regional Agenda 21. The updated version of this policy sets the goal as "to maximize the conservation of the natural environment by minimizing consumption of resources and to establish a society of justice that equally guarantees quality of life for all people." The primary objective was to achieve economic stability for better living standards, social maturity that provides equal opportunity, and a healthy environment that conserves the ecological capacity. Technically, the strategies' target in establishing an environmentally sustainable national innovation system fosters a market foundation for environmental industry and environmental science and technology through the rational reform of environmental regulation. A long-term vision named The Third Comprehensive National Environmental Plan was prepared by the Ministry of Environment (MOE) for the years 2006–2015 with four major goals having different strategies. These strategies focus on the following themes: providing safe and quality living conditions, conserving the natural ecosystem, utilizing natural resources effectively, seeking eco-friendly economy, establishing environmental justice, strengthening cooperation with Asian countries, and initiating global sustainable development.

To realize circular economy where resource and energy usage create a virtuous cycle, the MOE focuses on "minimization of landfill waste" while adopting a "waste disposal charging system" based on the market mechanism from 2015. Imposing high waste disposal charges that exceed the recycling costs will result in increased recycling rate and reduced amount of unprocessed waste to be discharged into landfills. Through these measures, MOE expects to realize economic benefits such as reduced dependency on foreign resources while protecting the public from environmental pollution by safely processing hazardous wastes. In fact, countries that have prohibited direct disposal of unprocessed waste and adopted waste disposal charging systems including Germany, Sweden, and the Netherlands visualized their waste landfill rates getting dropped to less than 1 %. Waste landfill rates in Austria and Denmark (that have banned direct disposal and imposed waste disposal charges) stand at 3 %. Thus, the MOE seeks efficient utilization of land and resources by reducing the domestic waste landfill rate from 17 % in 2013 to 5 % in 2017. If the landfill rate is reduced to 5 % by 2017, the accumulated reduction amount will reach 5.48 million ton.

Besides, the resource circulation will be imposed and managed for each sector and industry to increase the usage of recycled or waste resource. In order to implement the aforementioned systems and policies, the "Circular Economy Promotion Law" will be proposed to the National Assembly this year. Contrary to indefinite permit system of pollutant discharging units based on acceptable concentration level (maintained since its introduction in the 1970s), a new permit system will be introduced for the installation of pollutant discharging units that can protect the environment and create jobs. Now, the government plans to shift to a new re-permit system based on the best available technology (BAT). Under the existing permit system, operation of the discharging unit was permitted indefinitely once the acceptable concentration level is met making it difficult to cope with the changing circumstances such as technological advancement or the discovery of a new pollutant. With the introduction of the new permit system, approximately KRW 760 billion (US$ 760 million) worth of investment on discharging facility annually and creation of 13,800 jobs are expected. Meanwhile, by promoting the development of advanced technology and applying these technologies in the field, the Ministry plans to nurture highly competitive industries that drive the nation's exports.

2.2.2 Policies Promoting Eco-friendly Industrial Structures

Considering the dependence of Korean economy on manufacturing industry in the future, the Ministry of Trade, Industry, and Energy (MOTIE) has been concentrating its policy capabilities to expand the development base such as industry supply and demand and the market base (technology, manpower, and deregulation), so as to achieve world class competitiveness. The 2010 Industrial Vision of Korea focuses on strategies to address the salient features that would enable Korea to emerge as one of the four industrial superpowers by 2011. The most striking feature of this policy pertaining to our focus is Chapter 30 of Agenda 21, which states that the involvement and cooperation of business organizations are vital factors in achieving sustainable development. Industrial environmental policy has drastically changed after the MOTIE enacted "Act to Promote Environmental Friendly Industrial Structure (APEFIS)" in December 1995. Based on the APEFIS, the MOTIE established an institutional system for cleaner production (CP) and EMS based on ISO 14001 as an implementing tool. The first comprehensive master plan for environment friendly industrial development was made and operated based on APEFIS. This plan includes streamlining the supporting system, CP transfer and dissemination, promoting environmental industry, and stimulating environmental management. The CP transfer and dissemination deals with technology transfer, international collaborative projects, supply chain environmental management (SCEM), EMS, and EIP. MOTIE revised APEFIS to include EIP (new article 2–7 definition of EIP, 4–2 construction of EIP) in 2005 and to include designation of EIP (new article 4–2) in 2008 to continue the EIP project systematically.

2.2.3 Energy Policies

The Korean government has made significant efforts to regulate energy supply and demand and energy prices. Since Korea has few natural resources, dependence on overseas sources has risen from 87.9 % in 1990 to 96.5 % in 2011. The share of energy imports among total imports also increased from 15.6 % in 1990 to 32.9 % in 2011. The five major industries that contribute to this policy are petroleum, natural gas, electricity, nuclear power, and coal industry. The total energy demand is expected to increase by 3.2 % annually by the end of 2010. This figure is substantially lower than the expected annual economic growth rate of 6 %. There has been a new shift in paradigm in maintaining the existing energy policy guidelines of Korea. The strategies adopted include (1) shifting from government-led to market-driven policy, (2) management of energy demand, and (3) industry energy characteristics. The visions are to follow international environmental regulations, open new ventures with private sectors, reform existing technologies, and block economic globalization.

2.3 Korean EIP Program

2.3.1 Concept of Eco-production, EIP, and Industrial Symbiosis

There exists no universally agreed definition of eco-production. However, in a broader context, eco-production refers to manufacturing of a product which has a significantly lower impact on the environment during its production, use, or disposal and is greener in comparison with other products in the same category or with similar functionality. Eco-production activities are encouraged in EIPs. According to the US President's Council on Sustainable Development definition, "EIP is a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gains in environmental quality, and equitable enhancement of human resources for the business and local community" (Chertow 2007).

By becoming EIPs, the industrial complexes will enable the tenants to become more efficient and to reduce pollution through a variety of strategies. Some of the features that enable greater competitiveness include (Lowe and Koenig 2006):

- Improved intercompany collaboration within the industrial complex and within supply chains enables synergy in environmental protection, community benefits, and competitive bidding.
- Shared services and facilities to lower costs of individual companies, especially small- and medium-scale enterprises, and affordable access to cleaner production training and consultation are strategically important for SMEs.
- Company-to-company exchanges of material, energy, water, and services enhance the efficiency of each unit of input.
- A cluster of resource recovery companies utilizes by-products not absorbed through company exchanges.
- A cluster of environmental technology and service companies supports companies in the complex, especially SMEs, in improving product and process design, avoiding waste generation, and gaining higher efficiency.
- A management unit provides services for resource management, infrastructure, services, and knowledge management to companies, utilities, the local community, and regional networks.
- The management of infrastructure for the complex seeks high performance technologies and management practices in sewage and rainwater treatment, recycling, and recovery technologies, efficient use of fossil fuels, use of renewable energy sources, and efficient transportation and food services.
- Jointly managed emergency prevention, preparedness, and response systems reduce the risks and costs of major incidents and increase the investment security in the complex.
- The EIP provides its services and know-how as center of excellence in all aspects of resource efficiency, serving industry, commerce, and municipalities as a source of innovation on a regional scale.

EIPs have the potential to affect the companies that participate in them, the managers of EIPs, the members of the communities that host them, and the wider community. Thus, to achieve the aforementioned benefits, it is required that all stakeholders responsible for the development of the industrial sector participate, support, and collaborate in the transition of traditional/conventional industrial complexes to EIPs. Membership in an EIP can potentially bring economic benefits to companies by improving their efficiency, reducing their infrastructure requirements, providing access to better information about their customers and suppliers, and reducing their costs for regulatory compliance. More importantly, the EIPs may improve the economic efficiency of member firms by eco-production through improved utilization of energy and resources among the members, taking advantage of economies of scale and scope, improving the flow of information between customers and suppliers in the industrial park.

EIPs have the potential to bring economic and environmental benefits to the communities in which they locate. The EIP can provide a basis for industrial recruitment, bringing new jobs and income to a community. An EIP may lead to the development of industries that add value to the products leaving a community, increasing local income. Finally, an EIP arrangement may improve the competitiveness of existing companies, preventing plant closures and the accompanying job losses. The EIP can also reduce the environmental burden of existing industrial activities and mitigate the environmental impact of new firms. As members of the EIP begin to use each other's by-products in their production activities, they may reduce their production of solid waste. As the EIP reduces the cost of activities such as solvent recycling, EIP companies may generate less hazardous waste. The application of water cascading techniques may reduce pollutant discharges to water and reduce the use of freshwater. The collocation of EIP companies can reduce air emissions from combustion of fossil fuels.

EIPs seek to optimize use of resources through the separate action of their companies, through the interaction between companies exchanging by-products, and finally through integrated resource utilization systems. However, by-product exchange (BPX) is simple to communicate and sometimes offered as the inadequate definition of an EIP. A BPX is a set of companies seeking to utilize each other's by-products (energy, water, and materials) rather than disposing of them as waste. The creation of BPXs has been one of the most frequently attempted strategies that enable companies to gain new revenues from some by-products or at least save the costs of disposal. On the demand side, customers may gain local sources of supplies at reduced costs. Forming a BPX appears to be an easy way for a company to begin practicing efficiency of resource use and to learn other ways to improve environmental performance (Lowe and Koenig 2006).

Thus, in general, EIP is used to indicate formally constituted industrial parks that pursue activities to maximize the resource efficiency. Industrial symbiosis (IS) networks or symbiotic transactions refer to the exchanges in which at least three different entities are involved in exchanging at least two different resources (Chertow 2007) and/or bilateral exchanges including by-product synergy, green twinning and kernels, and utility sharing systems. Industrial symbiosis describes the mutualistic interaction of different industries within a certain industrial cluster for exchange of resources resulting in economic and/or environmental benefits (Chertow 2000). It focuses on improving the resource productivity and eco-efficiency of production and consumption process by transforming the waste of one company into the valuable input of another. Recent literatures depict some practical examples of industrial symbiosis found in Kalundborg, Denmark (Jacobsen 2006), Puerto Rico, USA (Chertow and Lombardi 2005), the Rotterdam Harbour and Industrial Complex, The Netherlands (Baas and Boons 2007), United Kingdom (Mirata 2004), Kwinana and Gladstone, Australia (van Beers et al. 2007), and Guigang, China (Zhu et al. 2007).

As reported from the Kalundborg experience, industrial symbioses are expected to develop spontaneously (Chertow 2000; Jacobsen 2006). Spontaneous networks are driven by the economic advantages offered by the present market conditions and demands, with companies acting on their own behalf (Chertow 2007). Conversely, the existing industrial complexes sometimes evolve toward symbioses when they are motivated by many benefits and environmental policies. In the United States, Canada, Europe, and East Asia, EIPs were also planned in an attempt to put industrial symbiosis into practice during the mid-1990s. A much closer analysis of these cases reveal that, although industrial symbioses tend to develop through the spontaneous action of companies, these systems can be designed and consistently promoted via policy instruments. More recently, several countries in East Asia such as Taiwan (Chao et al. 2010), South Korea (Park et al. 2008), Japan (van Berkel et al. 2009), and China (Shi et al. 2010) are promoting “designed” symbiosis networks in various industrial complexes based on their national EIP demonstration programs.

These benefits can be conceptualized by schematic diagram depicted in Fig. 2.2. Each company obtains resources from both external sources and from the other EIP members. Each company also has two types of waste: waste that is discharged to outside of the EIP and waste that is exchanged with other companies in the EIP. Thus, from the context of EIP, eco-production is a key driver for companies as it can help

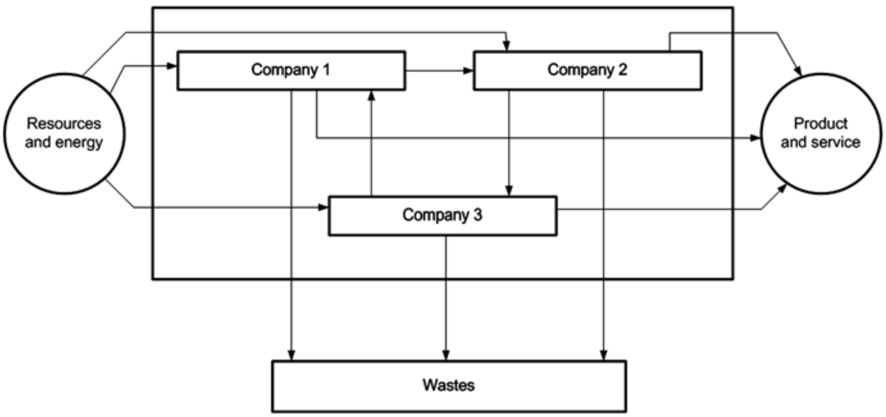

Fig. 2.2 Schematic diagram showing IS among three companies in an EIP (Adapted from Park and Behera 2014)

them to produce better goods and services while using fewer resources and generating less impact, thereby improving both their environmental performance and their bottom line.

The systems' understanding of EIPs indicates that an EIP will achieve profitable return on investment (ROI) while demonstrating an environmentally and socially sound form of industrial real estate development. This model of industrial development will be a major hub for sustainable regional development. To achieve the mission, the creation of IS networks among companies is seen as one of the many strategies that optimize resource consumption and reduce pollution in an industrial park or region. EIP teams benefit from seeing the overall EIP system as one for optimizing all resource flows in an industrial park while reducing all environmental and social impacts.

2.3.2 EIP Project Management in Korea

In 2005, the Korea National Cleaner Production Center (KNCPC) with the support of the Ministry of Trade, Industry, and Energy (MOTIE) started a 15-year, 3-phase project titled, "Eco-industrial Park (EIP): construction for establishing infrastructure of cleaner production in Korea" (Fig. 2.3). Subsequently, in late 2006, the ownership of this project was transferred to Korea Industrial Complex Corporation (KICOX), affiliated to the Ministry of Trade, Industry, and Energy (MOTIE). By becoming EIPs, Korea's industrial complexes will enable resident industries to become more efficient and to reduce pollution through a variety of strategies such as improved intercompany collaboration within the industrial complex and within supply chains, shared services, and facilities to lower costs of individual companies, especially small- and medium-scale enterprises, company-to-company exchanges of material, energy, water, and services, etc.

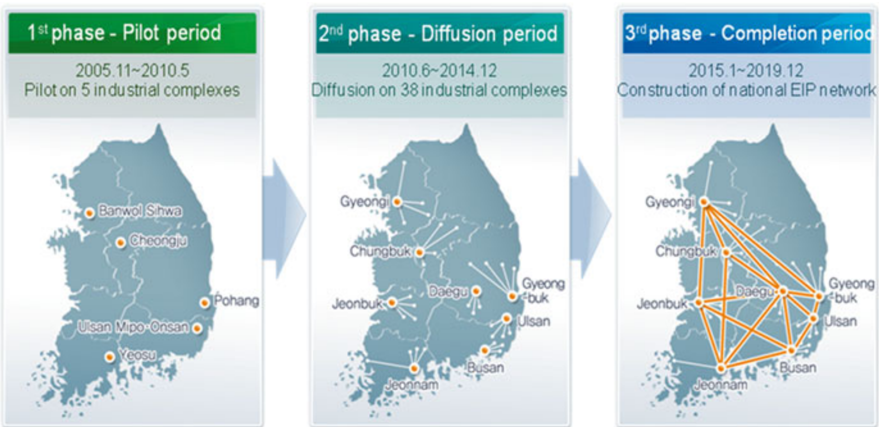

Fig. 2.3 Korean EIP master plan (2005–2019) (Source: KICOX)

To spread the concept of industrial ecology in a variety of industrial complexes, eight regional EIP centers affiliated with KICOX were established in 2012 in South Korea. The first and foremost step in the EIP initiatives is to select the "champion" of the regional center who is capable of bringing people and organizations together and stimulate their participation in establishing lasting, successful applications of industrial ecology. Personal involvement in development of the EIPs and a deep understanding of the local society and culture also contribute to a "champion" being effective in promoting the growth of EIPs. The team for each EIP center was set up under the guidance of a champion, whose role was considered to be highly important in establishing the EIP. The champion was selected by the KICOX, upon the recommendation of the local municipal city government. In general, the champions could be academic experts or company managers who have, over time, demonstrated to possess deep understanding of the local society and culture and have proven track records of industrial innovation.

The salient feature with the EIP project in South Korea lies in the transformation of successful research outcomes into business with a potential to provide triple bottom line benefits. To begin with, the symbiosis projects are submitted to the regional EIP centers where the proposals are screened and sent to KICOX for further evaluation by its assessment committee (Fig. 2.4).

The funding mechanism of EIP project is presented in Fig. 2.5. A maximum of 75 % of the total research budget is supported by the KICOX, and the rest is invested by the project participants (Fig. 2.7). In some special cases, the local city government supports deficits in the funding, on a case-to-case basis, if a particular symbiosis project has a significant local/regional environmental effect, and the participating companies are unable to bear higher costs. On successful commercialization of the

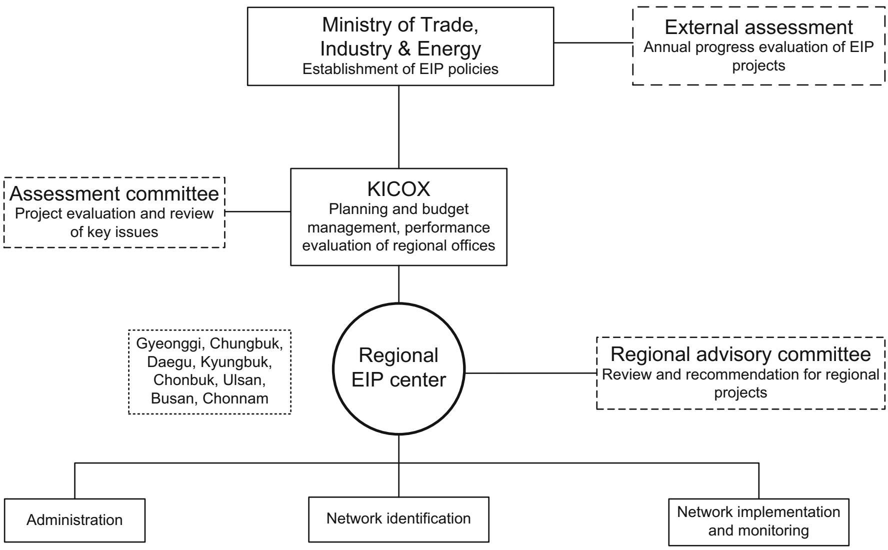

Fig. 2.4 Operation of the EIP projects in Korea (Source: KICOX)

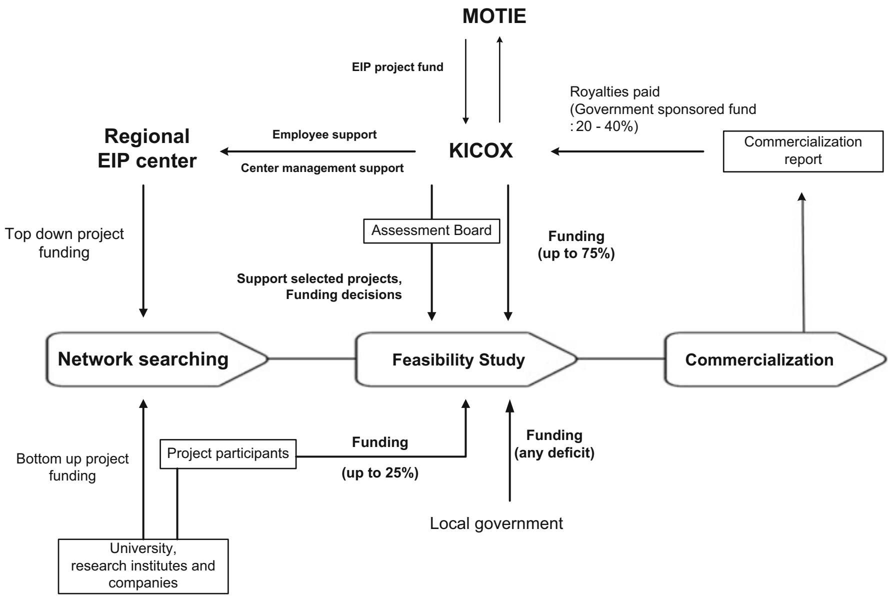

Fig. 2.5 Funding mechanism to support the development of industrial symbiosis networks (Source: KICOX)

project, the companies were to return royalties to the government, which were within 20–40 % of the funds sponsored by the main organization, the KICOX.

2.4 Ulsan EIP Project

2.4.1 Status of Ulsan National Industrial Complexes

Presently, Ulsan is the largest industrial city of South Korea (industrial capital of Korea) consisting of a number of industrial complexes at both national and regional level (Table 2.1). As of 2012, there are two national industrial parks and four agricultural industrial complexes, 17 regional industrial complexes, and one free trade zone in Ulsan. Currently, more than 1,300 companies reside and more than 120,000 people are working in the two national industrial complexes. With very high density of industries and close proximity to the Pacific Ocean, the Ulsan national industrial complexes play an important role in the Korean economy and the local community.

The Ulsan industrial complexes have been continuously evolving from conventional industrial complexes to EIPs, based on sustainable development policies adopted by existing industries (Park et al. 2008).

The detailed features of Ulsan national industrial parks (Ulsan Mipo and Onsan) are mentioned in Tables 2.2 and 2.3.

Table 2.1 Industrial complexes in Ulsan city (As of Dec 2012, KICOX)

Classification	Complex name	Land area (km^2)	Key industries	Remark
National industrial complex	Ulsan Mipo	45,653	Automobile, oil refinery, shipbuilding, petrochemicals	897 moved in
	Onsan	19,765	Nonferrous metal, oil refinery, pulp	325 moved in
Rural, agricultural industrial complex	Dalcheon	262	Assembly metal, electric/electronics	78 moved in
	Sangbuk	139	Auto parts, 1st metal	8 moved in
	Duseo	123	Auto parts, assembly metal	14 moved in
	Dudong	70	Transport equipment	3 moved in
Regional industrial complex	Maegok #1	556	Auto parts, machinery	52 moved in Opened in 2006
	Maegok #2	76	TBD	Under construction
	Maegok #3	158	TBD	Under construction
	Modularized	863	Company for modularized parts	21 moved in Opened in 2008
	New industrial	2,013	IT, new materials	27 moved in Opened in 2011
	Gilcheon	1,266	Mechatronics, machinery	54 moved in Opened in 2008
	High-tech valley	2,928	Semiconductor, electric/electronics	Opened in 2012
	Jungsan #1	128	Machinery, electric/electronics	17 moved in Opened in 2009
	Jungsan #2	349	TBD	Under construction
	KCC Ulsan	1,211	Chemical	3 moved in Opened in 2013
	Waji	124	TBD	1 moved in Opened in 2013
	Jak dong	149	TBD	Under construction
	Jun eup	71	TBD	Under construction
	Hwa san	98	TBD	Under construction
	Banchon	1,378	TBD	Under construction
	Leehwa	697	TBD	Under construction
	Bong ge	254	TBD	Under construction
Free trade zone		1,297	TBD	Under construction

TBD to be decided in a later stage

Table 2.2 Some detailed features of Ulsan national industrial parks (As of Dec 2012, KICOX)

Item		Ulsan Mipo	Onsan
Area	Total (km^2)	45,653	19,765
	Plant (km^2)	37,953	16,814
Number of companies	Move in	897	325
	In operation	803	279
Capacity of water supply (m^3/day)		705,000	340,000
Capacity of wastewater treatment (m^3/day)		250,000	150,000
Production (Billion USD$)[a]		155.1	55.1
Export (Billion USD$)		68.13	26.40
Number of employees		99,435	16,679

[a]US$ = 1,000 Korean Won

Table 2.3 Industrial categories in Ulsan national industrial parks (As of Dec 2012, KICOX)

Category	Ulsan Mipo	Onsan	Total
Food products	8	–	8
Textile products	5	–	5
Wood/papers	16	3	19
Petrochemicals	135	66	201
Nonferrous	31	8	39
Steel	16	21	37
Machinery	231	71	302
Electrical, electronics	99	6	105
Transport equipment	138	67	205
Others	29	6	35
Services	95	31	126
Total	803	279	1,082

In order to be the sustainable industrial capital of Korea, in 2004 “Eco-Polis Ulsan” was declared based on “The Master plan of Eco-Polis Ulsan,” in which the Ulsan EIP pilot project has been added as one of the action plans. The goal of Eco-Polis Ulsan is the harmonious coexistence of industries, environment, and human beings. Support from Ulsan Metropolitan City for sustainable development through the Eco-Polis Ulsan initiative provided good preconditions for the Ulsan EIP transition. Through these initiatives, the city of Ulsan has given top priority to the environment in implementing policies such as urban planning, construction of roads and transportation systems, and establishment of industrial parks. Both the Eco-Polis Ulsan program and the Ulsan EIP initiative share an integrated approach at the city level to applying industrial ecology principles for overall development in the region. The present national policy of pursuing a sustainable industrial strategy can help renovate the traditional industrial parks in Ulsan by applying advanced environmental technology and creating opportunities to introduce industrial symbiotic networking into the large-scale industries along with other medium- and small-scale companies to be city level sustainable eco-production platform.

2.4.2 Role of Ulsan EIP Center

The major goal of Ulsan EIP initiative was to establish Ulsan EIP center and innovate and renovate the Ulsan Mipo-Onsan industrial complexes in order to transform them into EIPs by the systematic implementation of IS. The Ulsan EIP center established in 2007 is affiliated to Korea Industrial Complex Corporation (KICOX) and consists of industry practitioners and academic experts, including representatives of the University of Ulsan. It disseminates its approach by providing guidance and networking to the stakeholders (Park and Won 2007). The key stakeholders in the Ulsan EIP project are Ulsan EIP center, Ulsan Metropolitan City government, companies in the Mipo-Onsan industrial park, and above all, KICOX.

The role of Ulsan EIP center in the three important phases of EIP transition initiative is discussed as follows:

1. *Data collection*: EIP center collects data from all the companies in the Ulsan Mipo-Onsan industrial complexes.
2. S*ymbiosis identification* and *feasibility study*: Based on the processing of data in terms of supply and demand obtained from the companies, possible linkages are identified in the EIP center. Further, the Center for Clean Technology and Resource Recycling in the University of Ulsan extends the research and development support to evaluate the feasibility of any project.
3. *IS Implementation*: This stage involves support to the participating companies to implement the identified linkages. To assist the functioning of the existing synergies, EIP center would act as a front-runner to negotiate with the stakeholders to overcome diverse barriers. In this initiative, the three key factors that are considered to be crucial for the business model development are as follows:

    (1) *Economic factors*: Benefits should overcome the investment.
    (2) *Technical factors*: IS can be achieved with the currently available technology.
    (3) *Institutional factors*: IS activities must be allowed by the existing law.

2.4.3 Industrial Symbiosis Network Strategy in Ulsan EIP Transition

Though IS had already been developed in Ulsan industrial parks on a company-to-company basis, these were unplanned in nature and were not aimed at converting the existing industrial parks to EIPs. The EIP center's effort toward the Ulsan EIP transition has resulted in the establishment of 22 IS networks within a period of 6 years (2006–2012). Based on the experiences and lessons learned from the establishment of two symbiotic networks (1) between Yoosung Company and Hankuk Paper and (2) between Sung-am municipal waste incineration facility and Hyosung Company in Ulsan, the EIP center developed its own site-specific strategy (Fig. 2.6) to transform the existing industrial parks into EIP (Fig. 2.7).

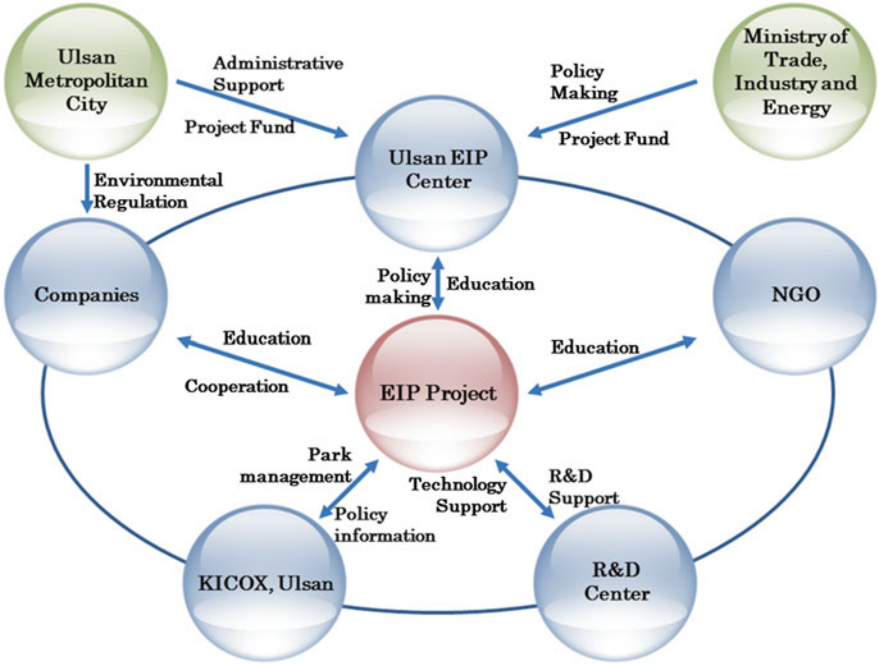

Fig. 2.6 Organizational hierarchy of Ulsan EIP project (Source: KICOX)

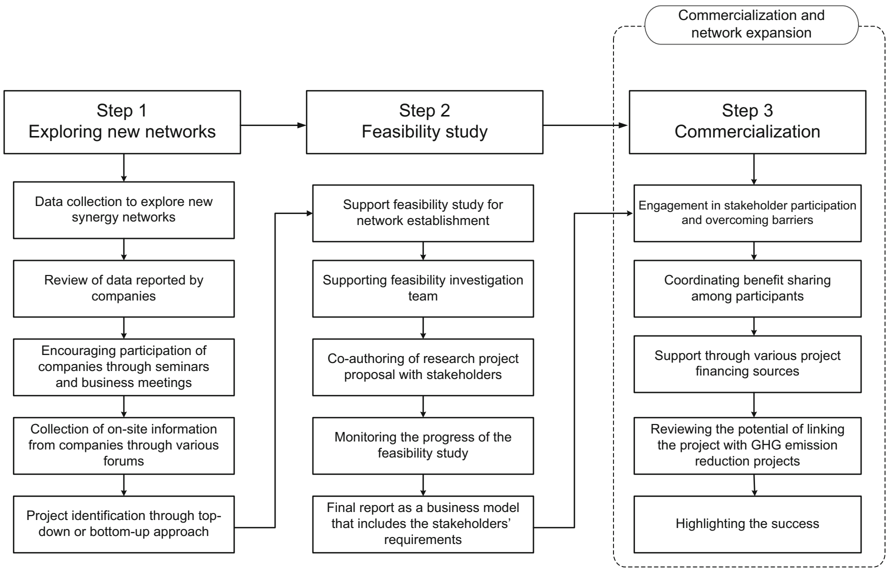

Fig. 2.7 "Research and development into Business" (R&DB) approach tailored for the development of the "designed" industrial symbiosis networks (Source: Adapted from Behera et al. 2012)

In step 1 of the R&DB framework, the potential synergy networks were identified, either by a top-down or bottom-up approach. In a top-down approach, raw data is collected from the local and central government agencies based on the production and waste emission information of the companies. On the other hand, in a bottom-up approach, on-site input and output data of the companies are collected from the company managers by visiting the companies directly and through various synergy forums, such as petrochemical technology forums, organic sludge recycling forums, and waste and by-product recycling forums, new water forums, and EIP innovation forums, with members selected from companies, universities, and city governments.

The partners were subsequently recruited to participate in a potential synergy network, followed by a feasibility investigation (step 2). A feasibility investigation entails an assessment of the potential uses of by-products, an assessment of the techno-economics and environmental feasibilities, and a conceptual design for the particular network type. Upon successful approval of the proposals, the project management agency approaches the regional EIP center to collect the research fund to start the project. Based on the results from feasibility investigation, a convincing business model (the final report of the feasibility investigation) was produced for the implementation of the synergy network. The key elements of the business model are outlined as follows: (1) quantity and quality of resource and energy to be recycled; (2) potential supplier, catalyzer, and recipient; (3) technology to be applied; and (4) basic design including investments and benefits. The business model included all the liabilities, risks, and rights pertaining to the investments and benefits of the stakeholders.

The most important element in the R&DB framework was the commercialization and implementation of the newly identified networks (step 3). The EIP center manages negotiations among the participating companies, overcoming barriers related to finances or any existing laws that may possibly hinder the implementation of the projects. To overcome the financial barriers, the EIP center recommends financial support for the newly developed synergy networks based on their business model. There are diverse financing sources in Korea, both governmental and private, to fund companies that are interested to undertake symbiosis-related projects and activities. Policy funds from the central and local governments can be availed either with a subsidy or at a nominal rate of interest for the projects contributing to water and energy saving and waste recycling. Alternatively, the businesses between the symbiosis partners can also be financed through the private investment business models available in South Korea. The symbiosis networks can also be formed without subsidies if the concerned parties have enough potential to invest in the project. Above all, the companies do not need to bear higher costs in order to participate in the synergy networks. They are attracted by the economic benefits of the projects, which are proportionately shared by the companies based on their investments to the projects. Reduction in long-term environmental impacts is another motivation.

Similarly, to overcome the legal barriers, the feasibility investigation of the projects is usually carried out under the premises of the existing laws. However, in some exceptional cases, the institutional barriers are overcome by coordinating with the local and central governments. For instance, as per the existing South Korean law, public roads cannot be used by any private company for its own benefit. However, based on results of the feasibility investigation for a particular synergy network, the Ulsan EIP center strives to persuade the local government so as to negotiate with the central government, thereby allowing the developed synergy networks to use public roads. In this way, EIP centers help the stakeholders in terms of administrative, regulatory, and financial regulatory assistance information. Social familiarity due to an existing common culture and trust among the stakeholders is considered as the vital parameter that often assists in minimizing the uncertainties or risks of failure. After mutual agreement among the participating companies and the Ulsan EIP center and the signing of the contract, infrastructure design is implemented, and the construction of the facilities signals the beginning of the synergy networks.

2.4.4 Networking Evolution and Some Case Studies in Ulsan National Industrial Parks

All the developed symbiosis networks in Ulsan began with a proposal (through a top-down or bottom-up approach) through feasibility investigation to produce a business model, which attracts the stakeholders to implement the synergy networks through negotiation, contract, and then investment. Due to the emergent characteristics of these symbiosis networks, sharing of benefits is considered to be very important during negotiations.

The Ulsan EIP center has, so far, facilitated and supported a list of 56 synergies that appear most likely to be beneficial on the basis of their expected business and sustainability benefits. Of the total, 22 networks are currently in operation (Fig. 2.8), while 21 are under negotiation and/or at the design stage and 13 are under feasibility investigations. A brief description of 13 important networks in operation is given below.

1. *Industrial waste incineration plant supplying steam to a paper mill*
   The incinerators in Yoosung Corp. incinerate about 95 ton/day of industrial waste. Before the development of symbiosis, the heat generated due to the incineration of industrial waste was not utilized for any beneficial purposes. However, steam is presently being generated via this waste heat and is supplied to a nearby paper mill (Hankuk Paper). Steam, in the amount of 23.5 ton/h, is generated through the incineration of 80 ton/day of industrial waste, of which 12 ton/h is supplied to the paper mill. Before the development of synergy, the paper mill was using 343.63 lit/h of B – C oil to generate 10 ton/h of steam.
2. *Municipal solid waste incineration plant supplying steam to a TPA manufacturing company*
   The Sung-am municipal waste incineration facility (MWIF) has two incinerators, each with an incineration capacity of 115,000 ton/year. Forty-five ton/h of steam (pressure: 16 kgf/cm^2) was produced by utilizing the heat generated as a result of incineration of municipal solid waste (300 ton/day). Out of 45 ton/h of steam, 23 ton/h was utilized to generate electricity (1,500 kWh), 11 ton/h was utilized to make hot water, and the rest was condensed to water. However, after

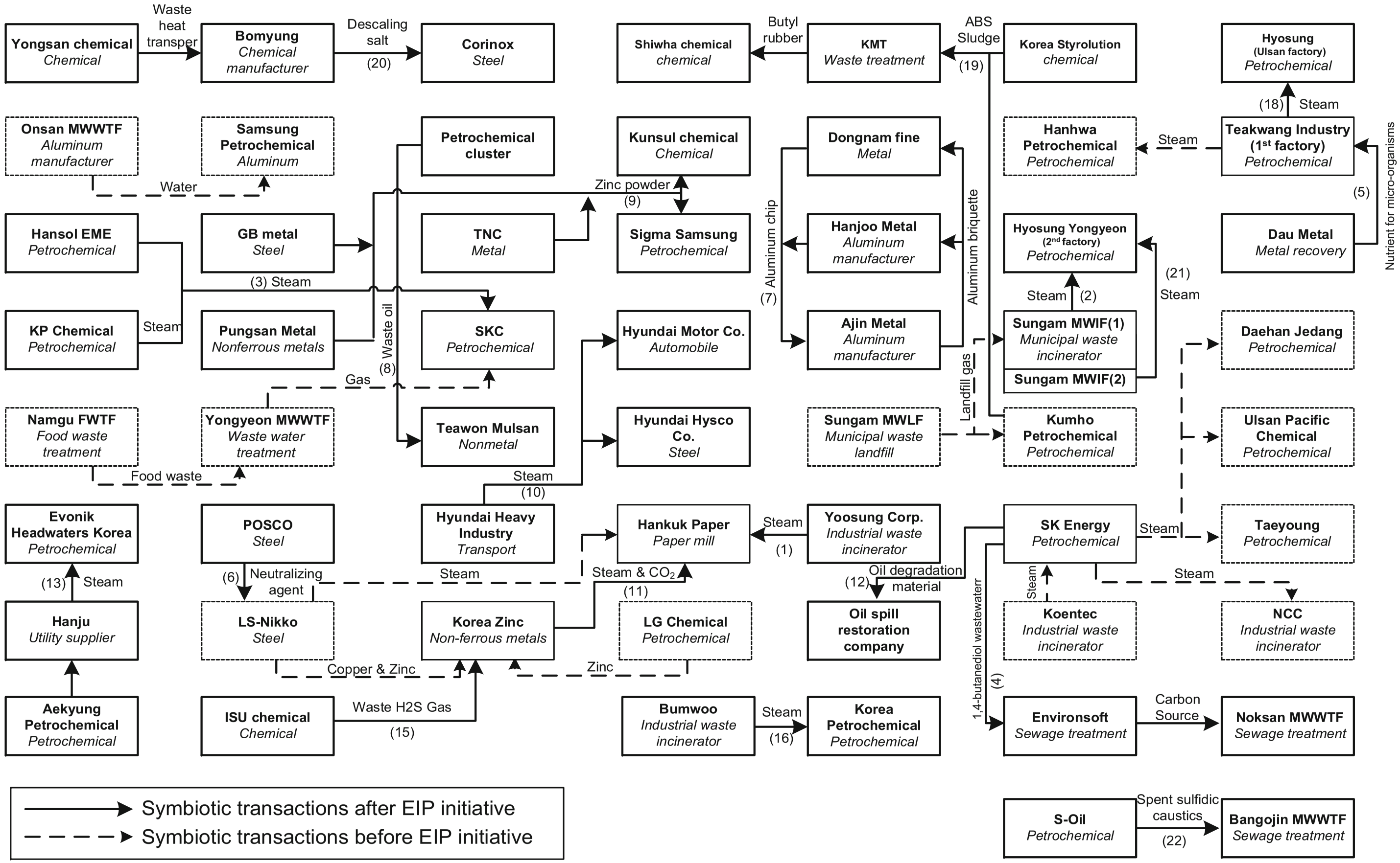

Fig. 2.8 Symbioses existing in Ulsan EIP (*dashed-lined* and *solid-lined boxes* refer to companies involved in symbioses before and after EIP initiative, respectively), *numbers within bracket* along the *arrows* indicate the analyzed networks, *MWWTF* municipal wastewater treatment facility, *FWTF* food waste treatment facility, *MWLF* municipal waste landfill facility

the development of synergy, 30 ton/h of steam is supplied to a terephthalic acid (TPA) manufacturing company (Hyosung Yongyeon), and the rest 15 ton/h is used by the MWIF to meet its own requirement. Before the development of synergy, the TPA manufacturing company was consuming 67 lit/h of B – C oil to generate 7 ton/h of steam.

3. *Steam swap network among four companies*
   This network deals with the allocation of steam among four participating companies: KP Chemical, Korea PTG, Hansol EME, and SKC. KP Chemical produces low pressure steam (5 kgf/cm^2), and Hansol EME produces medium pressure steam (10 kgf/cm^2). Korea PTG (not shown in Fig. 2.5) receives steam from KP Chemical and Hansol EME and supplies 30 ton/h of high pressure steam (45 kgf/cm^2) to SKC. As a result, SKC reduced the coal consumption needed to run the boiler for its steam requirement, thus minimizing the adverse effects of environmental pollution. Korea PTG benefited economically by receiving low and medium pressure steam at a much cheaper price and selling high pressure steam at higher prices. Thus, this process of steam swap resulted in both economic and environmental benefits without reducing the high pressure steam at Korea PTG to low and medium pressure steam, respectively.
4. *Organic waste from 1,4-BDO process used as carbon source for denitrification in a municipal wastewater treatment plant (MWWTP)*
   Organic waste from a 1,4-butanediol (raw material for polyurethane, alkyd resin, and plastic) process in SK Energy was detoxified by removing a total of 99 % formaldehyde. This waste (16.8 ton/day) was then supplied to Noksan MWWTP to be used as an alternative low cost carbon source for nitrogen removal. Prior to the development of this synergy, the MWWTP was consuming methanol as a carbon source at an average rate of 7.92 ton/day. As a result, SK Energy established a sustainable solution to manage this organic waste, with disposal cost savings of approximately three million US$/year. Similarly, the MWWTP, which formerly used methanol as the external carbon source, had a cost savings of 0.7 million US$/year by purchasing the low cost carbon source.
5. *Conversion of high strength ammonia containing industrial wastewater to a nutrient for microorganisms*
   Ammonia was recovered from high strength industrial wastewater (generated in Dau Metal) and then converted it into a nutrient (ammonium phosphate), while maintaining the effluent nitrogen concentration within permissible discharge levels (<60 mg/L and <100 mg/L in water and air, respectively). This nutrient (30 ton/day) was utilized by the microbes during wastewater treatment in Taekwang Industry.
6. *Steel plant supplying neutralizing agent to a nonferrous metal alloy industry*
   Acidic wastewater discharged from the smelting process of a nonferrous metal alloy industry (LS-Nikko) was usually neutralized by $Ca(OH)_2$, and the waste gypsum produced was then disposed off in a nearby landfill. However, a modification of the process replaced $Ca(OH)_2$ with CaO and MgO (received from POSCO steel), resulting in the reduction of waste gypsum by 35 %, which will eventually save landfill space. Simultaneously, the resulting by-product

($MgSO_4$) can be used as a filler material in paper mills or in the preparation of pharmaceuticals, such as anticonvulsants.

7. *Reuse of waste aluminum chips as virgin raw material*
Aluminum chips generated from Dongnam Fine and Hanjoo Metal are efficiently recycled at Ajin Metal using a high performance compression molding machine and are presently being reused as high-density aluminum briquettes.
8. *Recycling of waste oil through a network employing an emulsified fuel oil (EFO) process*
EFO with a calorific value higher than 8,000 kcal/kg is produced from waste oil generated from industries such as petrochemical and chemical plants and automobile and shipbuilding companies in the Ulsan industrial complexes. As a substitute for petroleum oil or coke, the EFO (15,150 ton/year) is supplied to Taewon Mulsan (manufactures refined phosphate gypsum and supplies to cement factories) for its use in the kiln firing operation.
9. *Production of value-added zinc flakes from zinc dust*
Zinc powder (558 ton/year) (in the form of flake, dross, and ash) was collected from Pungsan Metal, GB Metal, and TNC and processed after which it was supplied to Kunsul Chemical and Sigma Samsung for the production of zinc-rich paints. A total of 1,676 ton/year of zinc waste was produced prior to the development of this symbiotic network, of which about 60 % (1,000 ton/year) is utilized for the production of zinc-rich paints. The use of flakes (instead of zinc powder or dust), after appropriate drying and curing, allows the formation of a dense coating that greatly improves the protective performance of the paints.
10. *Incineration facility in a heavy industry supplying steam to other companies*
The incineration facility in Hyundai heavy industry generates 27 ton/h of steam, out of which 20 ton/h is supplied to Hyundai Motor and Hyundai Hysco where liquefied natural gas was previously used to generate steam.
11. *Steam and carbon dioxide network between a zinc smelter and a paper mill*
This symbiotic transaction has been established between a zinc smelter (Korea Zinc) and a paper mill (Hankuk Paper). Hankuk Paper is supplied with steam (70 ton/h) and CO_2 (8 ton/h) from the cogeneration plant of Korea Zinc. The paper mill produces precipitated $CaCO_3$ more efficiently by utilizing the exhaust gas containing high concentration CO_2 received from Korea Zinc (that uses bituminous coal as the fuel).
12. *Recycling of waste activated sludge to be used as oil degradation material*
Waste activated sludge (200 ton/year) generated from an oil refinery (SK Energy), which was previously disposed either through incineration or by ocean dumping, is recycled to produce a biological agent (oil degradation material) that can be used for remediation of oil-contaminated soils.
13. *Steam network between a petrochemical company and a chemical manufacturing company*
The process heat generated at the Aekyung Petrochemical Company is utilized to produce steam and is then supplied to Evonik Headwaters Korea (H_2O_2 manufacturer) via a utility provider in the petrochemical cluster (Hanju Company,

not shown in Fig. 2.5). Before the establishment of a network between the Aekyung Petrochemical Company and Evonik Headwaters Korea, Hanju was supplying steam to Evonik Headwaters Korea. However, due to the supply of steam (15 ton/h) from Aekyung to Evonik Headwaters Korea, coal consumption in Hanju has dropped significantly, resulting in less resource consumption and reduced CO_2 and other air pollutant emissions.

2.4.5 Assessment of Triple Bottom Benefits of Ulsan EIP Initiative

2.4.5.1 Economic and Social Benefits

Economic and social benefits are the two most important aspects that are essential for consideration in infrastructure development. The best performance of the infrastructure can be achieved by accomplishing economically feasible, socially adaptable, financially viable, environmentally neutral or positive, and technically possible infrastructure development. In this context, payback period may be used as a parameter to show how the project is economically feasible from the economic viewpoint.

Out of the 22 successful networks in operation, nine networks deal with steam supply, and 13 networks deal with by-product exchange. The economic and environmental benefits (the reduction of CO_2 and other air pollutants such as SO_x, NO_x, and CO) in the networks currently in operation are summarized in Table 2.4. With a research support of 2.53 million US$, an investment of 78.80 million US$ could result in an estimated economic benefit of 84.39 million US$/year. The economic viability of the symbiotic activities in Ulsan is mainly assessed from the payback period of the on-going projects, for which a period of less than 2 years is most commonly accepted as a genuine period for environmental infrastructures. At present, industrial symbiosis in Ulsan is viewed as a strategy to enhance the resource and energy efficiency of manufacturing processes of the participating companies, besides simultaneously addressing poor environmental quality as well as depleting resources. Anew, it also provides new business development opportunities for the intermediate processing of the wastes/by-products. In addition to economic and environmental benefits, social benefits in terms of increased employee and community satisfaction due to employment generation and improved environmental quality fulfill the so-called triple bottom line benefits of industrial symbiosis. As an example of social benefits, when looked from employment generation perspective, the Hyosung Company Yongyeon 2nd plant (network #2, Table 2.4) has decided to invest an additional 150 million US$ to construct a new production unit to utilize its excess steam, which would result in the employment of an estimated 140 people. The benefits of the presented synergies (Table 2.4) serve as an important database and literature case studies to demonstrate that all of the participating parties benefit, both tangibly and intangibly, from the implemented synergies.

Table 2.4 Economic and environmental benefits from industrial symbiosis in Ulsan EIP

No.	Material	From	Intermediate processing	To	Research/negotiation period (month)	R&D fund (million US$)	Economic benefit: Investment (million US$)	Economic benefit: [a, b]Profit (million US$/y)	Economic benefit: Payback Period (year)	Environmental benefit: CO_2 reduction (ton/y)	Environmental benefit: Air pollutant reduction (ton/y)
1	Steam	Yoosung Corp.	–	Hankuk Paper	07/04	0.04	0.85	3.85	0.2	12,491	88.2
2	Steam	Sung-am MWIF	–	Hyosung Yongyeon 2nd plant	04/21	0.01	5	7.1	0.7	60,476	427.1
3	Steam	KP Chemical Hansol EME	Korea PTG	SKC	12/12	0.10	14	4.0	3.5	34,906.7	246.6
4	Aldehyde wastewater	SK Energy	EnvironSoft	Noksan MWWTF	07/02	0.04	0.13	1.99	0.07	NA	NA
5	Nutrient for microorganisms	Dau Metal	Sunkyuong Watech	Taekwang Industry(I)	12/NR	0.06	0.1	3.69	0.03	NA	NA
6	Neutralizing agent	POSCO	Ilsin Polytech	LS-Nikko	12/NR	0.15	0.05	1.15	0.04	NA	NA
7	Aluminum chip	Dongnam Fine Hanjoo Metal	Ajin Metal	Dongnam Fine Hanjoo Metal	12/NR	0.20	0.1	3.30	0.03	NA	1,325
8	Waste oil	Petrochemical cluster	Sinheung	Taewon Mulsan	12/NR	0.06	0.5	1.67	0.30	NA	NA
9	Zinc powder	Pungsan Metal, GB Metal, TNC	TNC	Kunsul Chemical Industry, Sigma Samsung	12/NR	0.19	2	5.43	0.37	315.7	NA
10	Steam	Hyundai Heavy Industry	–	Hyundai Motor, Hyundai Hysco	12/34	0.08	6	3.20	1.88	10,188	273.2
11	Steam and CO_2	Korea Zinc	–	Hankuk Paper	12/06	0.12	21	6.60	3.18	63,643	1,692.0
12	Oil degradation material	SK Energy	SGR Tech	Oil spill restoration company	24/NR	0.31	0.2	0.12	1.67	NA	NA
13	Steam	Aekyung petrochemical	Hanju	Evonik Headwaters Korea	12/06	0.1	1.5	2.82	0.53	33,094	NA

14	TPA Sludge	SK petrochemical	Dongshin Chemical	CNT, Hansol Chemical	12/	0.15	0.8	1.19	0.67	NA	NA
		Sam Nam Petrochemical									
15	Waste H_2S gas	ISU chemical	Encore Networks	Korea Zinc	14/03	0.23	0.6	5.97	0.10	NA	NA
				LS-Nikko							
16	Steam	Bumwoo		Korea Petrochemical	12/NR	0.09	10.0	5.56	1.80	25,084	NA
17	Organic Waste	Hyosung		Hyosung	12/NR	0.21	1.0	0.52	1.92		
		Ulsan plant		Ulsan plant							
18	Steam	Taekwang Petrochemical 1st plant	SK Energy	Hyosung	15/	0.15	6.0	9.2	0.65	50,396	
				Ulsan plant							
19	ABS sludge	Korean styrolution, Kumho Petrochemical	KMT	Shinhwa Chemical, Youngwon Tech	12/NR	0.08	0.52	1.28	0.41		
20	Waste heat transfer salt	Yongsan Chemical	Bomyung	Corinox	14/NR	0.04	–	0.40	–		
21	Steam	Seong-am incineration plant #2	Hyosung Yongyeon 2nd plant	Hyosung Yongyeon 1st plant	1/NR	0.01	8.2	14.7	0.6	39,427	
			Korea PTG	SKC							
22	Spent sulfidic caustic	S-Oil	SU engineering	Bangeojin Sewage Treatment Plant	12/	0.11	0.25	0.65	0.4	949.0	
			Total			2.53	78.80	*84.39*		*330,970*	*4,052.6*

NA not applicable, *NR* not required

[a]Profit is the summation of both supplier and recipient

[b]Assumption 1US$ = 1,000 Korean Won

2.4.5.2 Environmental Benefits

In addition to economic and social benefits, another goal of the IS is to improve the environmental standard through efficiency, further development, and information exchange of utilization of by-products in industry. Through these actions, the enterprises will minimize the utilization of energy, water, and natural raw materials.

The environmental benefits in terms of waste recycle and reduction, wastewater recycle, CO_2 reduction, emissions of five pollutants (SO_x, NO_x, TSP, CO, and VOC), and in addition the reduction in the utilization of energy were estimated (Table 2.5). For example, the benefits gained (in terms of reduction in the utilization of energy, CO_2 reduction, emissions of air pollutants) by the establishment of IS network between Sung-am MWIF and Hyosung Company were 18,850, 55,500 ton/year and 176.8 ton/year. Similarly, establishment of IS network between Yoosung Company and Hankuk Paper resulted in the benefits (in terms of reduction in the utilization of energy, CO_2 reduction, emissions of air pollutants) of 7,762, 19,058 ton/year and 135 ton/year, respectively. Besides, the contribution of the EIP initiative to the environmental quality of Ulsan city is mentioned in Table 2.5.

2.5 Lessons Learned and Policy Implications

There is widespread enthusiasm and commitment shown by the industries operating in Ulsan industrial parks to achieve sustainability by IS networks and, in a long run, to be a world class eco-production platform. This commitment is reflected in the disclosure of their baseline input and output data and their willingness to participate in the project. The currently established networks are more diverse and significant, which positions Ulsan well among the leading-edge examples of IS. Nevertheless, many IS opportunities still appear to exist, mainly in three broad areas: water, energy, and industrial by-products. It has been recognized by the Ulsan EIP center that the current situations and legislations are not enough to enable or encourage industries to implement some of the potential synergies proactively. The lessons learned and some of the policy implications from Ulsan EIP initiative are that sustainability of industrial city can be maintained by integrating the following critical factors into EIP transition plan to enhance collective eco-production capacity of the industrial park.

Economic factors:

(1) With the well-established business model, stakeholders can be attracted for investment on infrastructures that offers them a significant economic gains simultaneously contributing to a cleaner and greener environment.
(2) To achieve the greatest economic benefits, the EIP initiatives require substantial investment in infrastructure. Thus, barriers to investment, including liability and capital access, must be removed to promote ecologically sound park development.

Table 2.5 Contribution to environmental quality by Ulsan EIP initiative

	Industrial waste (ton/day, 2011)	Industrial wastewater (m^3/day, 2010)	Energy (ton/year, 2011)	CO_2 (ton/year, 2005)
Emission or consumption (energy) in Ulsan	6,550	358,000	24,409,000	64,303,000
Outcomes from 1st stage EIP project in Ulsan	95.15	201.46	104,359	265,510
Outcomes from 2nd stage EIP project in Ulsan	5.36	15.00	27,238	65,460
Outcomes from total EIP project in Ulsan	100.5	216.5	131,597	330,970.2
Contribution (%)	1.53 %	0.06 %	0.54 %	0.52 %

Environmental factors:

(1) Establishment of IS networks significantly enhances the environmental performance of the industrial parks and the local environment. Thus, environmental goals for EIPs should be developed through a participatory process involving all community stakeholders.
(2) Market incentives should be used widely in the encouragement and management of EIPs to enable cost-effective environmental protection within parks.

Social factors:

(1) The substantial social benefits such as new employment opportunities and contribution to quality of life in terms of minimized environmental pollution due to the establishment of IS networks need to be effectively communicated to key stakeholders (e.g., government, community, and other industries) so that existing barriers can be removed and appropriate policies can be put in place to enable further development of IS networks.

Institutional factors:

(1) Environmental regulatory systems must be flexible enough to allow park participants to trade their waste products so that environmental goals can be reached in the most cost-effective way for the entire park.
(2) Central and local governments should coordinate and streamline their regulatory requirements to bring the present environment regulations and standards in line with the EIP approach.
(3) Organizations such as EIP centers in Korea should be established so that stakeholders interested in developing EIPs can easily obtain regulatory, technical, and financial assistance information.

Industrial parks are very important urban infrastructures to maintain the sustainability of city by enhancing eco-production capacity for reduction of energy and resource consumption and emissions. The traditional industrial parks in Ulsan were not developed based on the triple bottom line benefit approach. Thus, there is plenty of opportunity to enhance the benefits through eco-production by transforming the existing industrial parks to EIPs. Thus, in a broader context, the designed or planned eco-production activities undertaken at the city or regional level may eventually contribute to the sustainability of global society, among others.

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Chapter 3
Special Economic Zones (SEZs) in Andhra Pradesh: A Stocktaking

Jayesh Ranjan

Abstract The state of Andhra Pradesh is a leader in the country for special economic zones (SEZs) on all the common quantitative and qualitative indicators of assessment. Yet, the performance of the SEZs can at best be described as mixed. The SEZs continue to be permeated with a number of concerns. The percentage of lands put under utilisation remains low. The trend to denotify already sanctioned SEZs is on the rise. Land aggregation for the SEZs is beset with numerous problems. There have been serious environmental concerns as well with a few of the SEZs. On the other hand, there are many impressive success stories also. Numerous SEZs in the state have been universally recognised for attracting high-value clients, for contributing significantly towards the well-being of the surrounding community, for taking care of the environment responsibly and for strategic utilisation of the lands in their possession. In days to come, new instruments of industrialisation being promoted by the government, like the National Manufacturing and Investment Zone and the Information Technology Investment Region, are bound to further erode the standing of the SEZs. It is felt that only those SEZs that have adequately mastered the success factors are going to thrive, while all the rest face an uncertain future.

3.1 SEZs in Andhra Pradesh: An Introduction

Andhra Pradesh is among the leading industrialised states in the country. The various advantages that it has enjoyed over the years – a geographical location close to the centre of the country; a longstanding culture of entrepreneurship; a huge pool of qualified and talented manpower; an abundance of land, water and natural and mineral resources; a plethora of knowledge-based institutions; a long coastline; a

This chapter was written when the state of Andhra Pradesh was a composite state. From 2 June 2014, the composite state has been bifurcated into the new state of Telangana and the residuary state of Andhra Pradesh.

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well-developed infrastructure; and investor-friendly policies of successive governments, to name the prominent ones – have also translated the state into becoming an important centre for trade, commerce, industry and investments. Thus, when the concept of SEZs was introduced in 2005 through the introduction of the SEZ Act and Rules, Andhra Pradesh was quick in cashing on the scheme. In the past 8 years or so, Andhra Pradesh has outperformed all other states on all the key parameters of evaluating SEZs, both on quantitative parameters like the number of approved, notified and operational SEZs and on performance parameters like export performance, investments and employment generated. The following Table 3.1 which gives the details of SEZs in Andhra Pradesh in both public and private sectors as on 1 October 2013 succinctly sums the state's position vis-à-vis the country as a whole.

It can be seen that a single state, Andhra Pradesh, accounts for nearly one-fifth of all approved, notified and operational SEZs in the country. The other states that come close to Andhra Pradesh are Maharashtra, Tamil Nadu, Karnataka, Gujarat and Haryana. It is suggested that the strength, comprehensiveness and effectiveness of the SEZ policy is an important determinant of the SEZ notifications in a state. The SEZ growth in a particular state is also driven by the level of industrialisation and the level of investment in industrial infrastructure in that state (ASSOCHAM 2013).

The performance data for the above SEZs located in Andhra Pradesh is also quite impressive, as the following Table 3.2.

As the data clearly tells, there is a steady growth year-on-year on all the three main parameters of investment, value of exports and direct jobs given in the SEZ units in Andhra Pradesh. Even in years worst affected by macroeconomic factors like global recession and liquidity crunch, the growth on all these fronts has been significant.

In terms of the sectoral dispersion of the SEZs, it is seen that IT/ITeS SEZs are in preponderance, accounting for over 55 % of the total notified SEZs. This is not surprising, as Andhra Pradesh was one of the early movers to latch on to the software and dotcom bandwagon, by creating a conducive and comprehensive ecosystem that facilitated the growth of the IT and ITeS industry in the state. Other sector-specific SEZs cover pharmaceuticals, biotechnology and specialised manufacturing areas like aerospace, garments, gems and jewellery, among others. A few multiproduct SEZs also exist, mostly promoted by the Andhra Pradesh Industrial Infrastructure Corporation (APIIC). The above sectoral dispersion follows more or less the national pattern. Table 3.3 shows the break-up of the notified SEZs in Andhra Pradesh.

Table 3.1 An abstract of SEZs in India and in Andhra Pradesh

	No. of formally approved SEZs	No. of in-principle approved SEZs	No. of notified SEZs	No. of operational SEZs
India	576	49	392	173
Andhra Pradesh	109 (**18.92 %**)	6	78 (**19.90 %**)	39 (**22.54 %**)

From the website www.sezindia.nic.in

Table 3.2 Performance of SEZs in Andhra Pradesh, 2008–2009 till 2012–2013

	2008–2009	2009–2010	% Growth	2010–2011	% Growth	2011–2012	% Growth	2012–2013	% Growth
Investment (in Rs. millions)	73.87	113.04	**53.03**	151.15	**33.71**	237.16	**56.90**	247.58	**4.39**
Exports (in Rs. millions)	30.33	55.67	**83.55**	138.91	**149.52**	181.66	**30.78**	261.47	**43.93**
Employment (direct)	32,967	53,365	**61.87**	82,741	**55.05**	117,232	**41.69**	142,898	**21.89**

Report of Development Commissioner, VSEZ submitted to DIPP, January 2014

Table 3.3 Sector-wise SEZs in Andhra Pradesh (as of 1 January 2014)

Sector	No. of formally approved SEZs	No. of in-principle approved SEZs	No. of notified SEZs
Building materials	1	1	1
Multiproduct	8	1	6
Engineering	1	1	
Pharmaceuticals	7	2	6
Petroleum and gas		1	
IT and ITES	57		43
Leather	1		1
Footwear	4		1
Paper	1		1
Manufacturing and warehousing			1
Apparel and textiles	5		4
Biotechnology	11		6
Electronics and hardware	3		3
Food processing	1		1
Aerospace	3		1
Aluminium	2		1
Agriculture and livestock prod.	1		
Gems and jewellery	2		1
Multiservices	1		1
Total	**109**	**6**	**78**

Report submitted by Development Commissioner, VSEZ to DIPP, January 2014

3.2 Areas of Concern

Though in a comparative sense at the national level, the response to SEZs from Andhra Pradesh appears to be overwhelming, there are a number of deficiencies seen in the operations of the SEZs. Despite having a large number of SEZs, the capacity utilisation of SEZ lands is just above 20 %, which though better than the national average of 15 % is a reflection of the lack of confidence in the concept of the SEZs. Huge tracts of lands and built-up space continue to remain unoccupied in practically all the SEZs in the state.

The growing trend of denotifying SEZs, either fully or partially, and converting them into ordinary industrial parks or put to other uses like commercial or residential is also symptomatic of this crisis of confidence and credibility. In Andhra Pradesh, 6 SEZs have so far been denotified (final or in-principle), while more than 20 have sought to reduce the SEZ area through the route of partial denotification.

Analysts point out that the development of a SEZ has a long gestation period, particularly for SEZs other than in IT/ITeS sectors. It may take a minimum of 5–10 years to construct and develop a SEZ and then start commercial operations and exports. When the concept was introduced in 2005, based on the hype created around the successes of the Chinese SEZs, it attracted a large number of international and domestic players because of the favourable incentives provided for in the scheme. But before the fruits of these benefits could be passed on to the developers, the rules were modified abruptly. In particular, the imposition of minimum alternative tax (MAT) and dividend distribution tax (DDT), which negated the basic premise of SEZs being tax-free havens, has come as a big negative. Many developers who invested with own and borrowed funds in the development of SEZs found it difficult to sell space by attracting new clients. Over the years, the ability to seek bank loans on attractive terms has also ceased, as the financial institutions now classify a SEZ project as a real estate project rather than an infrastructure project, the former attracting a higher rate of interest on the borrowings (The Hans India 2013).

The lack of market interest towards SEZs is also reflected in the fact that over the years, the conversion rate of notified SEZs into operational SEZs is coming down. Even when the developer has received a formal notification for his SEZ, he is found to hesitate in making it operational, as he is unsure of the returns he will get. In his calculations, keeping the SEZ idle and losing money are perhaps better options than running it and losing even more money!

SEZ developers and the occupants have voiced a few other concerns also regarding certain operational issues. Despite best efforts by the government, infrastructure gaps and bottlenecks remain, which serve as obstacles in getting new clients to the SEZ. Though Andhra Pradesh has a fairly efficient single-window system for facilitating permissions and clearances, there remain many gaps during implementation. Further, certain local laws of the state are found to be hindrances to the effective functioning of the SEZs. The lack of marketing support by the government to the private SEZ developer is another common grouse.

3.2.1 Land Agglomeration: An Eternal Conflict or a Win-Win?

Another contentious issue for the establishment of SEZs is land agglomeration. In the 78 notified SEZs in Andhra Pradesh, an extent of 42,590 acres of land is involved. There are two models of land agglomeration that are followed. One of them is for the developer to organise the lands on his own, by purchasing directly from the land owners. Alternatively, the developer seeks help from the government in pooling land. The government usually allots some lands that belong to itself or acquires land that can be given to the developer. In practice, a combination of all the above is followed. The developer buys some land parcel on his own and then seeks the help of the government to get additional land. The government again gives some government land and acquires some others from private owners to make a compact block altogether. In Andhra Pradesh, in the total extent of 42,590 acres for the 78 notified SEZs, 28,519 acres are private lands and 14,071 acres are government lands.

Contention arises when lands of private owners are sought to be acquired for the purposes of allotting them to SEZs. There are various fundamental causes for this conflict. There is a widespread public condemnation whenever lands are acquired for SEZs because this kind of development is not considered “pro-poor”. SEZs, in public perception, are seen as elitist and as an opportunity to enrich the already rich social class. Further, the mechanism of land acquisition is also not people-friendly.

The basic framework of land acquisition in India is The Land Acquisition Act of 1894 which is being followed for several years. This Act addresses the process of land acquisition in India and has been amended several times. A major deficiency of this Act is that it provides for land compensation based on the historical market value. In all the cases, the compensation has never been perceived to be adequate. A single, one-time cash payment system is followed. It fails to address speculation and price inflation. Another deficiency of the Act is that it excludes renters, labourers, sharecroppers, etc. In India, where the incidence of absentee landlord is on the rise and more and more lands are in the hands of lessees, this denial of compensation to those who are actually attached to the land appears very unfair. The acquisition process is characterised by top-down decision-making without any participation of the land losers. Once benefits of the SEZs start appearing, the value addition is captured by others and not the land losers.

Another common complaint is of inadequate relief and rehabilitation of the displaced families. Being primarily an agrarian society, there is an invaluable emotional attachment with land that is coming as an asset from generations to the present land owner. Such an attachment is suppressed through heartless application of law. Further, the concern for heritage, natural environment, etc. is rarely shown. For all these reasons, land acquisition for SEZs is perceived as an instrumentality of the state to perpetuate social stratification and provides undue benefits to the already affluent.

In Andhra Pradesh too, there have been umpteen cases of large-scale public protests whenever a SEZ project is announced to be located at a particular site. This is manifested usually during the stage when a public hearing is conducted to discuss the environmental ramifications of the project. During these public hearings, there have been many instances of large-scale public protests taking the form of violence, police action to quell it and resultant injuries and even fatalities.

In wake of these problems, several innovative models of land acquisition have emerged over the years but have remained "project-based" and not mainstreamed as a policy. Some of these innovations include novel forms of compensation like providing developed land to the land losers in lieu of the lands taken from them, providing a form of perpetual income to the land losers by making them equity partners in the SEZ project and arranging for payments over a longer period of time through an annuity model besides an upfront payment component, to name a few. It is only now that the Government of India is coming out with a new legislation called The Land Acquisition and Rehabilitation and Resettlement Act (LARR) 2013. It seeks to address concerns of farmers and those whose livelihoods are dependent on the land being acquired, while facilitating land acquisition for industrialisation, infrastructure and urbanisation. Some of the innovations mentioned above that have proven to have worked quite well in stray cases have been factored into this new Act. Thus, now the land losers will be entitled to a much higher compensation. They have to be mandatorily involved in the decision-making process and their prior consent obtained. The relief and rehabilitation package to be offered in cases of displacement has to be announced upfront. Most importantly, the developer will have to share the benefits of value appreciation of the land with the land owners.

Such pro-people features of the Act will definitely lessen the heartburn and the public condemnation that are caused whenever lands are acquired for SEZs. However, there is an increasing concern voiced among the developers community whether they will be able to make the SEZ projects financially viable if they have to go through all the provisions of the new Act. There are many who have proclaimed that the new Act finishes all possibilities of new SEZs coming up in acquired lands. The only option left would be for developers to buy for themselves private lands wherever possible, without taking recourse to the formal land acquisition route.

Since the rules that give shape to the Act are yet to be formally notified, we do not as yet have the proof of the concept, as to whether the development of new SEZs will slow down on account of the new Act or whether the developers will find it comfortable to work within the ambit of the new Act, since a genuine partnership with the land owners is now possible. For all the critics of the Act, who find the provisions of the Act to be totally unfriendly to industry, it is to be pointed that much of this seems to be of their own making. There have been many cases, particularly in urban and peri-urban areas, of developers making windfall profits through SEZs simply by trading in the lands acquired for the SEZs. The lands are bought at very cheap rates, and by the time many hands change, the rates increase manifold, thus bringing abnormal returns to the developer. Since the industry failed to self-regulate against such misuses, it is high time that the Government stepped in with appropriate regulations. There could possibly be a slowdown in the growth of SEZs; nevertheless, through practice, some models are expected to emerge where land agglomeration provides a win-win situation both for the developer and the land loser.

3.2.2 Environmental Concerns in the SEZs

SEZs are known for the potential environmental damages in lieu of the relaxed guidelines and norms. There have been a few publicised cases in Andhra Pradesh also wherein serious environmental concerns have been raised in the operations of the SEZ. One such case, that of a pharmaceutical SEZ, exemplifies how environment can be given the short shrift while taking up bulk drugs manufacturing activity. This SEZ is spread over an area of 2,400 acres and has allotted lands to over 50 bulk drug manufacturing companies. Drugs manufacturing is by nature a polluting activity, in terms of both gaseous and liquid emissions. As a result, such units are permitted to operate only after they install all the safeguard equipments which ensure that all effluents are treated fully before they are emitted in the environment. The Andhra Pradesh Pollution Control Board (APPCB) is the regulatory agency on behalf of the government that monitors the installation and functioning of the antipollution measures.

In the case of this SEZ, the possibilities of air and water pollution were acknowledged during the process of obtaining Environmental Clearance (EC) from the Ministry of Environment and Forests. As a part of the process, the developer prepared an Environment Mitigation Plan (EMP) in which they committed themselves to installing all the safeguards. In the public hearing as a part of the EC process too, the same commitments were reiterated. The main element of the commitment was that the developer will install a Common Effluent Treatment Plant (CETP) which will ensure that all liquid discharges were treated to the permissible standards before being let out. Further, each individual manufacturing unit will install their own treatment facilities to take care of the gaseous discharges so as to maintain purity in the air quality.

However, within a year of the units getting operational, serious deficiencies in complying with the APPCB norms were noticed. The total capacity installed for the CETP was only 3.5 MLD as against a requirement of 5 MLD. As a result, high TDS effluents were getting discharged even without treatment. APPCB inspections also revealed that quality standards of treatment were not being complied with for low TDS effluents also, particularly with respect to COD parameters before the disposal. Instead of using steam stripper in the machinery to improve the process efficiency, the developer was using hot air stripper process and adding hydrogen peroxide at a later stage to bring down the COD. The developer further failed to develop a landfill for disposing off the solid and hazardous waste. No special mechanism was provided for controlling smoke and the smell. In fact, frequent complaints from the surrounding villages about the foul smells emanating from the SEZ became commonplace. It was only after tremendous pressures put on the developer by the regulators, including the threat of getting the units physically closed, that these deficiencies were rectified over a period of time.

This example illustrates a key conflict inherent in the SEZs. On the one hand, the stress is on how quickly to dispose the lands to manufacturing units, and how quickly can the units begin to manufacture and export. Ratings for the SEZ go up, as these are the conventional parameters on which they are evaluated. On the other hand, there is a risk in violating environmental guidelines, as compliance with these guidelines is considered to be cumbersome and time-consuming. If speed of execution is the essence, then anything which can potentially slow it down is seen as a matter of inconvenience which is then attempted to be bypassed or short-circuited. In this scenario, environment is considered to be the major roadblock. While a policing approach was mainly relied upon in the above example to set right the wrongs, a more balanced solution will be the carrot-and-stick. If developers are incentivised for basic compliance and incentivised additionally if they can actually install “green” features in their SEZs, we are bound to see more and more SEZs complying with all the environmental regulations. A stick will then just be an exception, rather than the rule.

3.3 Success Stories of SEZs in Andhra Pradesh and an Exploration of the Underlying Causes for Success

Being the national leader in terms of the number of SEZs, it is but natural that there would be many cases of successes in the SEZs located in Andhra Pradesh. The highlights of some of these successes are captured briefly, as follows.

3.3.1 Apache SEZ

This is a product-specific SEZ located in Nellore district, which focuses on the manufacture of footwear. The entire line of footwear is exported and is sold under the world-renowned brand of Adidas. The SEZ unit is owned by a Taiwanese company. The remarkable achievement of this SEZ, among other parameters, is in terms of providing employment to the locals. To date, it has given jobs to 7,439 people from its catchment area villages. What is extremely noteworthy about the nature of employment is that each of the 7,439 persons has been employed as a permanent worker. The status of being a permanent worker is accorded right from the first day in the job. In modern times when even the Government shirks from providing permanent employment and relies instead on contracting or outsourcing models, the fact that a Taiwanese company has provided permanent jobs to not a few hundred but to over 7,000 people is indeed commendable. Besides, in its employees, the company is close to achieving a gender parity of 50:50. From a ratio of 33 % women to 67 % men employees in 2009, it has now reached a break-up of 45:55, and it expects to make it 50:50 within the next 2 years.

3.3.2 Sri City

Sri City is another private SEZ located in Nellore district. Its achievements can be counted on many fronts. For one, it has relatively very high capacity utilisation (26 % against a national average of just 15 %). Further, it boasts of an impressive array of multinational clients like Isuzu motors, Pepsi, Kobelco, Alstom, Kellogg's, etc. All these companies have been attracted to this SEZ because of the world-class infrastructure, a very competitive land pricing and the single-window facilitation services the developer provides. The SEZ developer follows a very professional marketing strategy. It has a full-fledged marketing team which proactively approaches prospective clients to make a sales pitch. It liaises very effectively with the embassies and trade missions of other countries. A marketing innovation is to appoint as consultants former diplomats of other countries who have worked in India before to credibly present the case of Sri City before the companies of that country. Another praiseworthy feature in this SEZ is the provision of a host of support facilities, like schools, professional colleges, high-class sports facilities and a motel, to name a few.

3.3.3 Aerospace SEZ

The first SEZ in the country (and so far the only) to be dedicated to aerospace is located in the outskirts of Hyderabad city. The TATA group is the anchor client, and it has three units in joint venture with Lockheed Martin, Sikorsky and Nova. The SEZ is an exemplar of transfer of sophisticated cutting-edge aerospace technology from the developed countries to India.

3.3.4 Gems and Jewellery SEZ

The Hyderabad Gems SEZ occupies the number one position in gems and jewellery SEZ category in the list of 17 most prominent SEZs in India, as published in the Annual Report (2012–2013) by the Ministry of Commerce and Industry, Government of India (2013). This recognition is due to the significant progress made in terms of exports, investment and employment generation. This SEZ generated physical exports worth Rs 21.35 billion in 4 years (2008–2009 to 2011–2012), provided employment to 7,167 persons including 3,326 women and saw an investment of Rs 2.15 billion. The Hyderabad Gems SEZ is also rated very highly in its CSR work, by training and providing jobs to persons with disabilities. So far, it has employed 350 persons with disabilities and is ranked as one of the topmost employers in Andhra Pradesh in this category.

3.3.5 Brandix Textiles SEZ

The textiles SEZ in Visakhapatnam are developed by the Sri Lankan textile player Brandix. Besides its own units, the SEZ houses a number of other leading manufacturers. The SEZ has succeeded in the development of the entire ecosystem required for the textiles industry. It has a training centre within the SEZ where people from the catchment area villages, particularly women, are trained in different aspects of garment making. Further, the SEZ houses a whole range of units that cover the entire range of production process like thread manufacturers and buttons manufacturers, whose products are utilised by other units within the SEZ. The other valuable addition in the SEZ is the provision of social infrastructure by the developer itself, like executive housing, workers' dormitories, health centre, etc.

3.3.6 IT/ITeS SEZs

Andhra Pradesh is one of the leading software developers and exporters among all the states in the country, and hence it comes as no surprise that a large number of IT and ITeS SEZs are located in the state. Of the 39 operational SEZs, over 2/3 are catering to IT and ITeS. Both the models of a SEZ – developer-owned and company-owned – are prevalent. Among the company-owned ones are the ones belonging to the topmost IT companies in India like TCS, Infosys, Wipro, Mahindra Satyam, Infotech, etc. The IT/ITeS SEZs operated by developers also have among their clients some of the leading international and domestic companies. Many of these IT firms are engaged in high-end software development. The exports performance from the IT/ITeS sector has been witnessing phenomenal growth (65 % in 2010–2011; 26 % in 2011–2012) and has contributed significantly to the state's GSDP (28 % in 2011–2012).

3.3.7 Pharma City SEZ

A modern SEZ, dedicated exclusively for pharmaceutical companies, has been developed in a PPP mode by APIIC and M/s Ramky Co. Pvt. Ltd. Some of the leading bulk drugs, formulations, vaccines and medical devises manufacturers are located in this SEZ. Apart from internal infrastructure of very high standards, the other remarkable feature of this SEZ is the provision of a number of common facilities like common effluent treatment plant (CETP), a common marine outfall and common testing facilities, to name a few. The management structure of the SEZ is run on democratic principles, with the APIIC, the private developer and the client units forming into a body which is mandated to collectively take all operational and management decisions for the SEZ.

3.3.8 APSEZ

The APSEZ, promoted by the Government entity Andhra Pradesh Industrial Infrastructure Corporation (APIIC), is the largest SEZ in the country in terms of extent. It is located in Visakhapatnam district. APIIC has entered into an agreement with Sumitomo Corporation of Japan for development of a utilities centre that will provide electricity, natural gas, steam, water supply, waste treatment and disposal, common data centre facility, etc. All these services will be reliable, qualitatively superior and delivered at the doorsteps of the individual units.

3.3.9 Factors Behind the Successes

An analysis of the successful case studies reveals a number of causative factors. All the developers like Apache, Brandix, Sri city and Hyderabad Gems and anchor clients like TATA have made positive efforts towards generating goodwill among the local community through a host of welfare measures. Job training and employment appear to be the best ways to directly benefit the local community through the SEZ. Other welfare measures cover interventions in the areas of housing, education, health, drinking water and sanitation, etc. Successful SEZs have also utilised the lands available to them judiciously. Wherever possible, they have developed the right mix of processing and non-processing areas. They have shown a professional approach in marketing and attracting high-value clients to their SEZs. They have maintained high standards in provision of services to their clients. They take care about the surrounding environment and show concern in keeping their production processes clean and energy-efficient. They are also found to be proactive in assisting their units in resolving local issues like clearances and permissions. Many of them have been able to showcase latest technological innovations in their manufacturing processes and, in that way, facilitate the transfer of modern science and technology in the country.

3.4 Future Prospects for SEZs

Despite the evidence that in quantitative terms, SEZs have shown a year-on-year growth in terms of their export performance, investments and employment, the many deficiencies that continue to plague the system have the potential of shackling further long-term growth of the SEZs. In any case, despite the growth, the trajectory of reaching the full potential from the SEZs can fall much short of the expectations.

Two developments of recent origin have an important bearing on the future prospects of SEZs – one positive and the other negative. The positive growth opportunity for the SEZs comes in the form of the recent amendments brought to the SEZ Rules during 2013 (Maroo 2013). In view of the difficulties in land agglomeration being faced by the developers and the government alike, the minimum land requirements for setting up SEZs have been reduced. This relaxation, particularly for IT and ITeS sectors, can turn out to be quite useful, since these SEZs are mostly located in big cities, where acquiring even a small piece of land is a big challenge. Other new provisions like broad banding of sectors within a SEZ can provide greater flexibility in using the land tracts to the developer. Easier exit provision is another new amendment that can help the developer to transfer the ownership subject to fulfilling certain prescribed conditions (Mehta 2013).

At the same time, the future of SEZs, particularly those in the manufacturing sector, is likely to be impacted by another new policy that has been brought out by the Government of India. In the new National Manufacturing Policy announced during 2012, a target of raising the contribution of manufacturing to the GDP from the present 15 to 25 % within the next 5 years has been declared. One main instrument to achieve this ambitious target is the National Investment and Manufacturing Zones (NIMZs). NIMZs are large industrial townships with a minimum extent of 15,000 acres and having a clearly demarcated processing and non-processing area. Anchor clients from various manufacturing categories will be allotted lands in the processing areas. Ancillaries will also be encouraged to populate the processing area. Development in the non-processing area can be through a private developer, through the Government or through the public-private partnership (PPP) mode. Government of India has already commenced giving in-principle approvals to the NIMZs, and like the SEZs, the highest number of approved NIMZs is in Andhra Pradesh (three NIMZs are sanctioned in Andhra Pradesh).

There are some significant advantages of the NIMZs when they are compared to the SEZs. The responsibility of the entire land agglomeration in a NIMZ is with the state Government. Thus, a private developer gets ready-made access to land, unlike in the case of SEZs, where he either has to make effort to procure the land by himself or seek support of the Government for land acquisition, which under the provisions of the forthcoming Act cannot be taken as a certainty. Further, the extent of lands in a NIMZ is on a much bigger scale as compared to the SEZs. The minimum land requirement for a NIMZ is 15,000 acres. On the other hand, the largest SEZ in the country, namely, the APSEZ in Visakhapatnam, is spread over just 5,595 acres.

The larger scale of the land extent in a NIMZ can facilitate a proper cluster of industry. The main anchor manufacturing client can provide a large production facility keeping in mind the present production demand as well as future expansion possibilities. In addition, all its vendors and suppliers can be accommodated in the same vicinity, thus making its operations efficient and cost-effective. By contrast, we seldom see the whole range of supply chain being co-located in the same facility in a SEZ due to space constraints. The larger scale gives another advantage to the NIMZ. The non-processing areas can be comprehensively developed as a township to provide for housing for executives and workers and various kinds of social infrastructure like school, colleges, hospitals, shopping, recreation, etc. The lack of many of these around SEZs, particularly in SEZs farther from cities and towns, is seen as a major bottleneck in achieving full capacity utilisation.

NIMZs can further enjoy another noteworthy advantage over the SEZs, if a proposed policy addition by the Government of India comes through. As per the already announced policy, the entire trunk infrastructure like external road, rail and air connectivity, water and power supply, waste disposal, etc will have to be provided by the respective state governments, who can tap Viability Gap Funding (VGF) from the Government of India if these are sought to be developed under the PPP mode. In a very recent development, it is learnt that the Government of India now proposes to provide cent percent grants to the state governments for the development of trunk infrastructure. Usually, if the investment in the trunk infrastructure is borne by the state governments, as is the norm in Andhra Pradesh, the investment is recovered from the units by loading the development costs on them. The SEZ developer thus pays for both land costs and the development costs to the government. The land price for the industrial unit goes up accordingly. On the contrary, in the NIMZ, the units will not have to pay for the development costs.

It is to be therefore seen whether the NIMZs will upstage the manufacturing SEZs and will become the dominant model of industrial development in the future. A similar policy for IT and ITeS units, called the Information Technology Investment Regions (ITIR) whose contours are in the process of being fleshed out currently, but which proposes many features similar to the NIMZs, can potentially have the same impact on IT/ITeS SEZs.

3.5 Conclusions

The Andhra Pradesh experience can at best be characterised as a mixed story. There are outstanding successes, yet the general scenario remains gloomy, with no signs of increasing optimism or confidence in the future. The new modifications in the Act have been generally welcomed, though many consider it to be case of too little, too late (e.g. Lavi 2013).

Two broad trends in the state appear contradictory of sorts. On the one hand, the exports, investments and employment in the operational SEZs are growing tremendously. At the same time, the overall capacity utilisation remains poor, while cases of SEZs getting denotified or kept unoccupied even after notification are the order of the day. A microanalysis of the Andhra Pradesh SEZs can help resolve this paradox. The SEZs that are owned and operated by companies themselves which are producing mostly for the export market (e.g. Apache, Hyderabad Gems, Brandix, TATA and many IT/ITeS SEZs) are seen to be flourishing. Despite induction of taxes like MAT and DDT and factors like the global recession, they have done exceedingly well. Their business strategy is in tune with the SEZ policy, and they have been able to capitalise on the incentives provided. It is through their contribution that the state's performance is maintained at high and respectable levels. The SEZs developed by property developers, including quite a few developed by the government, are finding the going tough, on the contrary. Policy changes like the withdrawal of some tax benefits have hit them hard, as they find it difficult to attract new clients.

Though a crystal-clear prognosis is not wise, it can be suggested that established players who service international markets themselves will stay in the SEZ fold and continue to thrive. New policy instruments like the NIMZs and the ITIRs can be turned to their own advantage. For the rest, the future remains uncertain and possibly not so rosy.

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Chapter 4
Enhancement of Eco-production Capacity in Chittagong Export Processing Zone (CEPZ), Bangladesh, Employing Korean EIP Transition Strategy

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Abstract In many developing countries, industrial zones have played a central role in fostering industrial development. However, they were also the major contributors of greenhouse gas (GHG) emissions. This implies that industrial zones can be platforms to reduce GHG emissions in industrial sectors which enable green growth and support low-carbon economies. Eco-industrial parks (EIPs) could be one of such platforms to realize low-carbon development through the introduction of the IS concept. Governments like the Republic of Korea have been successful in transforming the traditional industrial parks to EIPs by the national initiatives since 2005. The IFC, World Bank, has initiated Low-Carbon Zone Project in Chittagong Export Processing Zone (CEPZ), Bangladesh, by employing diverse tools and methodologies, including Korean industrial symbiosis (IS) experiences. The potential IS opportunities in CEPZ were identified by analyzing the demand for energy in particular steam and electricity and exploring potential symbiotic networks based on the energy production and consumption survey and analysis by both top-down and bottom-up approaches. For the proposed symbiosis networks to be implemented in a fast, durable, and resilient manner in Bangladesh, right policy and regulatory framework, targeted mitigation activities, as well as awareness campaign and knowledge-sharing were recommended.

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4.1 Introduction

An export processing zone (EPZ) is a territorial or economic enclave in which goods may be imported and manufactured and reshipped with a reduction in duties and/or minimal intervention by custom officials. Major incentives in the package of incentives provided to investors in EPZs include duty-free import of raw materials and equipments and export of finished goods, tax holiday, exemption from dividend tax, single-window clearances, and no ceiling on foreign and local investment. EPZs have played an important role in economic growth, particularly in employment generation, export diversification, and investment creation for developing countries such as Bangladesh, India, China, and Vietnam. EPZs play a prime role as economic instruments for attracting foreign direct investment (FDI), boosting export-led growth and technology and skill transfer.

For developing countries, special economic zones (SEZs) or EPZs can be useful tools as part of an overall economic growth strategy to enhance industry competitiveness and attract FDI. Through SEZs, governments aim to develop and diversify exports, support local industry and clusters, and create jobs. SEZs may also allow for more efficient government regulation of enterprises, provision of off-site infrastructure, and environmental controls.

As part of the initiative to increase the private sector investment, the Government of Bangladesh (GoB) had undertaken various plans and programs to incentivize foreign investment. Implementation of the EPZs in the country was one of the key avenues to achieve this objective. There are eight EPZs in the country now, and these EPZs have triggered impressive growth in exports, mainly in the ready-made garment (RMG) sector, at an average annual rate of 23 % since 1993, reaching nearly USD 2.9 billion by FY2010 and employing almost 28,000 people.

The People's Republic of Bangladesh is listed among the Next Eleven (N-11) economies as having a very high potential of becoming the world's largest economies (after the BRIC[1] economies) in this century. It is the only least developed country featured in this list. The country reported a GDP of USD 100 billion (at current prices) in 2010–2011 with a GDP per capita of USD 775. GDP growth rate stands at 6–7 % and is projected to be about 6.6 % in 2015. The service sector contributes about 50 % to the national GDP followed by the industry sector at 30 %. Inflation has been around 8–9 % in the year 2010–2011[2] but is expected to go down to 4 % in 2015. The economy growth rates is projected to be about 6.2 % in 2015 which is higher than comparative countries in Asia like Malaysia (5 %) and Thailand (5 %). Income per capita is projected to grow at 3.6 % in this decade over the 2010 income per capita of USD 482 per capita.

[1] Brazil, Russia, India, China.

[2] Board of Investment, Bangladesh (PMO).

However, the country is faced with a number of critical issues which could hinder its growth. Some of these issues include (a) power demand–supply gap, (b) high cost of captive generation, (c) high energy subsidy, and (d) frequent hikes in power tariffs.

(a) *Power demand–supply gap*: In 2011–2012, the power demand was 6,832 MW while the installed capacity was only 5,500 MW, which is a shortage of about 25 %. With growth in the economy, the power demand is also expected to grow. Even though the government has plans to add around 9,426 MW additional power capacity to the National Grid by 2015, the GoB is already behind schedule by about 30 % as per present status. This is mainly due to unavailability of indigenous gas supplies, and gas has been the primary fuel for power generation so far.
(b) *High cost of captive power generation*: Limited new gas connections and frequent power outages are forcing enterprises to shift to heavy fuel oil (HFO)-/diesel-/oil-based power generation. Presently, HFO (USD 9.37/GJ) is almost three times more expensive than natural gas (USD 2.34/GJ). Since HFO is imported in the country, the price is further expected to go up (linked with increasing crude prices). This is increasing the operating costs as well as adding to environmental degradation.
(c) *High energy subsidy*: Due to increasing oil prices, electricity prices are also increasing. However, to artificially keep down power prices, the government is providing huge subsidies to this sector (around 2 % of GDP), and as a result, the national exchequer is bleeding.
(d) *Frequent hikes in power tariff*: Power tariff has been hiked a number of times in the recent past. In fact, very recently, the government has proposed a tariff for uninterrupted source of power at BDT 14.49/kWh. Besides increasing fuel costs, another major reason for increase in power generation costs can be attributed to the average efficiency of power generation, which is one of the lowest, when compared to other similar economies. In Bangladesh, the average efficiency of power generation ranges between 28 and 32 %, while other countries like Thailand and Indonesia have power generation efficiencies between 35 and 40 % and India, Malaysia, and the Philippines have even higher efficiencies at 40–45 %. The poor efficiency of gas-based power generation is due to the fact that most power plants are over 15–20 years of age.

As climate change emerges as a key global development challenge and IFC promotes economic growth through sustainable development and has a long track record of implementing successful EPZs around the world, it is worthwhile to innovate the industrial development in Bangladesh through IS (Chertow 2000) by using the EPZs as sound platforms for gradual reduction of GHG emissions as well as pilot enabling regulatory environments for low-carbon economies.

IS describes the mutualistic interaction of different industries within a certain industrial cluster for exchange of resources resulting in economic and/or environmental benefits (Chertow 2000). It engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to IS are collaboration and the synergistic possibilities offered by geographic proximity (Chertow 2000). Industrial symbioses have the potential to significantly mitigate the GHG emissions through (1) interfirm energy exchange, (2) energy saving from secondary material recovery, (3) waste-to-energy recovery, and (4) energy saving from reduced transportation due to industrial co-location.

International Finance Corporation (IFC), the private equity arm of the World Bank, provides practical recommendations on how to design, promote, and implement SEZs that benefit firms, employees, and the wider private sector development of host countries. In this particular project, the Korea Industrial Complex Corporation (KICOX) assisted the investment climate team of IFC in Bangladesh to convert the CEPZ into low-carbon green EPZ by adopting IS as the supporting tool. The overall objective was to identify (1) potential IS opportunities in CEPZ, (2) short- and long-term plan for IS implementation, and (3) short-term business model development.

The overall objective of this work was to identify cost-effective GHG emissions reduction opportunities that may be available in the CEPZ and to provide practical implementation plan to significantly reduce its GHG emissions. The conclusions of this analysis will be used both as a basis to start a dialogue with relevant stakeholders and also as a starting point to elaborate future actions and policy recommendations within various levels of the GoB. This would help in identifying areas for potential GHG emissions mitigation, developing implementation plans, and establishing a policy framework to facilitate and promote the deployment of GHG mitigation options.

4.2 Overview of CEPZ

Under BEPZA Act (1980), there are eight EPZs (Dhaka EPZ, Chittagong EPZ, Mongla EPZ, Comilla EPZ, Ishwardi EPZ, Uttara EPZ, Adamjee EPZ and Karnaphuli EPZ) in Bangladesh since 1983. These EPZs, owned and operated by BEPZA, have triggered impressive growth in exports (16 % of the country's exports originate from EPZs), mainly in the ready-made garment (RMG) sector, at an average annual rate of 23 % since 1993, reaching nearly USD 2.9 billion by FY2010 and employing almost 28,000 people. As many as 305 companies from 35 countries have invested in these EPZs giving employment to 309,477 people.

Among these EPZs, Chittagong EPZ (CEPZ) and Dhaka EPZ account for more than 80 % of the companies operating in the EPZs and 90 % of the jobs and exports. These zone's location and infrastructure provide advantages to investors, such as proximity to a port and the Dhaka metropolitan area, which in turn provides access to critical institutional support (e.g., customs authority), and proximity to infrastructure services. The CEPZ is one of the most successful industrial zones in Asia and has been instrumental in attracting foreign investment to Bangladesh. It is the oldest and largest EPZ, located 3.1 km away from the Chittagong seaport, spread over 453 acres of land and generating 156,690 jobs and investment of 85.84 million USD (in 2010–2011). The CEPZ has a number of small and medium enterprises. Major sectors include the Garments Industry (involving all the segments of the Garment Value chain), Textile Industry, Footwear Industry, Garments Accessories, Electrical and Electronic Goods Manufacturing Industry, Metal Products Manufacturing Industry, and Plastic Good Manufacturing Industry. It emphasizes the importance of such industrial clusters to leverage a country's competitive advantage.

The power demand is rapidly rising in the Chittagong area as well with a forecast of 10 % rise in power demand every year which would lead to expected demand of around 992 MW in 2015. There is capacity addition plan of 475 MW by 2015 out of which 375 MW is to come from natural gas-based sources. However, acute gas crisis might impact the power supply scenario adversely, and it is unlikely that the new gas-based power capacity would be installed in the near future. Presently, there is already gas demand–supply gap to the tune of 0.6 million Nm^3/h in Bangladesh. Major gas fields in Chittagong area is on the verge of drying up as evident from production figures which came down from 259,600 to 29,500 Nm^3/h in 10 years. The present gas demand is met by shutting down alternately Chittagong Urea Fertilizer Limited or Raujan Power Plant and by restricting all kinds of new connections in Chittagong.

At the moment, the future of Bangladesh in terms of gas is very uncertain and unknown. The government so far has taken the initiative for the third round bidding for allocating off-shore gas block to the international oil companies like Cairn Energy, Shell, etc. Natural gas is the main energy resource of Bangladesh for commercial consumption. The total reserve of natural gas is estimated to be around 20.4 trillion cubic feet (TCF) of which 5 TCF has already been consumed as of 2008–2009. There have been recently discovered coal reserve of 2,514 million tons; however, this has not been utilized to its full potential due to various geological and technological reasons. Hence, a shortfall in gas supply would majorly impact the economic growth of the country.

Many industries which are already established with the uncertainty of power have shifted to generate their own power from either diesel or heavy fuel oil (HFO). However, this is an extremely high-cost proposition – present HFO price in the international market is USD 9.37 per GJ which is three times more expensive than natural gas (available in CEPZ) which costs USD 2.34 per GJ. Since HFO is imported in the country, the price is further expected to go up (linked with increasing crude prices) and hence impact profitability of the enterprises in a major way.

4.3 Low-Carbon Green EPZ in Chittagong

4.3.1 Strategy for Low-Carbon EPZ

For retrofitting the CEPZ into a low-carbon green EPZ, a framework as depicted in Fig. 4.1 might be adopted.

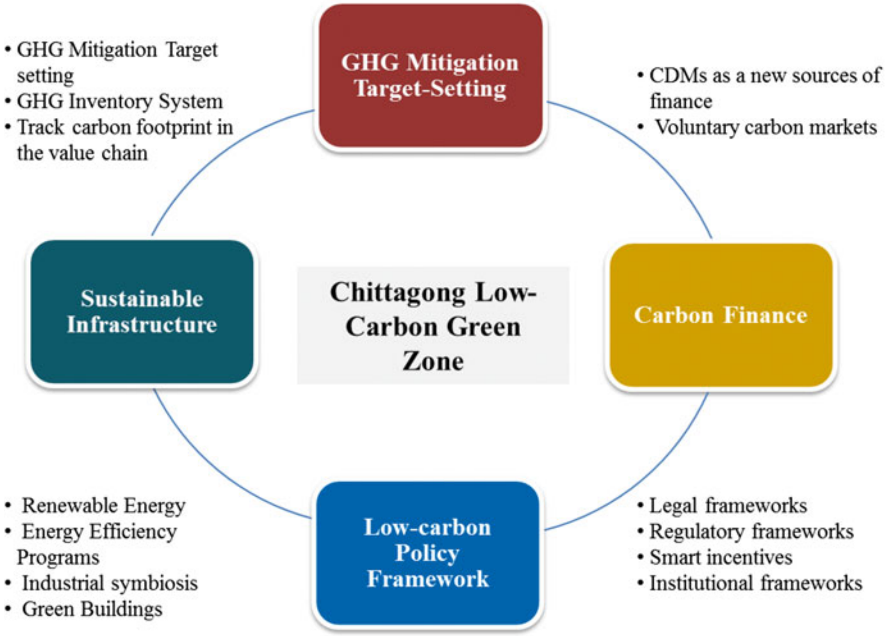

Fig. 4.1 Low-carbon green EPZ framework (Source: IFC, World Bank (2013))

The conversion of EPZs to low-carbon green EPZs could pioneer the demonstration of the EPZs to efficient, low-carbon economies at different level of economic well-being. The benefits of establishing low-carbon green EPZs through the application of IS are foreseen to be manifold. First, like the EPZs, they would provide a focus for attracting qualitatively different foreign investments away from low value addition and simple processing and assembly of manufacturing goods toward research and development, high-end design, modern logistics, and other new areas. Second, in addition to acting as testing grounds for new products, services, and infrastructure, low-carbon green EPZs could become areas in which low-carbon technologies would thrive. Third, these low-carbon green EPZs could become focal points for international cooperation, for example, through carbon finance (emission trading and the clean development mechanism), concessionary loans, or aid efforts from public entities like regional development banks or critical international partners. Fourth, these low-carbon green EPZs could enable experimentation for creating an enabling regulatory environment and progressive governance framework toward the development of low-carbon economies. Fifth, these low-carbon green EPZs could serve as centers of excellence on climate change impacts and adaptation, where expertise on climate change impacts and understanding of the necessary technologies needed to adapt could be brought together and translated into joint ventures and policy solutions in order to boost the country's adaptive capacity.

The target of this proposed work was to establish business model for 3–4 IS networks, and the following were the steps to reach the target.

A. Identify potential IS opportunities.

- Analyze the demand for energy in particular steam and electricity.
- Analyze the demand for material and water for investment and opportunities.
- Identify potential symbiotic transactions based on the input and output analysis.
- Develop a list of companies for IS networking.

B. Short- and long-term plan for IS implementation.

- Provide road map for short- and long-term symbiotic transactions in waste and by-product exchange, wastewater recycle, and waste heat reuse with schematic diagrams
- Evaluate GHG emission reduction upon establishment of IS networks.
- Evaluate performance of the transactions with possible economic and environmental benefits.

C. Business model development.

- Business model for at least 3–4 networks considering the interest of stakeholders

As shown in Fig. 4.2, in step 1(a) of the strategy for low-carbon EPZ, the potential synergy networks were identified, either by a top-down or bottom-up approach. In a top-down approach, basic information was collected from 63 companies situated in CEPZ. This was done by availing the geographical information of CEPZ

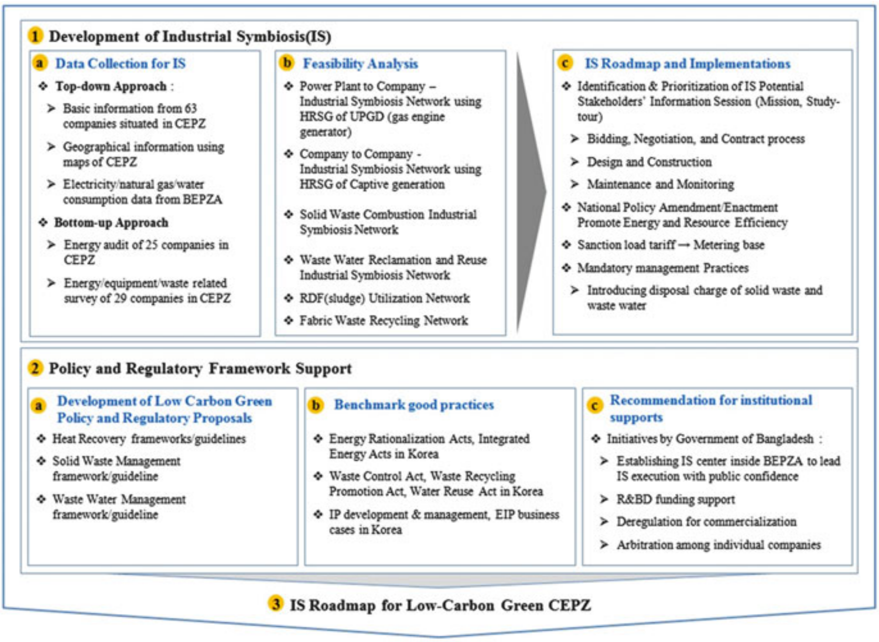

Fig. 4.2 Strategy for low-carbon EPZ through Korean EIP model application

and collecting the electricity and gas consumption data from BEPZA. On the contrary, in the bottom-up approach, on-site energy audit of 25 companies and equipment/waste emission survey of 29 companies in CEPZ were made by visiting the companies directly.

The partners were subsequently recruited to participate in the potential synergy networks, followed by a feasibility investigation (step 1b). The feasibility investigation entails an assessment of the potential uses of by-products, an assessment of the techno-economics and environmental feasibilities, and a conceptual design for the particular network type. Based on the results from feasibility investigation, a convincing business model (the final report of the feasibility investigation) was developed for the implementation of the synergy network. The key elements of the business model are outlined as follows: (1) clear indication of a network to recycle resources among companies; (2) initiative to start business between companies that supply, demand, and recycle by-products; (3) presenting companies with potential demand; and (4) the implementation of the developed technology. The business model included all the liabilities and rights pertaining to the investments and benefits of the stakeholders (Behera et al. 2012).

The most important element in the low-carbon EPZ framework was the IS road map and implementation of the newly identified networks (step 1c). This step includes negotiation and contract among the participating companies, overcoming barriers related to any existing laws that may possibly hinder the implementation of the projects and also exploring the existence of any national policy that promotes energy and resource efficiency. Besides, mandatory disposal charges for solid waste and wastewater generated by the tenants in CEPZ were introduced.

In step 2, support related to policy and regulatory framework for various networks would be examined. For instance, guidelines pertaining to heat recovery and waste or wastewater would be examined; international best practices would be referred to provide the regulatory support. Some catalytic organizations such as EIP centers in Korea (Park and Won 2007) were recommended to be established within BEPZA to lead in executing the IS networks. Finally, in step 3, the road map for establishing the IS networks would be established for retrofitting the CEPZ into low-carbon green CEPZ.

4.3.2 Energy Consumption and Waste Heat Recovery Potential in CEPZ

The data pertaining to energy consumption (electricity and natural gas, Tables 4.1 and 4.2) in the CEPZ was collected through top-down and bottom-up approaches. The firms were segregated based on their energy consumption. Based on this information, potential partner companies were selected for development of symbiosis (Table 4.3). The bottom-up approach involves the energy audit of 25 companies in CEPZ and energy-/equipment-/waste-related survey of 29 companies in CEPZ.

Table 4.1 Electricity consumption pattern in CEPZ (top-down approach)

Range (kWh)	No. of firms	Consumption	Percentage
Less than 100,000	24	1,244,610	0.72
100,000–500,000	63	17,707,324	10.23
500,000–1,000,000	35	25,904,237	14.96
1,000,000–5,000,000	42	94,694,474	54.7
5,000,000–10,000,000	5	33,550,758	19.38
Total	169	173,101,402	100

Source: Developed by authors using the data from BEPZA

Table 4.2 Natural gas consumption pattern in CEPZ (top-down approach)

Range (kWh)	No. of firms	Consumption	Percentage
Less than 100,000	17	854,211	1.22
100,000–500,000	27	6,992,821	9.95
500,000–1,000,000	7	4,298,772	6.12
1,000,000–5,000,000	20	40,425,467	57.54
5,000,000–10,000,000	3	17,685,093	25.17
Total	74	70,256,365	100

Source: Developed by authors using the data from BEPZA

Table 4.3 Potential partner companies for development of symbiosis

	Gas consumption (m^3)			Boiler
Name of enterprises	2010	2011	Average	–
M/S Kenpark Bangladesh (Pvt.) Ltd.	3,810,980	3,857,113	3,834,047	–
M/S Seatex Ltd.	3,142,877	2,478,024	2,810,450	–
M/S Young International (BD) Ltd. (5)	2,556,003	3,036,665	2,796,334	–
M/S Chuji Industrial Co. Ltd. (5)	2,706,925	2,281,883	2,494,404	7(2) ton
M/S Qualitex Industries (BD) Ltd.	1,592,318	2,763,226	2,177,772	8/9 ton
M/S Bangladesh Spinners and Knitter	2,085,231	1,848,079	1,966,655	–
M/S Mithun Knit and Dye (CEPZ) Ltd.	1,977,534	1,573,372	1,775,453	–
M/S Al-Hamidi Textile	1,203,253	1,379,565	1,291,409	–
M/S Youngone Shoe Accessories	1,369,583	1,193,739	1,281,661	–
M/S Merim Co. Ltd. (6A)	1,244,222	1,193,218	1,218,720	7.7(3) KW
M/S Regency Garments Ltd. (UNIT-2)	1,177,111	1,254,603	1,215,857	–
M/S Regency Garments Ltd. (7)/(UNIT-3)	1,069,408	1,257,886	1,163,647	8.15(3) KW
M/S Denim Plus (BD) Ltd.	1,136,982	1,038,774	1,087,878	–
M/S Siams Superior Ltd. (8)	852,546	1,171,902	1,012,224	–

Source: Developed by authors using the data from BEPZA

Table 4.4 Waste heat recovery from flue gas in UPGD

Category	Before recovery	After recovery	Remark
Exhaust gas discharge rate (Nm^3/h)	26,389	26,389	Per unit
Exhaust gas temp. (°C)	530	200	$\Delta t = 330$
Heat value saved (kcal/h)	–	2,873,762	–
Steam conversion (kg/h)	–	4,462	10 kg/cm^2g saturated steam

Source: Developed by authors using the data from BEPZA

Based on the data collected from CEPZ, it was understood that the number of companies that recover their waste heat is very rare in CEPZ. Captive power plants are the common facilities in textile mills for their utility. It was also estimated that ~30 % of thermal energy supplied for power generation to internal combustion engines leaves as waste heat through stack. In CEPZ, electricity is produced by United Power Generation and Distribution (UPGD) and nine companies with captive power plants. Five electricity generators (based on natural gas fuel) in UPGD generate a total of 45 MW (9 MW each). The combustion process in these generators produces flue gas at very high temperature of 500 °C, and these flue gases are emitted into the atmosphere without any heat recovery. The potential of waste heat recovery was calculated at 4.5 ton/h per generator, and it was estimated that a total of 173,448 ton of steam can be generated annually by waste heat recovery from the flue gas in the gas engine generators. Based on the energy audit report, energy recovery potential from captive generators and UPGD was estimated to be 28.5 ~ 44 ton/h as steam (Table 4.4).

4.4 Energy Networking Scenarios in CEPZ

The potential IS opportunities in CEPZ were identified by analyzing the demand for energy (steam and electricity) and identifying potential symbiotic transactions based on the input and output analysis. The networks were mainly explored by top-down and bottom-up approaches. While the top-down approach involves the basic information of 163 companies, geographical information using the map of CEPZ, and the electricity/natural gas/water consumption data collected from BEPZA, the bottom-up approach involves energy audit of 25 companies in CEPZ. The symbiotic networks can be designed based on the Korean R&DB model (Behera et al. 2012) to reduce energy consumption, save fuel, and reduce the emission of carbon and other pollutants. The potential of IS was evaluated in terms of investment, return on investment, and environmental benefits including GHG emission reduction as summarized in Table 4.5.

Table 4.5 Summary of energy IS projects

Cases	Technology	Capex	Energy savings/ GHG mitigation potential	Return on investment
UPGD-to-company IS network	Installation of HRSG at the outlet of the five existing gas engines in United Power to generate steam	2.8 ~ 3.3 million USD (229 ~ 264 million BDT) for a 22 ~ 37.5 TPH HRSG installation	Saving potential of 15 ~ 25 million Nm^3 of LNG	Payback estimated 1.7 ~ 2.5 years
		~0.15 million USD (12.6 million BDT) for pipeline construction	GHG mitigation potential of 33 ~ 57 Thousand tCO_2	Estimated IRR ~18 %
Company-to-company IS network	Installation or operation of HRSG at the outlet of the individual captive generators	~92 thousand USD (7.5 million BDT) for a 1.5 TPH HRSG installation	Saving potential of 3.7 ~ 4.7 million Nm^3 of LNG and/or ~0.4 million liter of diesel	Estimated payback 0.4 ~ 1.7 years
		~59 thousand USD (4.8 million BDT) for pipeline construction	GHG mitigation potential of 9 thousand tCO_2	

Source: Developed by authors using the data from BEPZA

4.4.1 UPGD-to-Company Energy Network

The exhaust gas temperature in the rear part of gas engine generator is as high as 530 °C, which results in significant heat loss. So, recovery of this waste heat from the exhaust gas is suggested. Installation of HRSG (heat recovery steam generator) on the stacks in the rear part of gas engine generators is suggested to generate steam which can be supplied to the companies in CEPZ. As a result, UPGD can earn the revenue in terms of selling the generated steam to different companies in CEPZ. Figure 4.3 shows some of the low-hanging possible networks between UPGD and some companies in CEPZ.

The first option represents UPGD-to-company IS network using waste heat recovery steam generation. By installation of heat recovery steam generator at the outlet of the five existing gas engines in United Power, 22 ~ 37.5 TPH steam can be recovered. This option will save 15 million Nm^3 of natural gas consumption and 33 thousand tCO_2 emission at least, with a less than 3-year payback (about 280 million taka investment). The second option represents company-to-company IS network using the recovered waste heat for steam generation. By installation or even operation of heat recovery steam generator at the existing captive generator in individual

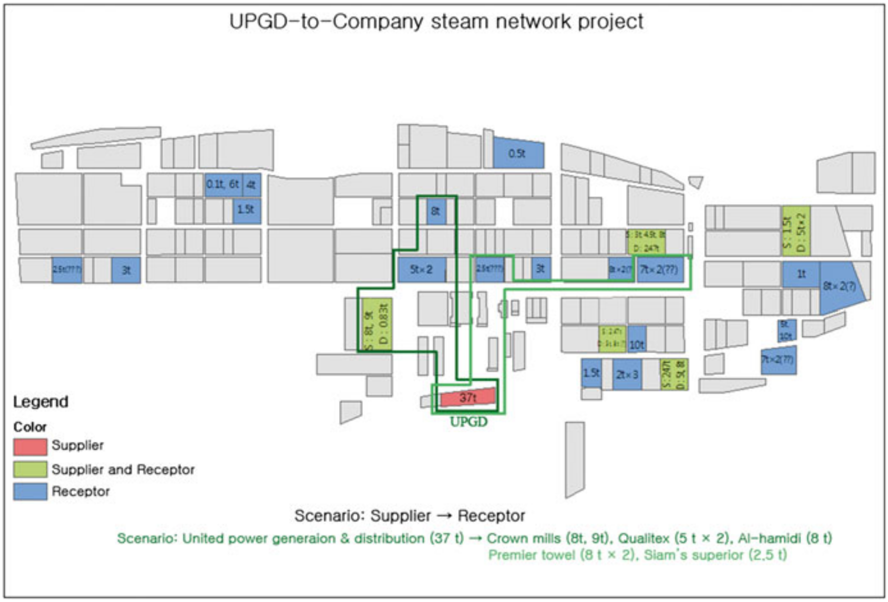

Fig. 4.3 UPGD-to-company energy symbiosis network UPGD

companies, 6 TPH steam can be recovered. This option will save 4 million Nm^3 of natural gas consumption and 9 thousand tCO_2 emission at least, with a less than 2-year payback (about 12 million taka investment). The third and the fourth options represent the solid waste combustion and wastewater reuse IS networks. By installation of incineration plant and purification plant, solid waste and wastewater can be recovered as steam and water. These options can be considered as long-term IS potential solving waste landfill and water shortage problems.

In order to facilitate IS network implementation, priority of potential scenarios for each option has been suggested. The first two options related to energy IS networks have high priorities due to high saving effects and short payback periods. The next two options have lower priorities, because these options require introducing the concept of disposal charge. Therefore, at this point of time, we are focusing on the UPGD-to-company steam IS and company-to-company steam IS network. Figure 4.4 represents the schematic diagram of the proposed IS networks. Figure 4.4 shows the UPGD-to-company steam IS map in CEPZ. Red-colored company represents potential steam supplier, which is UPGD, and the blue-colored companies represent potential steam users. We developed the potential IS scenario including three user companies near UPGD, marked by the dark green line. Recovered steam from UPGD can be supplied to crown mills, Qualitex, and Al-Hamidi. Distances between supplier and user companies lie in between 450 and 650 m. The light green line shows the additional potential IS scenario including Premier Towels and Siams Superior. This scenario can be considered under the expansion of a new generator in the future.

4.4.2 Company-to-Company Energy Network

Figure 4.4 shows the company-to-company steam network scenarios in CEPZ. One of the interesting facts marked by black line is that there is existing IS network of steam and electricity between Karnaphuli Sportswear and Youngone Shoe Accessory. These two companies are a kind of family companies under the Youngone Group. Based on the collected data, we developed several IS scenarios including three potential steam supplier companies possessing captive generators, viz., Universal Jeans, Pacific Jeans, and Karnaphuli Sportswear. The first two IS scenarios marked by purple and pink lines represent steam recovery from Universal Jeans, which is already having a waste heat steam generator. So, only the pipeline installation cost is necessary. Between the two potential steam users, Section Seven Apparels and Merim, Section Seven is preferable because they are now using diesel to produce steam, which is ten times more expensive and environment unfriendly than natural gas.

The next scenario marked by blue lines represents steam recovery from Pacific Jeans to Univogue Garments. Pacific Jeans also have a waste heat steam generator. Therefore, only the pipeline installation cost to Univogue Garments is necessary. The last scenario marked by red line shows steam recovery from Karnaphuli Sportswear to Regency Garments; the distance between these two companies is only 140 m. Nevertheless, these scenarios could be changed or modified during the negotiation and implementation stages.

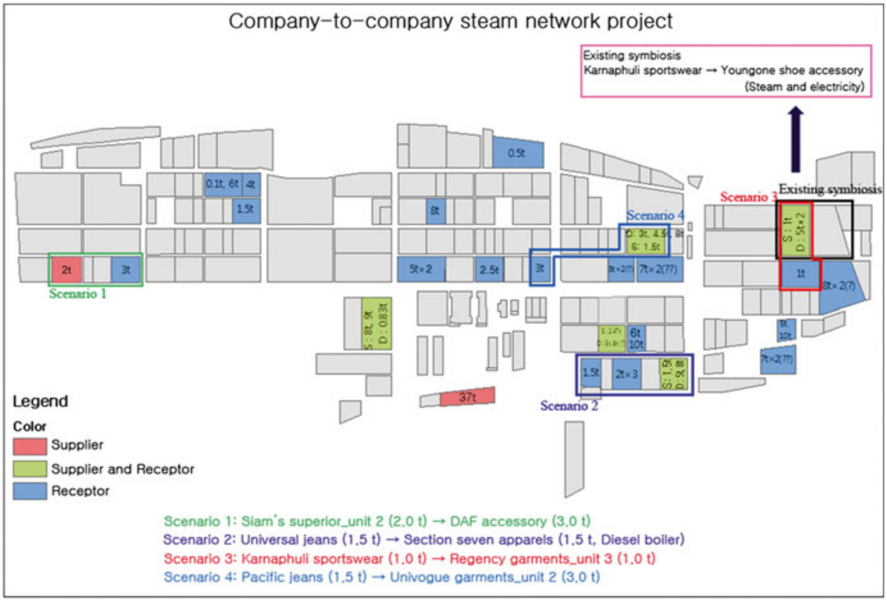

Fig. 4.4 Company-to-company energy symbiosis network

Considering the amount and recycling possibility of waste materials generated at CEPZ, for IS, we should consider combustible waste and wastewater. Because some of the combustible wastes such as fabric, paper, and plastic are being traded for recycling outside CEPZ, there is little chance to build new recycling network at CEPZ using these wastes as raw materials. We should consider waste-to-energy IS network with nonrecyclable combustible wastes. There are two possible approaches for solid waste-to-energy IS network. One is to manufacture refuse-derived fuel (RDF) with combustible wastes and to supply it to steam boilers as a fuel. The other is to combust the wastes in incinerator and recover waste heat to generate steam. As RDF manufacturing is an energy-consuming process, installation of incineration plant using combustible solid waste to generate steam is considered to be a more energy-efficient option.

It is estimated that about 3.5 million USD (288 million BDT) is required to be invested to install a 30 ton/day solid waste treatment facility which can result in 8 TPH steam generation. It can save about 5 million Nm^3 of LNG a year (GHG mitigation potential of 6 thousand tCO_2). The solid waste treatment plant could be located within a place of steam demander, which is located close to big combustible waste generators (Youngone, HKD International, MZM Textile, Sea Tex to Al-Hamidi, Qualitex Industries, and Kenpark). To set up the plant, a minimum of 30 m × 40 m area is required.

With municipal solid waste, Chittagong City Corporation (CCC) can be the supplier for the incineration plant. Including CCC, combustible waste suppliers should pay waste disposal charge to incineration plant operator. Considering the situation of no solid waste disposal charge at CEPZ, introduction of solid waste disposal charge is a prerequisite. Capital investment to the incineration plant could be made by BEPZA, steam demander, and/or CCC. Assuming 1,400 BDT/ton as disposal charge, payback period is estimated to be 11.4 years.

Aside from energy networks, the development of wastewater reclamation and reuse network is another aspect which is related to looming water scarcity, water pollution control measures, and protection of the aquatic environment. BEPZA supplies about 4,000 m^3/day of water, which meets only 20–25 % of water demand in CEPZ. One-third of the facilities operated in CEPZ are commonly found to install and operate their private well on-site to cope with the scarce water supply situation. Therefore, wastewater reclamation and reuse system can be recommended to high water consumption industries such as the dyeing industry for economic and environmental reasons. Reclaimed water can be used for cooling, boiler feeding, stack scrubbing, and process water.

Usually, textile processing facilities generate large quantities of wastewater with a strong color, high concentration of suspended solid, a broadly fluctuating pH, high temperature, and high concentration of chemical oxygen demand (COD). In order to recycle wastewater in textile mills, conventional wastewater treatment methods (biological and chemical treatment) need to be strengthened by additional equipment such as micro-filtration, membrane, or R/O system.

It is estimated that about 0.2 million USD (16 Million BDT) is required to construct a 250 ton/day wastewater treatment facility. It means that wastewater reclamation potential per year is 90 thousand tons. The plant would better be located within factory premises with conventional wastewater treatment with sufficient capacity. Large wastewater generators such as Qualitex Industries (59,521 TPY), Univogue Garments (44,902 TPY), Global Fabrics (23,897 TPY), Peninsula Garment (20,501 TPY), Al-Hamedi Textile (24,551 TPY), Globe Textile Mills (16,084 TPY), and Kang Book (8,626 TPY) can be the supplier in the wastewater recycling network. Also recycled water would better be used by demander near the plant. Implementation of water reclamation and reuse system can largely be influenced by current and future water price. If the water supply and wastewater disposal cost are too low, wastewater recycling would not be economic. So, for realization of wastewater recycling network in CEPZ, adequate water pricing structure is a prerequisite (increase of industrial water price, introduction of wastewater disposal charge). Assuming future water price to be 45 BDT/m^3 and wastewater disposal charge 25 BDT/m^3, payback period is estimated to be 8.71 years.

4.4.3 Potential Energy Saving Through Transfer of Korean Experience to CEPZ

The cost of power in the CEPZ has risen more than five times in the recent past; meanwhile, the demand for electricity continues to rise, making energy efficiency measures an important factor in reducing costs. Moreover, major global purchasers of ready-made garment (RMG) products are increasingly introducing stringent criteria on supply chain partners for greater compliance with climate-friendly green operations.

Preliminary analysis shows that GHG emissions can be significantly reduced in the CEPZ through the use of efficient power production, upgrading of industrial processes, and implementation of an IS network that converts outputs from firms, such as heat or steam, to inputs to be reused by nearby firms. The energy IS opportunity includes steam generation by waste heat recovery from the UPGD and the captive generation companies in CEPZ. As shown in Fig. 4.5, by the introduction of UPGD-to-company IS network, there is a net saving of 14,325 TOE and the company-to-company IS network would result in a saving of 2,865 TOE, both accounting for a total of 17,190 TOE energy saving.

4.5 Recommendations

4.5.1 Short-Term Recommendations

- Continuous awareness, education, and training activities for reaching the consensus on transforming CEPZ to low-carbon EPZ
- Establishment of the Pilot Green Cell in CEPZ to follow up the IS road map by KICOX
- Theoretical and practical capacity building of the engineer in CEPZ on low-carbon, environmental, and energy technology and IS with the support of KICOX

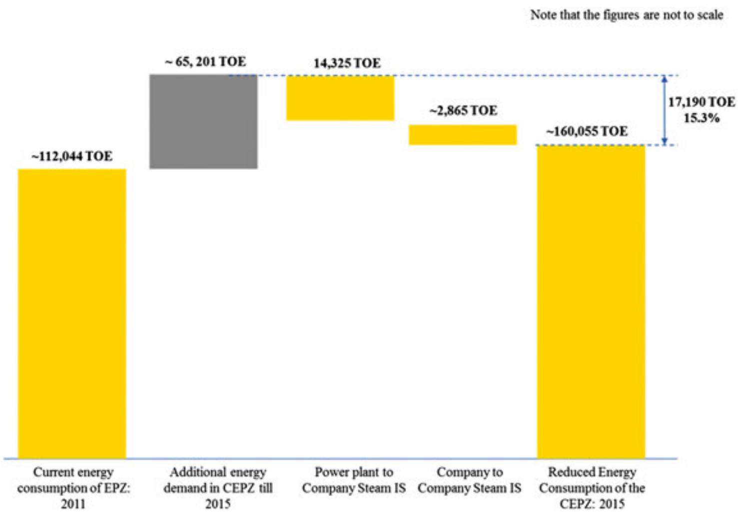

Fig. 4.5 Energy saving through energy IS networks in CEPZ

- Utilizing UPGD-to-company energy networking as a pilot IS implementation project for Bangladesh version of IS manual creation by the Green Cell in CEPZ when permitting the energy networking with the support from KICOX
- Company-to-company IS project proposed in this report can be implemented step by step by the Green Cell in CEPZ with the consultation from KICOX
- Developing strategies such as incentives and disincentives, attracting the stakeholder to participate in IS activities

4.5.2 Mid-/Long-Term Recommendations

- Amendments of the existing national policies to promote energy and resource efficiency by the Government of Bangladesh.
- Introduction of heat recovery framework/guideline by the Government of Bangladesh (BERC, DoE). Adequate waste management regulation introduction: BEPZA can introduce waste management regulation within EPZ with DoE and MoEF. Regulation should include waste generation and disposal reporting system, standards on waste disposal by materials. Information on waste generation can be shared between companies, which pursue better opportunities for IS network.
- Stricter environment management regulation enforcement (DoE, BEPZA): With poor environmental management system in Bangladesh, enterprises hardly can

be motivated to find opportunities to reduce waste generation and reuse and recycle to establish IS network.

- Waste and wastewater disposal charge introduction (DoE, BEPZA): It needs adequate level of waste disposal price (incineration, landfill and wastewater treatment charge) and resource price (water, electricity, etc.). Price polices can motivate enterprises to waste reduction, material efficient process, and IS network.
- Cooperation among BEPZA, enterprises, and Chittagong City Corporation (CCC): BEPZA can play a huge role to find potential IS opportunities between enterprises and to promote them. Sharing information, long-term discussion, and cooperation between stakeholders are necessary to implement IS network. Especially, enterprises association at CEPZ for waste management and IS can help build trust. Also, for economy of scale, industrial and municipal solid waste could be considered together in terms of recycling or treatment facilities investment. So, CCC also should join in the cooperation structure.
- Based on the R&DB feasibility research, regional IS network among companies in CEPZ and Chittagong City should be continuously expanded to achieve low-carbon CEPZ.

4.5.3 Other Miscellaneous Recommendations

- Amendments may be made to the existing national policies to promote energy and resource efficiency.
- Detailed information on interest of the stakeholders toward their participation in the IS networks is required.
- For negotiation and contract, discussion with stakeholders should be carefully managed.
- Design, construction, and maintenance of networks should be carefully monitored.
- The GoB should introduce heat recovery framework guideline.
- Initiatives by the GoB should be taken for establishing IS center inside BEPZA to lead IS execution with public confidence.
- R&DB funding support should be introduced to encourage the industries for participation in IS.
- Commercialization of the IS networks should be deregulated.
- International best practices (viz., industrial park management and EIP business cases in Korea) and acts in support of IS (e.g., Energy Rationalization Act, Integrated Energy Act, Waste Control Act, Waste Recycling Promotion Act, and Water Reuse Act in Korea) should be encouraged in Bangladesh and elsewhere.
- Expansion of IS networks across the boundary of EPZs is necessary to encourage urban symbiosis.

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Chapter 5
Scenario of Urban Transport in Indian Cities: Challenges and the Way Forward

Sanjay Kumar Singh

Abstract Cities and towns play a vital role in promoting economic growth and prosperity. Although less than one-third of India's people live in cities and towns, these areas generate over two-thirds of the country's income and account for 90 % of government revenues. In the coming years, as India becomes more and more urbanized, urban areas will play a critical role in sustaining high rates of economic growth. But economic growth momentum can be sustained if and only if cities function efficiently – that their resources are used to maximize the cities' contribution to national income. City efficiency largely depends upon the effectiveness of its transport systems, that is, efficacy with which people and goods are moved throughout the city. Poor transport systems stifle economic growth and development, and the net effect may be a loss of competitiveness in both domestic and international markets. Although Indian cities have lower vehicle ownership rate, number of vehicles per capita, than their counterparts in developed countries, they suffer from worse congestion, delay, pollution, and accidents than cities in the industrialized world. This chapter provides an overview of urban transport issues and challenges in India. Rather than covering every aspect of urban transportation, it primarily focuses on those areas that are important from policy point of view. The chapter first reviews the trends of vehicular growth and availability of transport infrastructure in Indian cities. This is followed by a discussion on the nature and magnitude of urban transport problems such as congestion, pollution, and road accidents. Building on this background, the chapter discusses the policy measures to improve urban transportation in India.

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5.1 Introduction

India is urbanizing. Its urban population is growing at an average rate of around 3 % per year. The average rate of growth of the urban population is not expected to change significantly during next 10 years or so. Assuming decadal increase of around 32 %, India's urban population is expected to increase from 377 million in 2011 to 500 million in 2021. In terms of percentage of total population, the urban population has gone up from 17 % in 1951 to 31.2 % in 2011 and is expected to increase up to around 35 % by the year 2021.

During the 2000s, 91 million people joined the ranks of urban dwellers – which implies that the growth rate in urban areas remains almost the same during the last 20 years; urban population increased by 31.5 % from 1991 to 2001 and 31.2 % from 2001 to 2011. However, the number of metropolitan cities – those with a million-plus population – has increased sharply over this period. From 35 in 2001, the number of metropolitan rose to 53 according to the Census of India, 2011. Out of these 53, eight cities – Mumbai, Delhi, Kolkata, Chennai, Hyderabad, Bangalore, Ahmedabad, and Pune – have population more than five million. India's big cities now account for a larger share of total urban population – a trend that has been observed since independence. In 2011, the share of metropolitan cities was 42.6 %, up from 37.8 % in 2001 and 27.7 % in 1991.

The distribution of urban population by city size widely varies and is skewed towards larger cities. One specific feature of India's urbanization is the increasing metropolitanization, that is, growth in the number and size of cities with a million-plus population. The trends indicate the continued urbanization and metropolitanization in the years to come. Often, there is a debate as to whether it is an index of development or distress. The very process of urbanization has sometimes been looked as something undesirable. While the objections used to be on social and moral grounds earlier, the criticism lately is more on economic grounds such as provision of requisite infrastructure and civic amenities at rapidly escalating per capita costs (Padam and Singh 2004). Despite all the objections, the rate of urbanization has not even retarded, not to speak of its being halted. Certain inevitability about the process is being accepted steadily. It is now felt that urbanization is necessary for the benefits of sharing modern technology for the growth and development of the entire national economy. In India, urban areas contribute more than 60 % of the national income. In the coming years, as India becomes more and more urbanized, urban areas will play a critical role in sustaining high rates of economic growth.

But economic growth momentum can be sustained if and only if cities function efficiently – that their resources are used to maximize the cities' contribution to national income. Economic efficiency of cities and well-being of urban inhabitants are directly influenced by mobility or the lack of it. City efficiency largely depends upon the effectiveness of its transport systems, that is, efficacy with which people and goods are moved throughout the city. Poor transport systems stifle economic growth and development, and the net effect may be a loss of competitiveness in both domestic and international markets.

Although Indian cities have lower vehicle ownership rate than their counterparts in developed countries, they suffer from worse congestion, delay, pollution, and accidents than the cities in developed countries. In Kolkata, for example, average speed during peak hours in Central Business District (CBD) area goes down as low as around 10 Km/h. The problem of congestion and delays is not only faced by Kolkata but also by most of the big cities which indicates both the amount of time and energy that are wasted and the scale of opportunity for improvement. A high level of pollution is another undesirable feature of overloaded streets. The transport crisis also takes a human toll. Statistics indicate that traffic accidents are a primary cause of accidental deaths in the Indian cities.

The main reason for all these is the prevailing imbalance in modal split besides inadequate transport infrastructure and its suboptimal use. Public transport systems in cities have not been able to keep pace with the rapid and substantial increases in demand over the past few years. As a result, people have turned towards personalized modes such as mopeds, scooters, motorcycles, and cars and intermediate public transport modes such as auto rickshaws, tempos, and taxis. Cities cannot afford to cater only to the private vehicles, and there has to be a general recognition that policy should be designed in such a way that reduces the need to travel by personalized modes and boosts public transport particularly bus transport system. Much needs to be done if public transport is to play a significant role in the life of a city. Measures need to be taken to enhance the quality as well as quantity of public transport services and to impose constraints on the use of private vehicles. People should also be encouraged to use non-motorized transport, and investments may be made to make it safer. It must not be forgotten that cities are the major contributors to economic growth, and movement in and between cities is crucial for improved quality of life (Singh 2005).

5.2 Vehicular Growth and Availability of Transport Infrastructure in Metropolitan Cities

During the year 2011, 142 million vehicles were plying on Indian roads (Table 5.1). According to the statistics provided by the Ministry of Road Transport & Highways, Government of India, the annual rate of growth of motor vehicle population in India has been around 10 % during the last decade. The basic problem is not the number of vehicles in the country but their concentration in a few selected cities, particularly in metropolitan cities. In 2011, vehicle ownership rate in metropolitan cities had crossed the mark of 300 vehicles per 1,000 people, whereas all India average was just more than 100 vehicles per 1,000 people (Figs. 5.1 and 5.2). Vehicle ownership rate in many big cities including Delhi has already crossed the mark of 400 vehicles per 1,000 people (Fig. 5.2). It is interesting to note that nearly 35 % of the total vehicles in the country are plying in metropolitan cities alone, which constitute just around 13 % of the total population. During the year 2011, nearly 17.5 million

Table 5.1 Total number of registered motor vehicles in India: 1951–2011 (in thousands)

Year (as on 31 March)	All vehicles	Two-wheelers	Cars	Buses	Goods vehicles	Others
1951	306	27	159	34	82	4
1961	665	88	310	57	168	42
1971	1,865	576	682	94	343	170
1981	5,391	2,618	1,160	162	554	897
1991	21,374	14,200	2,954	331	1,356	2,533
2001	54,991	38,556	7,058	634	2,948	5,795
2002	58,924	41,581	7,613	635	2,974	6,121
2003	67,007	47,519	8,599	721	3,492	6,676
2004	72,718	51,922	9,451	768	3,749	6,828
2005	81,499	58,799	10,320	892	4,031	7,457
2006	89,618	64,743	11,526	992	4,436	7,921
2007	96,707	69,129	12,649	1,350	5,119	8,460
2008	105,353	75,336	13,950	1,427	5,601	9,039
2009	114,951	82,402	15,313	1,486	6,041	9,710
2010	127,746	91,598	17,109	1,527	6,432	11,080
2011	141,866	101,865	19,231	1,604	7,064	12,102

Source: Transport Research Wing, Ministry of Road Transport & Highways, Government of India, New Delhi. Road Transport Year Book *(2009–10 & 2010–11)*
Note: (1) Cars include jeeps and taxis. (2) Others include tractors, trailers, three-wheelers (passenger vehicles)/LMV, and other miscellaneous vehicles which are not separately classified

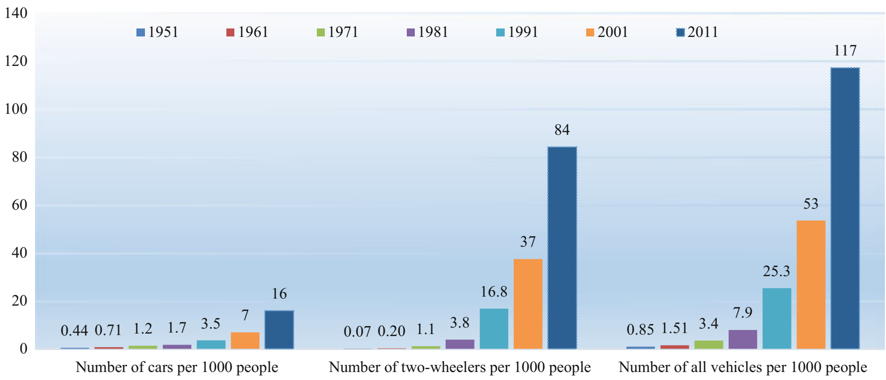

Fig. 5.1 Growth in vehicle ownership in India from 1951 to 2011 (Source: Developed by the author using the data from Road Transport Year Book *(2009–10 & 2010–11)* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

vehicles were plying in four big cities (Delhi, Bengaluru, Chennai, and Hyderabad) alone, which constitute 12.3 % of all motor vehicles in the country (Table 5.2). Delhi, the capital of India, which contains around 1.4 % of Indian population, accounts for nearly 5 % of all motor vehicles in the country.

Traffic composition in Indian cities is of a mixed nature. There is a wide variety of about a dozen types of both slow and fast-moving vehicles. Two-wheelers and

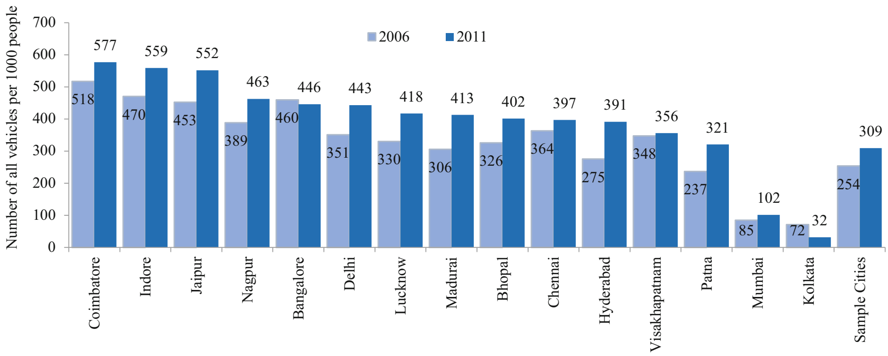

Fig. 5.2 Vehicle ownership rate in selected metropolitan cities in India: 2006–2011 (Source: Developed by the author using the data from Road Transport Year Book *(2009–10 & 2010–11)* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

Table 5.2 Total number of registered motor vehicles in selected metropolitan cities in India: 2006–2011 (year as on 31 March and no. of vehicles in thousands)

Metropolitan cities	2006	2007	2008	2009	2010	2011	CAGR (%) 2006–2011
Bengaluru	2,617	2,179	2,640	3,016	3,491	3,791	7.7
Bhopal	476	524	571	617	674	755	9.7
Chennai	2,338	2,518	2,701	2,919	3,149	3,456	8.1
Coimbatore	750	827	910	1,002	1,110	1,241	10.6
Delhi	4,487	5,492	5,899	6,302	6,747	7,228	10.0
Hyderabad	1,522	2,181	2,444	2,682	2,728	3,033	14.8
Indore	771	844	929	1,007	1,098	1,213	9.5
Jaipur	1,051	1,177	1,289	1,387	1,549	1,694	10.0
Kolkata	948	987	573	581	411	445	−14.0
Lucknow	750	801	962	1,025	1,107	1,211	10.1
Madurai	364	402	440	478	530	603	10.6
Mumbai	1,394	1,503	1,605	1,674	1,768	1,870	6.1
Nagpur	824	884	946	1,009	1,079	1,157	7.0
Patna	405	437	471	516	581	658	10.2
Visakhapatnam	462	472	515	559	586	617	5.9
Sample cities	19,159	21,228	22,895	24,774	26,608	28,972	8.6

Source: Transport Research Wing, Ministry of Road Transport & Highways, Government of India, New Delhi. Various Issues. Road Transport Year Book
Note: (1) CAGR indicates compound annual growth rate. (2) From 2007 to 2008, there is a sudden drop in no. of vehicles registered in Kolkata because the Calcutta High Court in July 2008 ordered a ban on commercial vehicles registered before January 1, 1993, from Kolkata and its outskirts

cars account for over 85 % of the vehicle population in most of the metropolitan cities. For example, among the selected cities given in Table 5.3, two-wheelers and cars account for over 85 % of the vehicle population in all the cities except Patna. Moreover, they account for at least 90 % of total vehicles in Bhopal, Coimbatore, Delhi, Lucknow, and Nagpur. Two-wheelers alone account for more than 80 % of

Table 5.3 Private transport vehicles in selected metropolitan cities in India: 2006 and 2011 (year as on 31 March and no. of private transport vehicles in thousands)

Metropolitan cities	Two-wheelers (2006)	Two-wheelers (2011)	Two-wheelers CAGR (%) 2006–2011	Cars (2006)	Cars (2011)	Cars CAGR (%) 2006–2011
Bengaluru	1,897	2,625	6.7	400	711	12.2
Bhopal	387	603	9.3	37	81	17.1
Chennai	1,593	2,398	8.5	393	599	8.8
Coimbatore	631	1,023	10.2	74	138	13.1
Delhi	2,852	4,395	9.0	1,223	2,116	11.6
Hyderabad	1,141	2,144	13.5	189	491	21.0
Indore	605	930	9.0	66	128	14.1
Jaipur	790	1,248	9.6	116	208	12.5
Kolkata	420	182	−15.4	364	195	−11.7
Lucknow	637	971	8.8	88	166	13.6
Madurai	300	494	10.4	21	38	13.2
Mumbai	714	1,045	7.9	409	563	6.6
Nagpur	696	968	6.8	54	89	10.7
Patna	280	448	9.9	45	85	13.4
Visakhapatnam	384	470	4.1	31	63	15.1
Sample cities	13,325	19,944	8.4	3,510	5,671	10.1

Source: Transport Research Wing, Ministry of Road Transport & Highways, Government of India, New Delhi. Various Issues. Road Transport Year Book

the total vehicles in number of metropolitan cities. For example, among the selected cities given in Table 5.3, in Nagpur (84 %), Coimbatore (82 %), Madurai (82 %), Bhopal (80 %), and Lucknow (80 %), two-wheelers accounted for at least 80 % of the total vehicles. Analysis of data presented in Tables 5.3 and 5.4 reveals that, during the year 2011, the share of buses is negligible in most of the Indian cities as compared to personalized vehicles. For example, two-wheelers and cars together constitute at least 90 % of the total vehicles in Lucknow (94 %), Coimbatore (94 %), Bhopal (91 %), Nagpur (91 %), and Delhi (90 %), whereas in these cities, buses constitute only 0.3 %, 0.5 %, 0.5 %, 0.4 %, and 0.6 %, respectively.

Table 5.5 presents existing modal split in terms of percentage of trips made on different modes including walking and bicycling across Indian cities. When compared with desirable level of modal split (Table 5.6), it was found that the share of mass transport is well below the desired range whereas the share of personalized transport and para transit is already above the optimal range in most of the Indian cities. What is worse is that the modal split does not appear to be moving in the right direction. Tables 5.3 and 5.4 reveal that, from 2006 to 2011, the growth in two-wheelers and cars is significantly higher than the growth in buses in most of the metropolitan cities. For example, in Mumbai, from 2006 to 2011, the number of cars increased at the rate of 8 % per year, whereas the number of buses grew only at the rate of 1 % per year.

Table 5.4 Public transport vehicles in selected metropolitan cities in India: 2006 and 2011 (year as on 31 March and no. of public transport vehicles in thousands)

Metropolitan cities	Taxis (2006)	Taxis (2011)	Taxis CAGR (%) (2006–2011)	Buses (2006)	Buses (2011)	Buses CAGR (%) (2006–2011)
Bengaluru	24.1	41.2	11.3	13.2	28.3	16.4
Bhopal	9.0	17.9	14.8	2.9	3.6	4.3
Chennai	41.0	72.4	12.1	28.6	37.2	5.4
Coimbatore	5.0	14.2	23.3	3.3	5.7	11.6
Delhi	13.5	62.8	36.1	25.4	45.8	12.5
Hyderabad	5.2	29.5	41.5	2.8	25.3	55.5
Indore	17.1	32.2	13.5	5.7	7.2	4.9
Jaipur	9.4	20.4	16.9	16.4	22.1	6.2
Kolkata	38.0	30.8	–4.1	10.5	4.2	−16.6
Lucknow	6.5	5.4	–3.7	3.8	3.0	–4.2
Madurai	7.4	12.8	11.7	3.0	5.2	11.7
Mumbai	58.0	50.9	–2.6	12.3	12.8	0.9
Nagpur	1.0	2.7	21.4	4.5	4.9	1.5
Patna	3.2	9.1	23.5	4.2	5.7	6.2
Visakhapatnam	4.4	8.0	12.6	1.0	1.5	10.0
Sample cities	243	410	11.1	138	213	9.1

Source: Transport Research Wing, Ministry of Road Transport & Highways, Government of India, New Delhi. Various Issues. Road Transport Year Book

Table 5.5 Existing modal split in Indian cities (as a %age of total trips)

City population (in million)	Walk	Mass transport	IPT		Car	Two-wheeler	Bicycle	Total
			Fast	Slow				
0.10–0.25	37.1	16.4	10.4	20.1	3.3	24.1	25.7	100.0
0.25–0.50	37.8	20.6	8.9	17.2	2.6	29.8	20.9	100.0
0.50–1.0	30.7	25.4	8.2	12.0	9.5	29.1	15.9	100.0
1.0–2.0	29.6	30.6	6.4	8.1	3.3	39.6	12.1	100.0
2.0–5.0	28.7	42.3	4.9	3.0	5.0	28.9	15.9	100.0
5.0 plus	28.4	62.8	3.3	3.7	6.1	14.8	9.4	100.0

Source: Singh (2005)

Table 5.6 Desirable modal split for Indian cities (as a %age of total trips)

City population (in million)	Mass transport	Bicycle	Other modes
0.1–0.5	30–40	30–40	25–35
0.5–1.0	40–50	25–35	20–30
1.0–2.0	50–60	20–30	15–25
2.0–5.0	60–70	15–25	10–20
5.0 plus	70–85	15–20	10–15

Source: Singh (2005)

Moreover, availability of transport infrastructure is not only inadequate but also used suboptimally in Indian cities. The area occupied by roads and streets in Class I cities (population more than 100,000) in India is only 16.1 % of the total developed area, while the corresponding figure for the United States of America is 28.19 % (Singh 2005). In general, the road space in Indian cities is grossly insufficient. To make the situation worse, most of the major roads and junctions are heavily encroached by parked vehicles, roadside hawkers, and pavement dwellers. As a consequence of these factors, already deficient space for movement of vehicles is further reduced.

The present urban rail services in India are extremely limited. Only four cities – Mumbai, Delhi, Kolkata, and Chennai – are served by suburban rail systems. The rail services in these four main cities together carry more than seven million trips per day. Interestingly, the Mumbai Suburban Rail System alone carries about 5.5 million trips per day. A few other cities also have limited suburban rail systems, but they hardly meet the large transport demand existing in these cities.

Although, few years back, bus transport services were available mainly in the cities located in southern and western regions of India, they are now available in most of the metropolitan cities, thanks to the Government of India's Jawaharlal Nehru National Urban Renewal Mission (JNNURM). Services are mostly run by publicly owned State Transport Undertakings (STUs) or Municipal Transport Undertakings (MTUs). Most of the passenger buses use the standard truck engine and chassis and hence are not economical for city use. There are very few buses in India specifically designed for urban conditions. Qualitatively, the available urban mass transport services are overcrowded and unreliable and involve long waiting periods. Overcrowding in the public transport system is more pronounced in large cities where buses, which are designed to carry 40–50 passengers, generally carry double the capacity during peak hours. As a result, there is a massive shift towards personalized transport, especially two-wheelers, and proliferation of various types of intermediate public transport modes such as auto rickshaws, tempos, and taxis (Figs. 5.3 and 5.4).

5.3 Vehicular Emission, Congestion, and Road-Safety Issues

The Indian metropolitan cities are facing serious environmental problem due to growing air pollution caused by fuels used in vehicles. Atmospheric pollutants commonly associated with motor vehicles are nitrogen oxides, hydrocarbons, carbon monoxide, sulfur oxides, and suspended particulate matters (SPM). Pollutants from vehicular emission have various adverse health effects (see Table 5.7 for details). One of the main pollutants, SPM particularly fine PM, has serious health effects. The ambient air pollution in terms of SPM in many metropolitan cities in India exceeds the limit set by World Health Organization (Singh 2008). Of a total of 127 cities monitored under the National Air Quality Monitoring Programme, only three have low air pollution, and 101 cities report at least one pollutant exceeding the annual average air quality standard (Central Pollution Control 2009). In fact, air pollution in many of India's cities has become atrocious and has already had serious health effects, especially in the form of respiratory diseases.

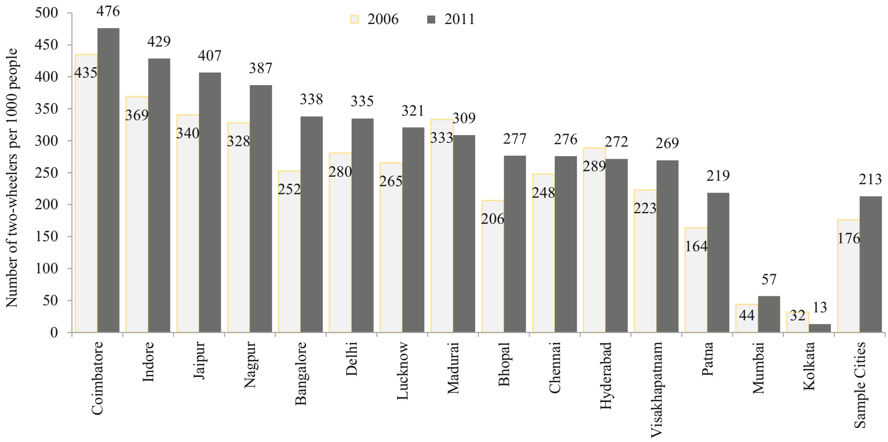

Fig. 5.3 Two-wheeler ownership rate in selected metropolitan cities in India: 2006–2011 (Source: Developed by the author using the data from Road Transport Year Book *(2009–10 & 2010–11)* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

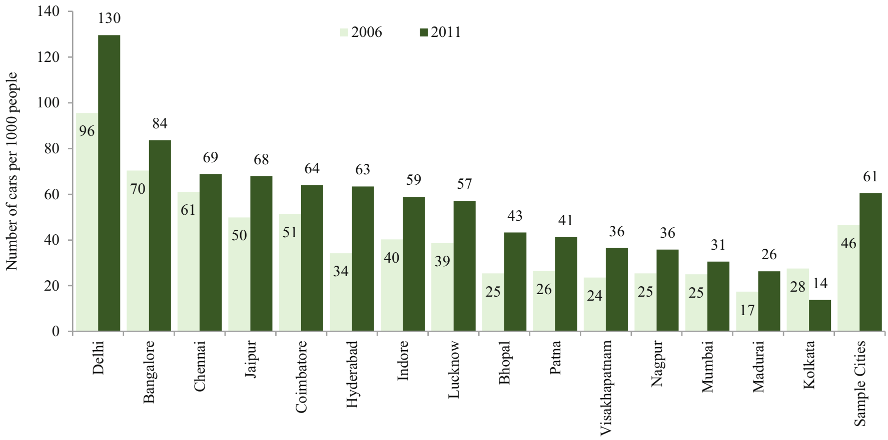

Fig. 5.4 Car ownership rate in selected metropolitan cities in India: 2006–2011 (Source: Developed by the author using the data from various issues of *Road Transport Year Book* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

There is a direct relationship between transport system and air pollution in a city. Vehicular emissions depend on vehicle speed, vehicle-km, age of vehicle, and emission rate. In general, the average peak-hour speed in Indian cities is far less than the optimum one. Growing traffic and limited road space have reduced peak-hour speeds to 5–10 Km/h in the central areas of many major cities. The quantity of all the three major air pollutants (namely, nitrogen oxides, hydrocarbons, and carbon monoxide) drastically increases with reduction in motor vehicle speeds. For example, at a speed of 75 Km/h, emission of carbon monoxides is 6.4 gm/veh.-km, which increases by five times to 33.0 gm/veh.-km at a speed of 10 Km/h. Similarly, emission of other

Table 5.7 Adverse health effects from vehicular emissions

Pollutant	Health effect
Carbon monoxide (CO)	This gas is created when fuels containing carbon are burned incompletely. Fetuses and persons afflicted with heart disease are at greater risk. CO hinders oxygen transport from the blood into the tissues. Therefore, more blood is required to be pumped to deliver the same amount of oxygen. Healthy individuals are also affected at higher levels of CO exposure. Large dose of CO can be fatal
Sulfur dioxide (SO_2)	This gas is created when fuel containing sulfur is burnt. High concentration of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. This gas mainly affects the functions of lungs
Suspended particulate matter (SPM)	At high concentration, particulate matter can adversely affect human health. There are two classifications of particulate matter: PM_{10} and $PM_{2.5}$. All particles smaller than 10 μm in diameter are classified as PM_{10} or coarse size particles. Fine size particles or $PM_{2.5}$ are those particles less than or equal to 2.5 μm in diameter. Diesel vehicle exhaust is the main source of PM in urban areas. These particles penetrate deeply into the lungs and are captured by lung tissue. The most dangerous aspect of PM pollution from diesel vehicles is the hundreds of different chemicals that are adsorbed to the particle. Exposure to PM pollution has been associated with respiratory and cardiac problems, infections, asthma attacks, lung cancer, and decreased life expectancy. Fine particulate (<2.5 μm) is thought to be more dangerous because of its ability to penetrate deeper into lung tissue
Nitrogen oxides (NO_x)	Nitrogen oxides contribute to the formation of ozone, production of particulate matter pollution, and acid deposition. Diesel engines produce a disproportionately large amount of NO_x when compared to gasoline engines because of their high temperature combustion process. Nitrogen dioxide has been shown to irritate lung tissue, cause bronchitis and pneumonia, and reduce resistance to respiratory infections. The health effects of ozone are magnified in the presence of nitrogen dioxide. Frequent or long-term exposure to high levels of nitrogen oxides can increase the incidence of acute respiratory illness in children
Hydrocarbons (HC)	Hydrocarbons are a class of reactive organic gases which are formed solely of hydrogen and carbon. The incomplete burning of any organic matter such as oil produces hydrocarbons. They contribute to the formation of ozone and the resulting smog problem. The primary health effect of hydrocarbons results from the formation of ozone and its related health effects
Air toxics	Air toxics are generally organic chemicals, including some hydrocarbons that are highly evaporative in nature. Benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein are typical examples of air toxics. Air toxics are pollutants that cause or are suspected of causing cancer in those exposed to them. Benzene has been shown to cause aplastic anemia and acute myelogenous leukemia. Known health concerns related to aldehydes include cancer, asthma, and respiratory tract irritation. It is also believed that these air toxics have impacts on the reproductive system by causing chromosomal aberrations or mutations. The health effects of particulate matter from diesel exhaust are thought to be attributable to the many air toxics that are adsorbed to the particles. These small particles penetrate deeply into the lungs and are the perfect vehicle for delivering air toxics into the body

Source: Singh (2008)

pollutants increases with the reduction in vehicle speed. Thus, prevalent traffic congestion in Indian cities particularly during peak hour not only increases the delay but also increases the pollution level. Problem is aggravated due to high average age and poor maintenance of vehicles (see Table 5.8 for age profile of on-road vehicles in India). With inadequate availability of mass transport services and increasing use of personalized motor vehicles, vehicular emission is assuming serious dimensions in most of the Indian cities (see also Table 5.9). It is amply clear that among various modes of road-based passenger transport, bus occupies less road space and causes less pollution per passenger-km than personalized modes (Table 5.10). This reveals the importance of bus transport in improving the air quality in urban areas.

India is also facing serious road accident problems. In 2011, latest year for which data is available, 142,485 people died and 511,394 people got injured due to road accidents. In a dubious distinction, India is the only country in the world which faces more than 16 fatalities and 58 injuries every hour as a consequence of road crashes. While in many developed and developing countries, including China, the situation is generally improving, India faces a worsening situation. During the last 10 years, road accidental fatalities in India have increased at the rate of 5.8 % per year, while the population of the country has increased only at the rate of 1.6 % per

Table 5.8 Age profile of on-road vehicles in India

Vehicle type	<5 years (%)	6–10 years (%)	11–15 years (%)	16–20 years (%)	20–25 years (%)	>25 years (%)
Two-wheelers	48.7	27.2	14.3	7.8	1.8	0.3
Cars	50.3	29.5	12.9	6	1.1	0.2
LCV	36.8	21.5	26.5	11.3	3.2	0.8

Source: Status of the vehicular pollution control programme in India (March 2010). Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India

Table 5.9 Estimated vehicular emission load in selected metropolitan cities in India

Name of the city	Vehicular pollution load (tons per day)				
	Particulates	Oxide of the nitrogen	Hydrocarbons	Carbon monoxide	Total
Agra	0.9	3.3	10.3	17.9	32.4
Bengaluru	8.1	29.7	117.4	207.0	362.2
Chennai	7.3	27.3	95.6	177.0	307.2
Delhi	12.8	110.5	184.4	421.8	729.4
Hyderabad	8.0	36.9	90.1	164.0	298.9
Kanpur	1.9	7.3	11.7	28.7	49.6
Kolkata	10.8	54.1	47.6	137.5	250.0
Mumbai	10.6	46.4	89.9	189.6	336.4
Grand total	60.4	315.4	647.0	1343.5	2366.3

Source: Status of the vehicular pollution control programme in India (March 2010). Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India

Table 5.10 Pollution rate and congestion effect of private and public transport vehicles

Type of vehicle	Average passenger per vehicle	Pollution load in gm/pass.-km	Congestion effect in PCU/pass.
Two-stroke two-wheeler petrol engine	2	7.13	0.375
Four-stroke two-wheeler petrol engine	2	4.76	0.375
Car with catalytic converter petrol engine	4	0.93	0.25
Bus with diesel engine	40	1.00	0.075

Source: Singh (2008)
Note: *PCU* Passenger Car Unit where 1 car = 1 PCU, 1 bus = 2.5 PCU, 1 scooter = 0.75 PCU, etc.

Table 5.11 Comparison of international fatality rates (2007/2008)

Country	Motorization rate (no. of vehicles per 1,000 people)	Fatality rate (no. of fatalities per 10,000 vehicles)	Fatality risk (no. of fatalities per 100,000 people)
India (2011)	117	10.0	11.8
Germany (2007)	534	0.9	6.0
Japan (2007)	593	0.8	5.2
New Zealand (2008)	733	1.1	8.6
Sweden (2008)	522	0.9	5.2
United Kingdom (2008)	525	0.9	5.4
USA (2007)	843	1.6	13.6

Sources: (1) Comparison of International Fatality Rates, Monash Injury Research Institute, Monash University, Australia (available at www.monash.edu.au/miri/research/reports/papers/fatals.html). (2) Motor vehicles (per 1,000 people), World Bank Data, The World Bank (available at http://data.worldbank.org/indicator/IS.VEH.NVEH.P3)

year. Consequently, fatality risk, road accidental deaths per 100,000 people, has increased from 7.9 in 2001 to 11.8 in 2011. Despite low level of motorization, India faces very high level of fatality risk in comparison to developed countries (see Table 5.11). Fatality risk in India is not only twice than that in some of the developed countries such as Sweden, the United Kingdom, and Japan but also still increasing rapidly. If the trend continues, the total number of road traffic deaths in India would increase by 100 % between 2011 and 2025.

Moreover, most of the metropolitan cities in India face relatively high burden of road traffic accidents in comparison to their mofussil counterparts. Also, there is a huge variation in fatality risk across cities of India, ranging from 3.0 fatalities per 100,000 people for Kolkata to 24.7 fatalities per 100,000 people for Patna in 2011 (see Fig. 5.5). During the same year, among the selected metropolitan cities, Patna (24.7), Visakhapatnam (23.9), Indore (19.6), and Lucknow (17.8) faced more than 50 % higher fatality risk than the all India average (11.8). From 2006 to 2011, fatality risk in four out of 15 selected metropolitan cities increased at higher rate than that in the country (9.5–11.8). Patna faced the highest increase in fatality risk (7.3–24.7) followed by Bhopal (8.7–15.9), Indore (12.5–19.6), and Visakhapatnam (20.7–23.9).

Figure 5.6 presents fatality rate across selected Indian metropolitan cities for the years 2006 and 2011. In 2011, fatality rate varied from 1.5 fatalities per 10,000 vehicles for Hyderabad to 9.4 fatalities per 10,000 vehicles for Kolkata. From 2006 to 2011, fatality rate has declined for most of the selected metropolitan cities. The decline is in line with expectation since as motorization increases, fatality rate decreases (Smeed 1972; Kopits and Cropper 2005). However, fatality rate in almost

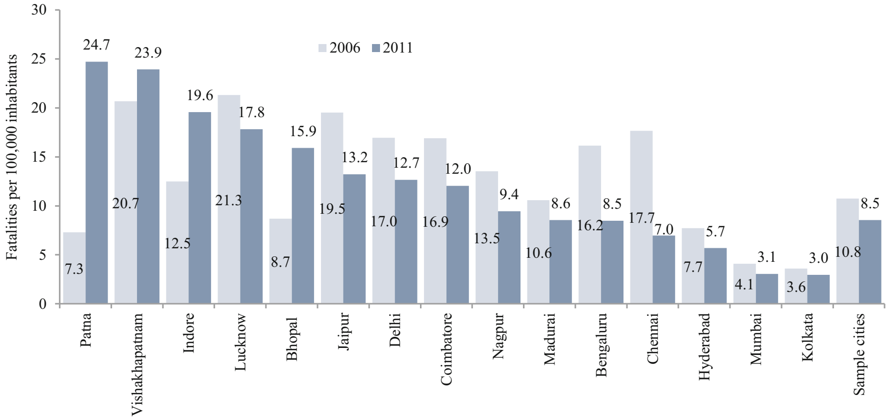

Fig. 5.5 Road accident fatality risk in selected Indian metropolitan cities in 2006 and 2011 (Source: Developed by the author using the data from *Road Transport Year Book 2006–07* and *Road Accidents in India 2011* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

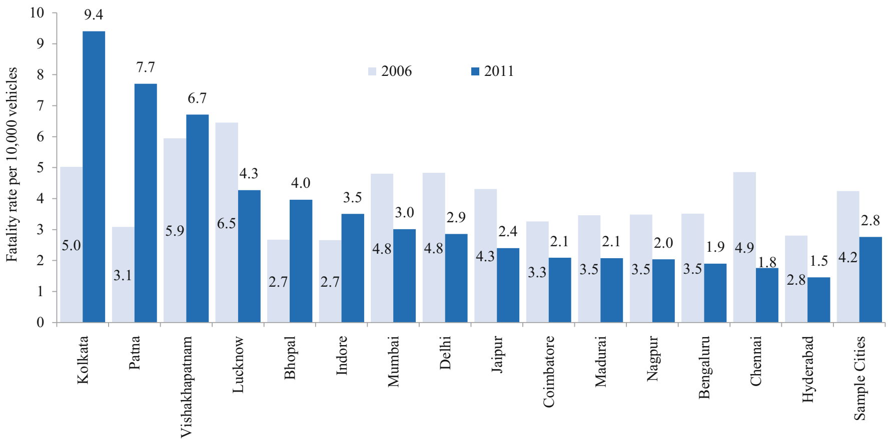

Fig. 5.6 Road accident fatality rate in selected Indian metropolitan cities in 2006 and 2011 (Source: Developed by the author using the data from *Road Transport Year Book 2006–07* and *Road Accidents in India 2011* published by the Ministry of Road Transport & Highways, Government of India, New Delhi)

Table 5.12 Pedestrian and motorized two-wheeler fatalities as a percentage of total road accident fatalities

City/country	Pedestrian	Motorized two-wheeler
Delhi, India (2009)	23	34
Kolkata, India (2009)	58	15
Mumbai, India (2009)	29	22
Australia (2009)	13	15
European Union (2009)	18	17
Japan (2004)	26	15
Singapore (2005)	24	55
USA (2009)	12	13

Source: Singh (2012)

all Indian cities is still higher than that in the developed countries. Fatality rate in many developed countries is less than one fatality per 10,000 vehicles (see Table 5.11).

The nature of road accident problem in Indian cities is different in many ways from that in their counterparts in the developed countries. Pedestrians, bicyclists, motorcyclists, and non-motorized vehicle occupants are often the most vulnerable in Indian cities, unlike cities from developed world where car and public transport users are the most vulnerable (see Table 5.12). Since pedestrians, cyclists, and non-motorized transport users are often from the lower socioeconomic groups, road accidents in Indian cities have a disproportionate impact on the poor and vulnerable in society (Singh 2009).

Why is the road-safety situation so bad in so many cities of India? The main reason for this appears to be the prevailing imbalance in modal split, inadequate transport infrastructure and its suboptimal use, and the lack of effective road-safety policies. Very few cities of India have an adequate public transport system. People rely primarily on personalized modes such as cars and two-wheelers, para-transit modes such as auto rickshaws and tempos, and non-motorized transport modes such as tricycles, bicycles, and walking. In most of the cities, two-wheelers and cars account for over 85 % of the motorized vehicle population, whereas the share of buses is negligible in comparison to personalized vehicles. In general, the road space in cities is grossly insufficient. There is hardly any provision for pedestrians and cyclists to safely use the road. Lane marking and traffic signs are usually missing, and the intersections often require geometric correction. To make the situation worse, most of the major roads and junctions are heavily encroached by parked vehicles, roadside hawkers, and pavement dwellers. As a consequence of these factors, already deficient space for movement of vehicles is further reduced.

The problem of traffic accidents gets aggravated because of mixed nature of traffic composition. Busy roads often carry a mix of fast-moving motor vehicles along with cyclists, pedestrians, and other non-motorized transport users. The experience shows that fatalities are concentrated around roads that are not fit for their purpose of carrying mixed streams of traffic safely. Many cities have somewhat dysfunctional roads with all the features that aggravate the traffic injuries and fatalities. Features such as roads with traffic volumes and speeds that they were not designed for, high proportion of young and inexperienced drivers, and high proportion of non-motorized transport users in the same road space are prevalent in a number of cities.

Also, there is a lack of effective road-safety policies in India. Even simple measures like use of seat belts and helmets, mandatory according to the Motor Vehicle Act 1988, are not properly enforced. One can get not only a driving license without having an adequate driving skill, but also drive the vehicle under the influence of alcohol particularly in smaller cities and towns. It is not uncommon to see over-speed and rash driving on city roads. Some of the city authorities are even unable to tackle the problem of stray cattle on the roads, which often jeopardize the safety of road users.

5.4 The Way Forward

5.4.1 Promoting Regional Economies and Compact Townships

There is a need to promote not only regional economies in such a way that reduces the need for long-distance travel but also self-sufficient compact townships which would reduce the need for short-distance travel within the cities. The promotion of regional economies should be complemented by the creation of compact settlement structures with the provision of shopping, services, and recreational facilities and work opportunities close to where people live, so that the trip distance is kept short. In other words, wherever possible, "towns of short distances" should be promoted (Singh 2006). There are many benefits of the compact township over urban sprawl, which include less car and two-wheeler dependency, thus lower emissions, reduced energy consumption, better public transport services, better accessibility, less traffic accidents, and better quality of life.

5.4.2 Focusing on Public Transport Particularly Bus Transport

Passenger mobility in urban India relies heavily on its roads. Although rail-based transport services are available in few mega cities, they hardly play any role in meeting the transport demand in the rest of the million-plus cities. The time has come to plan rail-based mass transport system in all the cities having population more than two million. However, considering the financial health of various levels of governments (central, state, and local governments) and investment requirement to introduce and improve rail-based public transport system, it is evident that bus transport will have to play a major role in providing passenger transport services in all million-plus cities. Therefore, urban transport plans should specially emphasize on bus transport system.

Table 5.13 Vehicle taxation in Indian cities

Vehicle tax (Rs. per year)	Lucknow	Delhi	Bangalore	Hyderabad	Ahmedabad
For a car priced at Rs. 4 lakh	667	533	2,400	2,400	1,333–2,000
For a public transport bus	7,880	13,675	108,000	5 % of the gross traffic earnings	7,092

Source: Centre for Science and Environment (2009)

Government regulation and control have exacerbated the poor operational and financial performance of publicly owned urban transport undertakings, which are the main provider of bus transport services in Indian cities. As cost of operation rises, transport system comes under financial pressure to raise fares, but politicians are under pressure to keep fares at existing levels. Unless the system is subsidized, it has to eliminate some of its less profitable or loss-making services. In democracy, politicians are bound to yield to pressure from those whose services are threatened and to insist on maintaining money-losing operations. Due to this, transport undertakings find it difficult to raise their revenue sufficient enough to meet the cost of operation.[1] In addition, they have to provide concessional travel facilities to various groups such as freedom fighters, journalists, students, etc., besides paying a high level of different kinds of taxes. The total tax burden for public transport vehicles per vehicles-km is 2.6 times higher than that for private vehicles (Table 5.12). It is increasingly becoming very difficult for loss-making urban transport undertakings to augment and manage their fleet, in turn leading to poor operational performance and deterioration in quality of services (Table 5.13).

With few exceptions, publicly owned urban transport undertakings in India operate at higher unit costs than comparable transport operations controlled by the private sector. Kolkata provides an opportunity to make a direct comparison between privately owned and publicly owned bus system. Public buses are operated by the Calcutta State Transport Corporation (CSTC), with fleet size of almost 1,000 buses and staffing ratio per operational bus of around 12. CSTC's bus productivity is hardly 100 km per bus per day, and its fuel productivity is less than 3.5 bus-kilometers per liter of diesel. As a result of low productivity, CSTC requires a huge subsidy since revenues cover only 26 % of the costs.[2] On the other side, there are nearly 2,000 private buses in the city. These buses are operated mainly by small companies or individual owners grouped into a number of route associations. Fares for private and public bus services are the same. Despite the similarity in fare rates, private operators have been able to survive financially without any government subsidy. Their success is attributed to high level of productivity, which is reflected in low staffing ratios and high fleet availability. The private bus operators in Kolkata,

[1] During the years 2010–2011, publicly owned urban bus transport undertakings in India incurred an accumulated loss of Rs. 32,695 million which is equivalent to a loss of Rs. 20.20 per bus-km.

[2] CSTC incurred a total cost of Rs. 2,514 million, whereas its total revenue was only Rs. 654 million during the years 2010–2011.

who hold almost two-thirds of the market, play a major role in meeting the demand and thus substantially reducing the financial burden on the state government. Furthermore, publicly owned urban transport undertakings often lack the flexibility of organization, the ability to hire and fire staff, or the financial discretion needed to adapt to changing conditions. In such circumstances, a policy which encourages private participation in the provision of bus transport services should be welcomed. One should note that there is an urgent need for restructuring of public transport system in Indian cities to enhance both quantity and quality of services.

Private participation in the provision of bus transport services has been very successful in Indore and Surat. Indore, which did not have a public transportation system until 2006, now has a city bus service with 104 buses run by a special purpose vehicle (SPV), the Indore City Transport Services Ltd. (ICTSL). ICTSL was set up in December 2005 by the Indore Municipal Corporation and the Indore Development Authority to operate and manage the public transport system through public-private partnership (PPP). It runs buses on 24 routes with 300 bus stops built on build-operate-transfer (BOT) basis. The marketing of bus services is done by a vendor who issues at least 15,000 monthly and daily passes at agreed rates every month, ensuring a monthly income of Rs. 4 million for the ICTSL. ICTSL has been making profits since its inception, and its profit has increased from Rs. 3.4 million in 2006–2007 to Rs. 10 million in 2009–2010. Surat is another successful example of private participation in the provision of bus transport services. Surat has 125 buses running on 44 routes, carrying 70,000 passengers daily. There are 87 bus stops on BOT basis, each earning a revenue of Rs. 40,000 per year. The urban local body gets a premium of Rs. 20,000 per bus from the operator for the contract period of 5 years. All city buses run on CNG and are owned, operated, and maintained by private operators. In both cases, Indore and Surat, operation of the bus services has been outsourced to the private sector, while the Municipal Corporations have found innovative ways of investing in public transport infrastructure and traffic monitoring systems of regulation and enforcement (Ahluwalia et al. 2011). This model of bus transport system may be adopted by all those cities where there is poor availability of public transport services.

5.4.3 Introducing Variety of Bus Transport Services

There is a need for variety of bus transport services. Given the opportunity, people reveal widely divergent transport preferences, but in many places authorities favor a basic standard of bus transport services. Presently, it is increasingly difficult to achieve good market acceptance with a single type of product. Bus transport operators operating in Indian cities still believe that the vast majority of its users make the same type of commuting trips every day and so promote package that essentially assume this regularity. It may be possible that the current users of bus transport services have such regular pattern of use, but certainly many of those that have left it had varying mobility needs that they felt poorly satisfied either by the services themselves or by the price deals available. Therefore, it is required to segment the supply of bus transport system to provide different services for different people and even to the same person at different occasions.

5.4.4 Improving the Efficiency of Bus Transport Operation

A serious effort should be made to improve the productive efficiency of bus transport operators so that they can enhance both quality and quantity of bus transport services. It is recognized that some form of competitive pressure is needed to ensure that a serious effort is made towards productive efficiency. This competitive pressure may be obtained either through direct competition for the market or through some form of systematic comparison with similar operators. Direct competition for the market, for example, through periodic tenders for the right to supply the service in a partly or totally protected environment, is more appropriate for cities where presently there is no bus transport operation. In this case, private operators may be encouraged to provide the service where a negative result will mean loss of business for the incumbent operator. This will have a competitive pressure on the operator to improve productive efficiency. Benchmarking, i.e., systematic comparison with similar operators, can effectively be used to improve the productive efficiency of publicly owned urban transport undertakings where a negative result will mean loss of job for the managers and some of the staff. This will improve productive efficiency of bus transport operation in those cities which are served by publicly owned transport undertakings.

5.4.5 Adopting Optimal Pricing Strategies for Transport Services

Pricing of transport is another key issue which should be addressed properly. Pricing policy could effectively be used to encourage the public transport and restrict the usage of private vehicles. So far, in India, operating cost of using the private vehicles is far less than the marginal social costs which encourage people to use private modes. Over the years, government policies have been very supportive towards automobile industry. Motorcycle and car ownership is seen as desirable and to be promoted at all costs. Coupled with this perception is the common view that development and support of the car and two-wheeler manufacturing industry is good for the economic development. For these reasons, government often implements policies that artificially lower not only the cost of vehicle ownership (through very low one-time registration fee, low sales tax, etc.) but also the usage of the same. There is no doubt that government should encourage automobile industry for overall economic development; it should find ways to restrict the usage of cars and two-wheelers. Private vehicles should pay their full external costs. Government should use market-based instruments such as annual registration fee, parking fee, road tax, fuel tax, congestion charges, etc., to increase the (actual) marginal cost of private vehicle use to a level where it is equal to the marginal social costs of the same. At the same time, government should promote public transport by abolishing annual motor vehicle tax and passenger tax levied on public transport vehicles.[3]

There is a need to have optimal pricing strategy for public transport services as well. Price of transport services must be seen not only as an instrument for cost recovery but also for driving consumers' behavior. Although there is no such thing as the 'right' price, there are optimal pricing strategies, which facilitate attainment of specific goals. The optimum price to achieve profit maximization may differ from the one needed to maximize welfare or to ensure the highest traffic revenue. Many economists recommend adoption of prices based on marginal costs particularly in case of public enterprises. The driving force behind the argument in favor of marginal cost pricing for public enterprises is the assertion that they ought to maximize welfare rather than profits. The adoption of marginal cost pricing may, however, in certain circumstances, result in an undertaking making a financial loss. The classic example of this is the decreasing cost industry where, because of high initial capital costs, the setting of charges equal to marginal cost will result in a financial deficit. This deficit may not be necessarily indicative of mismanagement. Most of the urban transport undertakings in India appear to operate on increasing returns to scale, and consequently marginal cost pricing will result in a financial deficit. When they are restricted to meet a revenue-cost constraint, it is required to find the second best set of prices which could be based on inverse elasticity rule.[4] The price and output combinations that it computes minimize the deadweight loss due to unavoidable deviation of price from marginal cost. Since this pricing rule takes into account price elasticity of demand, it is superior to the average-cost pricing rule that most urban transport undertakings tend to adopt.

Publicly owned urban transport undertakings can think of charging different (optimal) prices for different quality of services. Assuming that shift of consumers between different qualities of services is negligible, the availability of the range of services means that total potential consumer surplus will exceed that generated if only a single price and service package were available. Operator stands to gain as a result of this pricing strategy since costs of servicing each customer group are not drastically different.

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[3] During the years 2010–2011, urban transport undertakings in India operated with around 24,000 buses and paid Rs. 1,899 million to the government in different forms of taxes such as motor vehicle tax, passenger tax, special road tax, etc. Therefore, on an average, every bus operated by urban bus transport undertakings in India faces a tax burden of almost Rs. 80,000 per year.

[4] Inverse elasticity rule asserts that the optimal percentage deviation of the price of any goods or service from its marginal cost should be inversely proportional to its own price elasticity of demand.

Apart from this, one could also envisage differential pricing mechanism such as peak period, off-peak period, peak-direction, off-peak direction, etc., based pricing strategy. The problem of the peak is peculiar to transport sector. The problem here arises from systematic variation in demand, frequently over a relatively short period. The problem is further aggravated due to the fact that transport cannot be stored to reconcile the systematic changes in demand with smooth, even production. Reconciliation can only be through price. Justification of differential pricing for peak and off-peak passengers stems from the fact that marginal cost of production during peak exceeds that during off-peak. Charging peak and off-peak passengers prices that are equal to their respective marginal costs not only maximizes social welfare but also has potential to augment traffic revenue. Even after adopting such pricing strategy if traffic revenue is not sufficient to cover costs, then one may have to adopt second best pricing where price charged to a particular group of passengers equals marginal cost plus markup. The markup over marginal cost would be inversely proportional to the price elasticity of demand. For example, peak travelers whose demand is relatively inelastic could be charged a price substantially higher than the marginal cost as compared to off-peak passengers.

5.4.6 Enhancing Transport Coordination

To encourage people to use public transport, there is a need to have transportation system which is seamlessly integrated across all modes. The various modes of public transport including intermediate public transport have to work in tandem. Presently, different agencies, independent of each other, are operating different services in Indian cities. For example, in Delhi, metro rail is operated by Delhi Metro Rail Corporation Ltd., suburban rail service by Northern Railway, bus transport service by Delhi Transport Corporation, and taxi and auto rickshaw by private operators. There is a lack of coordination among these agencies. Since the ultimate objective is to provide adequate and efficient transport system, there is a need to have a coordinating authority with the assigned role of coordinating the operations of various modes. This coordinating authority may be appointed by the central or state government and may have representatives from various stakeholders such as private taxi operators, bus operators, railways, state government, etc. The key objective should be to attain the integration of different modes of transport to improve the efficiency of service delivery and comfort for commuters. At the same time, a single ticket system, where commuters can buy a transport ticket that is valid throughout the public transport network within the coordinating authority's jurisdiction, should also be developed and promoted. Integration between different modes of public transport provides quicker, easier, convenient, and more reliable journeys which are essential to promote the usage of public transport. Integrated transport system has potential to attract people away from the private cars and two-wheelers and thus can contribute for congestion relief and environmental preservation.

5.4.7 *Promoting Car Sharing*

Car sharing, also known as car pooling, is when two or more people share a car and travel together. It allows people to have the convenience of the car, but at the same time helps to reduce congestion and pollution through reduction in vehicle-kilometers. Car sharing may be organized through affinity groups, large employers, transit operators, neighborhood groups, or large car-sharing businesses (Singh 2006). Car sharing provides the potential to reduce the costs of vehicle travel to the individual as well as society. In order to promote car sharing, it is important to ensure that sufficient parking places are allocated to vehicles belonging to car-sharing groups at nominal or no parking fee.

5.4.8 *Restraining the Use of Polluting Vehicles and Fuels*

More than 50 % of motor vehicles in India are more than 5 years old. In general, emission performance of older vehicles is significantly inferior to newer vehicles because of poor maintenance and lax emission standards for in-use vehicles. The large number of three-wheelers and many two-wheelers still operate with two-stroke engines, which emit a high volume of unburnt particles due to incomplete combustion. Diesel cars now account about 50 % of total car sales in India, compared with less than 20 % few years ago. Diesel cars are becoming more popular because diesel price in India is significantly less than the petrol price. Government encourages this price differential primarily to help farmers and bus and truck operators. This price benefit is not meant to be available for personal cars. Although diesel cars emit less greenhouse gases, there are serious concerns about the public health effects of their NOx and particulate matter emissions particularly in densely populated metropolitan cities.

Therefore, government needs to check the use of polluting vehicles and fuels and promote cleaner technology and better fuels. Government may use the market-based instruments to do the same. For example, a relatively high annual motor vehicle tax, which may be increasing with the age of vehicle, may be imposed on two-stroke two-wheelers and three-wheelers and all vehicles that are more than 10 years old. Similarly, cars that use diesel could be discouraged in million-plus cities by levying cess on diesel in those cities.

5.4.9 *Tightening Vehicle Emission Standards and Inspection and Maintenance Programs*

Appropriate vehicle emission standards for new and in-use vehicles and a well-designed and operated inspection and maintenance (I/M) program are important elements of an overall strategy to reduce vehicle emissions and air pollution in

Table 5.14 Emission standards for new vehicles (light duty) in selected countries

<table>
<tr><th>Country</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td>India (entire country)</td><td colspan="2">Euro 1</td><td colspan="5">Euro 2</td><td colspan="3">Euro 3</td><td colspan="2">Euro 4</td></tr>
<tr><td>India (Delhi and other cities[a])</td><td colspan="2">Euro 2</td><td colspan="5">Euro 3</td><td colspan="3">Euro 4</td><td colspan="2">Euro 5</td></tr>
<tr><td>European Union</td><td colspan="2">Euro 3</td><td colspan="3">Euro 4</td><td colspan="5">Euro 5</td><td colspan="2">Euro 6</td></tr>
<tr><td>Hong Kong, China</td><td colspan="3">Euro 3</td><td colspan="3">Euro 4</td><td colspan="6">Euro 5</td></tr>
<tr><td>South Korea</td><td colspan="3"></td><td colspan="3">Euro 4</td><td colspan="6">Euro 5</td></tr>
<tr><td>Thailand</td><td>Euro 2</td><td colspan="8">Euro 3</td><td colspan="3">Euro 4</td></tr>
</table>

Sources: (1) Vehicular Technology in India | Emission Norms. SIAM India. Retrieved on 2011-02-02 from http://www.siamindia.com/scripts/emission-standards.aspx. (2) Emission standards for new vehicles (light duty). CAI-Asia 2008. Available at http://www.cleanairnet.org/caiasia/1412/articles-58969_resorurce_1.pdf

Note: [a]Includes Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Solapur, and Agra

urban areas. Stringent emission regulations and their effective implementation have produced good results in many developed countries (Asian Development 2003). However, emission standards in India are relatively lax compared to current Euro standards. At the present time, India lags behind the European new vehicle standards and fuels requirements by 6–7 years (Table 5.14). Hence, there is a need to review the emission standards of India and make them more stringent. It is required to set a goal to achieve parity with Europe, the United States, or Japan by the year 2015 at the latest.

It has been estimated that at any point of time, new vehicles comprise only 8–10 % of the total vehicle population in India. Currently, only transport vehicles, that is, vehicles used for hire or reward, are required to undergo periodic fitness certification (see Fig. 5.3 for existing inspection and maintenance system in India). The large population of personalized vehicles is not yet covered by any such mandatory requirement. Modern vehicles equipped with advanced pollution controls are even more dependent on proper functioning of components to keep pollution level low. Minor malfunctions in the air, fuel, or spark management system can increase the emissions significantly. Therefore, tightening of new vehicle emission standards should be followed by a similar tightening of in-use vehicle emission standards (Fig. 5.7).

The inspection and maintenance system, comprising inspection, maintenance, and certification of vehicles, is crucial for regulating pollution for the large fleet of

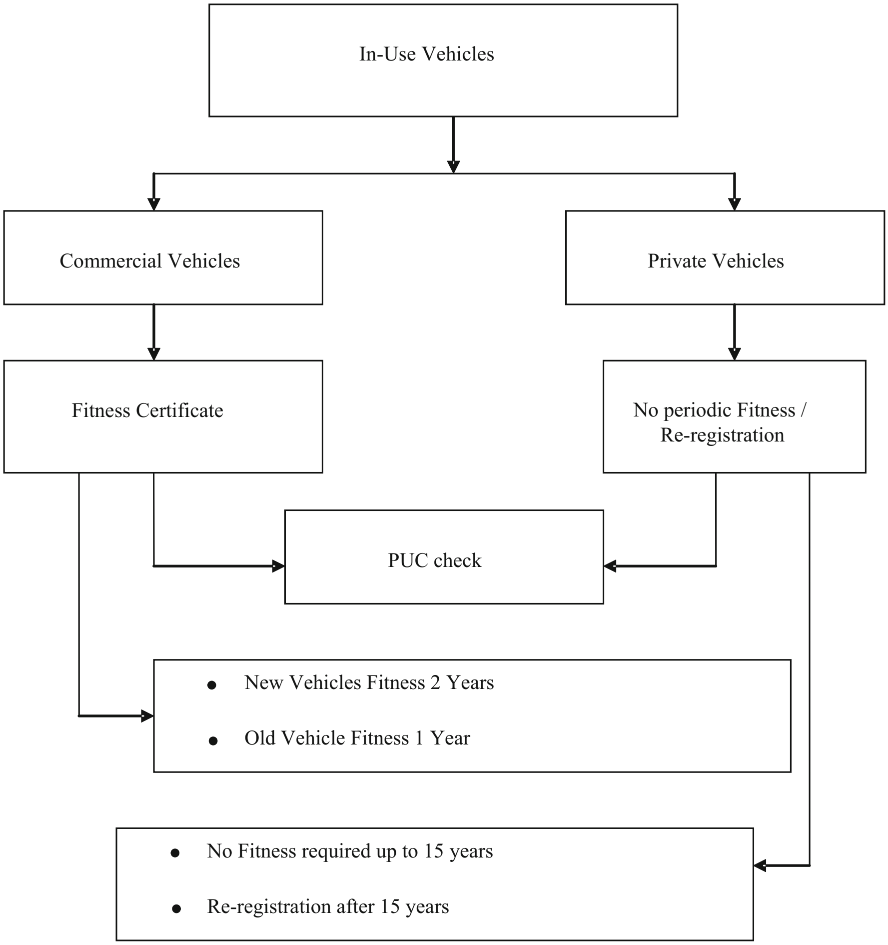

Fig. 5.7 Existing inspection and maintenance system (Source: Status of the vehicular pollution control programme in India (March 2010). Central Pollution Control Board, Ministry of Environment and Forests, Govt. of India)

in-use vehicles. At present in India, there is no regular fitness checking program for in-use private vehicles. Simple Pollution Under Control (PUC) checks came into existence in 1991 for all on-road vehicles. Commercial vehicles are required to undergo simple fitness checks in addition to PUC checks. However, these are isolated checks and are grossly inadequate. There is an urgent need to strengthen the existing inspection and maintenance program in the country.

Government needs to consider (1) whether it has adopted the appropriate in-use vehicle emission standards and test procedures on which to base I/M, (2) whether the institutional capacity and willingness to enforce an I/M program exists, and (3) whether the repair sector is sufficiently trained to carry out repair work on vehicles which fail the tests. If any of these aspects are found to be deficient, government should take appropriate measures to rectify the problems. To ensure the public acceptance and their participation in I/M program, public awareness campaign should be strengthened. Particular emphasis should be placed on the health benefits that can result from a successful I/M program.

5.4.10 Implementing Demand Side Management Measures

In general, Indian cities have not made much progress in implementing the demand side management measures, such as parking fee, fuel tax, congestion pricing, etc. Although measures that involve restraining the use of private vehicles are likely to be unpopular, a gradualist approach of progressively introducing restraints on road use, while at the same time improving public transport, is more likely to lead to a greater acceptance. It is expected that improved public transport and more efficient management of demand would help to combat the trend away from public transport towards greater use of cars and two-wheelers.

There is no doubt that the public transport is desired, but it cannot be encouraged without the implementation of sound and comprehensive demand side management policies. Such policies should not be implemented in isolation, but in conjunction with other transport planning, supply side management, and transport pricing measures. Public needs and road safety should also be considered in design of the policies even when these are directed to improve the air quality.

5.4.11 Using Supply Side Management Measures

As discussed earlier, traffic congestion on roads increases the level of pollution dramatically. Hence, there is an urgent need to use supply side management measures to tackle prevalent traffic congestion problem. One-way traffic system, improvement of signals, traffic engineering improvement measures for road network and intersections, bus priority lane, etc., could be used as short-term measures to ease traffic congestion. Road infrastructure improvement measures like new road alignments, hierarchy of roads, provision of service roads, bypasses, ring roads, bus bays, wide medians, intersection improvements, construction and repair of footpaths and roads, removal of encroachments, etc., should also be introduced at least in million-plus cities. These can be considered as medium-term measures. Besides short- and medium-term measures, there is a need to have long-term measures as well, involving technology upgradation and introduction of high-speed, high-capacity public transport system particularly along high-density traffic corridors. However, capital-intensive projects should be considered if and only if they are absolutely necessary. In many cases, instead of building underground railways or elevated highways, government would have done better to have increased the capacity of existing bus transport services. There should be careful appraisal of capital-intensive projects before implementing them in metropolitan cities.

5.4.12 Encouraging Green Modes

Transport policy should also encourage the need for developing *green* modes like bicycles, cycle rickshaws, pedestrians, etc. The potential of *green* modes is often underestimated since they are used primarily for short distances. But large fraction of journeys made by cars and two-wheelers are mainly for short distances, say, less than 6 km, a distance over which use of motor vehicle does not provide significant time advantage (Singh 2006). Moreover, motor vehicle emissions are high for short-distance travel because fuel consumption is high due to cold engine and because the catalyst is not yet working at full efficiency. Due to this reason, the use of *green* modes in place of motor vehicles for short distances has huge potential for pollution reduction. Green modes particularly walking and cycling have huge health benefits as well. However, to promote *green* modes, the safety concerns of cyclists and pedestrians have to be addressed adequately. For this purpose, there has to be a segregated right of way for bicycles and pedestrians. Apart from improving safety, this will help to improve traffic flow, increase the average speed of traffic, and reduce emissions resulting from low vehicle speed.

5.4.13 Improving Road Environment

Deaths and injuries resulting from road traffic crashes are a major and growing public health problem in India. There is no doubt that the approaches involving road-safety education and enforcement such as wear your *seat belts*, always wear *helmet* while driving, say no to *drunken driving*, and general adherence to *traffic rules* are essential in curtailing traffic accidents; however, it is equally important to realize that people will always make mistakes. Therefore, there is a need to focus on mediating the outcome of accidents by designing safer roads. Road accidents tend not to be evenly distributed throughout the road network. They occur in clusters at single sites, along particular sections of road, or scattered across whole residential neighborhoods. The road network has a significant effect on accident risk because it determines how road users perceive their environment and provides instructions for road users, through signs and traffic controls, on what they should be doing. Faulty road design can easily trigger a crash, whereas some elements of the road environment may mislead road users and thereby can increase the probability of errors.

Therefore, roads should be designed in such a way so that it is not only self-explaining but also forgiving. Accidents are less likely to occur on self-explaining roads, and injuries are less severe on forgiving roads. Roads are self-explaining when they are in line with expectations of the road users. Self-explaining roads show road users where they should be and how to use road safely. For example, a cost-effective, simple pedestrian refuge island (a small section of pavement or side-walk completely surrounded by asphalt or other road materials, where pedestrians can stop before finishing crossing the road) not only shows where to cross but also makes safe crossing much easier. It should be used when a street is very wide, as the pedestrian crossing can be too long for some individual to cross in one traffic light cycle. It should also be used when no light exists, and pedestrians need safe harbor after managing one direction of traffic, before taking on the next. The refuse island also calms drivers' speed and restricts overtaking at the crossing point. Forgiving roads protect road users in the event of an accident. Road design must recognize that accidents can occur and ensure that injuries and fatalities are minimized by protecting road users from hazards. For example, a simple engineering feature such as safety barriers can be used to separate fast-moving vehicles from people. Similarly, crash cushions (sand-filled plastic barrels, water-filled tubes, foam-filled cartridges, etc.) can be used to reduce the consequences of an accident (Singh 2012).

5.4.14 Enforcing Regulations to Improve Road Safety

Road accidents and related injuries and fatalities are highly dependent on the speed of motor vehicles. For example, for car occupants in a crash with an impact of 80 Km/h, the likelihood of death is 20 times what it would have been at an impact speed of 32 Km/h (Margie et al. 2004). Similarly, the probability of pedestrian being killed rises by a factor of 8 as the impact speed of car increases from 30 to 50 Km/h (Ashton and Mackay 1983). While in many developed countries, there is increasing use of in-built mechanisms in trucks and buses to restrict speeds above a certain limit, such devices are rarely used in India; if installed, they are disabled by the operators. Commercial bus and truck operations, particularly privately owned ones, are often based on timetables that put pressure on drivers to speed. In many places in India, private bus operators link the wages of drivers with the ticket receipts and number of trips, which encourages high speed. Although various states and union territories and city authorities in India have imposed speed limits on motor vehicles, enforcement of the same is almost nonexistent. There is an urgent need to strictly enforce the implementation of speed limits both on highways and city roads. In mix traffic environment, restriction on vehicle speed would also help in reducing causalities to pedestrians, cyclists, and other vulnerable road users.

Drivers' speed choice is influenced not only by legal speed limit but also by alcohol and drug use and driver's fatigue. Studies have shown that the accident risk increases rapidly when blood alcohol concentration exceeds the limit of 0.04 grams per deciliter (Margie et al. 2004). Fatigue as a result of lack of sleep, night driving, and working shift is also an important factor determining traffic crashes involving commercial and public transport vehicles. For example, in Indian trucking industry, 66 % of drivers drive continuously for more than 9 h a day, 20 % of drivers drive more than 12 h a day, and only 30 % of drivers drive for 5–8 h continuously a day (Debroy and Kaushik 2002). Since the overall cost of accidents due to alcohol and drug use and fatigue is largely borne by society rather than drivers and operators, government not only needs to sensitize the drivers and operators but also strictly enforce the existing laws in this regard.

5.4.15 Introducing Public Awareness Programs

Public attitudes influence politicians and policy makers and increase the political will to tackle problems. The adverse health effect of air pollution due to vehicular emission needs to be communicated to people as a means of influencing public attitudes. Deaths and injuries resulting from road traffic crashes are also a major and growing public health problem. Media, NGOs, and research institutions should be encouraged to highlight these issues, conduct independent analysis, and advocate possible solutions to policy makers and implementing agencies. At the same time, fair and equitable procedures for public complaints should be instituted. These can enhance awareness and understanding, influence public attitudes and public support, and create the necessary political will to tackle the problem of congestion, air pollution, and road safety.

At the same time, public awareness programs should also be initiated to communicate the benefits of public transportation, efficient vehicles and fuels, car pooling, green modes, self-explaining and forgiving roads, economical driving, etc. One should note that an economical driving alone can bring about fuel savings of up to 10–15 % per vehicle (Singh 2006). The fact that fuel consumption can be influenced by economical driving is not widely communicated to the public. The public should be given better information about the same. To promote economical driver training for individuals as well as companies, government should positively think to provide financial subsidies to driver training schools.

5.4.16 Strengthening Urban Institutions

Most Indian cities are struggling to address the transportation problem mainly because they are not equipped with the appropriate institutional capacity and required financial resources. This is because functional responsibilities for urban transport are fragmented among central, state, and local level governments where no one is in charge of overall coordination (see Table 5.15 for institutional arrangements for urban transport in India). Management of urban areas is primarily a responsibility of the state governments in India. However, several key agencies, those play an important role in urban transport planning, work under the central government, with no accountability to the state or local government. Central government is directly involved in the provision of suburban rail service through Indian Railways in four mega cities. The Ministry of Road Transport & Highways, Government of India, is responsible for the national highways, including the stretches within urban areas, and local governments have no role in the operations

Table 5.15 Institutional arrangements for urban transport in India

Function	Sub-functions	Agency responsible
Strategic and policy functions	Strategic planning	Ministry of Urban Development/State Transport Department/ State Urban Development Department
	Policy formulation	
	Capital financing	
Regulation of commercial issues	Fixation of fares/tariffs	Ministry of Railways/State Road Transport Corporation/ Regional Transport Office
	Monitoring quality of services	
Health and safety regulation	Setting standards	Ministry of Road Transport and Highways/Central Pollution Control Board/State Pollution Control Board
	Ensuring adherence to safety standards	Ministry of Road Transport and Highways
	Ensuring adherence to environmental standards	Central Pollution Control Board/State Pollution Control Board
Procurement and provision of public transport	Network and route design	Municipal Corporation/State Road Transport Corporation
	Identification of demand	Municipal Corporation
	Franchising/route allocation	State Road Transport Corporation
	Planning and provisioning of services	Municipal Corporation/Public Works Department
	Contract monitoring	
Supply of common infrastructure and other services	Inter-modal coordination	State Road Transport Corporation/Municipal Corporation/ State Transport Department
	Passenger information systems	
	Data collection and management	
	Dispute resolution	
	Management of common infrastructure	
	Public relations	
	Security services	Traffic Police
	Management of common ticketing facilities	Municipal Corporation/State Road Transport Corporation
	Management of revenue-sharing arrangement between operators	
Operation of services	Operation of publicly owned bus services	Municipal Corporation/State Road Transport Corporation
	Operation of privately owned buses	Private Bus Operators
	Operation of rail-based services	Ministry of Railways

Source: Ahluwalia et al. (2011)

and management of these stretches though they are heavily used for urban transport (Singh 2005).

State governments independently control local land use policies, motor vehicle and sales tax rates, bus transport systems, policies for private sector participation, etc. Most of the local governments at municipal level rely heavily on capital grants from the states for almost all infrastructure projects. Although Urban Local Bodies (ULBs) in India have been empowered by the Constitution (74th Amendment) Act, 1992, to assume responsibilities for development of urban transport, most of them do not have adequate power to raise financial resources. Their revenues mainly depend on property tax collection and intergovernmental transfer from the state. ULBs' revenues are barely sufficient for salaries and current expenditures, and most capital investments are funded through borrowing, often from the state Urban Infrastructure Development Corporations (UIDCs). Revenues from user charges imposed on publicly provided infrastructure services are minimal. Due to this, insufficient funds are available for operation and maintenance of existing assets which badly affects the service delivery.

Although the 74th Amendment of the Constitution aimed to provide administrative and fiscal decentralization at the local government level, the progress in this regard has been slow primarily because local governments are still dependent on higher level of governments for funding. They do not have power to raise additional tax revenue and are still dependent on intergovernmental transfer arrangements. As long as this situation continues, most cities may not be able to improve their infrastructure. There is a pressing need to empower the ULBs in the true sense so that they can raise funds for developmental projects in urban areas by their own rather than being dependent on states. Also, they may be authorized, through legislation, for overall coordination of activities relating to provision of transport infrastructure by various government agencies in their respective urban areas. Only then, they can augment the infrastructure base, provide improved quality of services on a sustainable basis to their residents, and contribute to the growth momentum of the Indian economy.

5.5 Concluding Remarks

Transport demand in most of the Indian cities has increased substantially due to increase in population as a result of both natural increase and migration from rural areas and smaller towns. Availability of motorized transport, increase in household income, and increase in commercial and industrial activities have further added to it. Unfortunately, public transport systems in Indian cities have not been able to keep pace with the rapid and substantial increase in travel demand. Rail-based public transport services and well-organized bus transport services are limited to few big cities only. Qualitatively, the available public transport services are overcrowded particularly during peak hours and involve long waiting periods. As a result, there is a massive shift towards personalized transport, especially cars and two-wheelers, and also proliferation of various types of intermediate public transport modes, such as auto rickshaws and taxis.

The increasing use of private motor vehicles in cities has been rapidly changing their modal-split structure. Motorization may have brought a higher level of mobility to the high-income segments of urban population, but its adverse impact in the form of congestion, air pollution, and traffic accidents is also substantial. Although these impacts are inherent to motorization, the excessively high level of impact faced by many Indian cities has a lot to do with the lack of effective public policy. The city cannot afford to cater only to the private cars and two-wheelers, and there has to be a general recognition that without public transport in general and bus transport in particular, cities would be less viable. Although rising income of the people is one of the most important reasons for change in modal-split structure, the more important reasons are to be found in the public transport system itself. Speed, service quality, convenience, flexibility, and availability favor adoption of private mode as the main mode of transport. Given the opportunity, people reveal widely divergent transport preferences, but in many places, city authorities favor a basic standard of public transport services. It is often thought to be inegalitarian to provide special services such as premium or guaranteed seats in return for higher fares. As a consequence, those who can afford private vehicle are successively leaving public transport. Until recently the main function of public transport was to satisfy the individual needs of the less affluent members of society, but now it has to contribute for congestion relief and environmental preservation. This requires a fundamental change of emphasis to fulfill its new role of attracting enough people away from the cars, two-wheelers, auto rickshaws, and taxis.

The problem of acute road congestion, rising air pollution, and a high level of accident risk faced by metropolitan cities of India is taking serious dimensions and worsening the people's quality of life. Without vigorous action, this problem would intensify, as rising population over the coming decades and the goal of growing economic prosperity put more pressure on the system. Reducing traffic congestion, vehicular emission, and accident risk requires a comprehensive strategy. The main objective of such strategy should be to provide and promote sustainable high-quality links for people, goods, and services to, from, and within the city. Strategy should be designed in such a way that it reduces the need to travel by personalized modes and boosts public transport system. This requires not only increasingly stringent emission standards, specifications for clean fuels, proper maintenance of in-use vehicles, optimal pricing of transport services, demand as well as supply side management measures, but also a complete overhaul of public transport system. The time has come to act now.

Note Another version of this chapter has already been published in *European Transport / Trasporti Europei* (an International Journal of Transport Economics, Engineering and Law) in 2012 (issue no.: 52; paper no. 5; pp. 1–26). I would like to thank the managing editor of the journal for granting us permission for the same.

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Chapter 6
Urban Transportation Planning and Investment in India: Emerging Challenges

S. Sriraman

Abstract

The capacity of the transport system and the low cost and dependability of the transport services has enabled an increasing number of people to seek the economic, social and cultural opportunities that urban living ideally provides. But paradoxically, metropolitan cities have now grown to the point where they threaten to strangle the transportation that made them possible …… with the technical ability to solve its transport problem well in hand, the modern city is confronted by transportation problems more complex than ever before. Despite all the methods of movement, the problem in cities is how to move. (Owen 1987)

6.1 Introduction

The above-mentioned quotation adequately sums up the current situation in cities across the world in regard to mobility. While transport or transportation (used interchangeably in this paper) has a major role in influencing the location of cities, it has had an even more significant role in defining (and be defined by) city shapes and sizes. The concentration of population, employment and activities in urban areas is, in fact, to a great extent very much due to transportation. Accordingly, movement of men and material became a significant feature. However, over the years, movement has been made increasingly difficult both due to factors within and outside the system, which provide for movement. In other words, a major emerging problem in urban areas concerns urban transport. Paradoxically, the cities have outgrown themselves and reached a stage when the transport system is hindered in its effective functioning.

Most of the cities in India have been facing urban transport problems for the last many decades, affecting the mobility of people and material and thereby the economic growth of urban areas. These problems are due to prevailing imbalance in modal split, inadequate transport infrastructure and its suboptimal use, no proper integration between land use and transport planning and no improvement or little

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improvement (or in most cases a worsening) in city bus services, which encourage a shift to personalised modes. Consequently, many cities in the country are facing serious problems, including significant levels of traffic congestion, air pollution from transport sources, high rates of traffic accidents and even inadequate access to basic transport facilities by poor and vulnerable groups including people with disabilities. The deteriorating urban environment threatens the 'liveability' and productivity of many cities. In many of the major cities, such as Mumbai, Chennai, Kolkata and New Delhi, the situation is so severe that the efficiency of their urban economy is being adversely affected, as is the health and welfare of the people living in them.

It is against this background that an attempt is made, in this paper, to propose an appropriate policy framework that needs to be in place to initiate and encourage useful solutions to tackle the urban transport problem in the Indian context. We make no attempt to outline the urbanisation process in India since it has been dealt with adequately elsewhere and also do not present a description of the recent urban transport scenario in terms of the transport sector characteristics since this can be found in a recent study (WSA 2008). This means that, in the next section, we spell out issues that are emerging as challenges on the urban mobility front. We then move on to an attempt to review in some depth current policies and interventions which, in turn, provide us a basis for our approach towards a new urban transport policy framework in the country.

6.2 Urban Mobility Challenges

As cities grow exponentially, an effective and sustainable transport system for people and goods movement is a prerequisite for sustainable economic growth. However, urban transport systems in most cities of the developing world like India are underdeveloped, and their transport capacity has been found to be grossly inadequate. Thus, residents are unable to fully exploit economic opportunities and lack the mobility needed to support economic growth.

Urban transport systems in most cities suffer from major constraints as insufficient financial resources, inefficient regulatory frameworks, poor allocation of road space, inadequate traffic management systems, institutional weaknesses and undeveloped public transport systems. Currently, these systems also rarely integrate social concerns and the specific needs of vulnerable groups, thereby rendering such systems ineffective in relation to poverty reduction. Drastic increases in the number of vehicles have strained our urban road networks, resulting in congestion for most of the day. Most of these factors disproportionately affect the urban poor in terms of limited accessibility to affordable transport services, ill health from pollution and road safety concerns.

In most cities, road networks, developed in an unplanned ad hoc fashion and without proper adherence to quality standards, are severely deficient in meeting developmental demand. Residential areas have few and inadequate tertiary or access roads and limited provisions for pedestrians, cyclists, etc. In addition, road networks have missing links, forcing the overuse of existing road sections and lack of circumferential roads resulting in congestion from traffic. Meanwhile, increases in the number and uses of vehicles surpass the capacity of road space, adding to congestion and air pollution. As a result, transport conditions in cities are characterised by severe congestion and aggravated by the poor discipline among drivers, incoherent enforcement of traffic laws and an eclectic mix of vehicles. A failure to respond promptly to rapid motorisation and the resultant congestion along with weak enforcement of vehicle emission standards results in degradation of the environment and stunts cities' growth potential.

Rapid urbanisation has also increased the number of urban poor. Efficient systems do contribute to urban economic growth thereby raising incomes and decreasing urban poverty. However, current urban transport systems, which do not fully integrate the specific needs of the poor, have worsened the perverse distributional effects of urbanisation. Overstrained public transport systems restrict urban residents, particularly the urban poor from actively participating in economic activities. The social exclusion engendered by urban transport makes it more difficult for the disabled to access jobs and services. As a result, the poor find it hard to break out of poverty. In addition, the poor are disproportionately exposed to the risks of polluted air. Moreover, the risks they face when they travel are higher than those of the non-poor because of the few safety provisions for pedestrians and cyclists at street crossings and slack enforcement of pedestrian crossing facilities. There is a definite need for urban transport policies and programmes to take the needs of the poor into account.

Poor traffic management, one of the biggest issues in many cities, is a combination of many factors: lack of coordination and overlapping responsibilities among various agencies, insufficient traffic police and traffic signals, flaws in traffic marking and ineffective enforcement of traffic rules and regulations. Accidents are common due to poor traffic management on the one hand and undisciplined use of the road by many types of vehicles using the roads on the other. Ineffective traffic management is also the result of encroachment by parked vehicles and commercial activity on roads thereby reducing road capacity and causing inadequate public transport services. Good traffic management cannot only improve the flow of traffic but can reduce negative environment impact. The need for efficient traffic management systems is therefore acute. Such systems will require (1) an appropriate transport policy framework under which governments can manage travel demand and (2) strategic plans that cover junction operations, enforcement, road use, driver re-education, public transport, parking, traffic signals, vehicle restrictions and circulation plan, pavement markings, vehicle condition and equitable allocation of road space.

While a large portion of the urban population relies heavily on public transport for its daily activities, public transport systems in most cities are not adequately developed, and investments have been severely limited. Bus and paratransit services, the predominant public transport services, are often exclusively operated by the private sector. The unregulated operation of private buses, particularly with regard to the allocation of routes and schedules, has spawned excessive competition, and as a result, the financial performance of public transport and the quality of service have deteriorated, negating the benefits derived in road construction. Improving the efficiency of public transport should not only lower costs but result in a flexible framework which makes public transport more accessible to the poor. To this end, solid institutional and regulatory structures are required that will help create efficient public transport systems that poor users can afford and that give incentives for proper maintenance, investment and service expansion.

Governments' weak capacities lead to low institutional coordination and an inefficient institutional framework. Government agencies have overlapping or poorly delineated responsibilities, planning and programming are chronically fragmented and largely ad hoc, and institutional arrangements for policy implementation are usually incoherent. Rapidly increasing urban populations require efficient use of limited land resources to support economic growth; however, planning for land use, urban development and transport management is loosely integrated, thereby constraining cities' growth potential, competitiveness and efficiency.

Private sector involvement in urban transport is generally limited to the provision of public transport services, including buses and taxis, auto rickshaws, etc. Despite growing recognition of the burden that investments in major roads, bye-passes, etc. place on municipal budgets, private sector participation in maintenance and construction is limited. Public mass transit systems require substantial investment and careful commercial management to ensure their financial viability for which private sector participation is crucial particularly in big cities. Planning and regulatory arrangements for private participation in urban transport must therefore be established.

Experience indicates that piecemeal approaches to sustainable urban transport development are likely to fail and that capital investments needed to be supported by policy, legal, regulatory and institutional reforms. More policy attention must be focused on building capacity in urban transport administration, on enhancing the role and quality of affordable public transport, on financing mechanisms and on needs of pedestrians and users of nonmotorised transport.

6.3 Current Policies and Interventions

6.3.1 The Policy Framework

The Government of India attempted to comprehensively address urban transport issues in the country by formulating a *National Urban Transport Policy* (NUTP) framework in 2006 (GOI 2006). While recognising the problem of increasing urban road congestion and its associated air pollution, the strategy puts primary emphasis on the need to increase the efficiency of use of road space by favouring public transport and by the use of traffic management instruments to improve traffic performance and by restraining the growth of private vehicular traffic. Complementing this is a strategy to reduce vehicle emissions by technological improvements in vehicles and fuels. The Government of India's proposed strategy is in many respects along the lines of international thinking on the approach to the urban transport problem. For example, the World Bank completed an Urban Transport Strategy review 'Cities on the Move' (World Bank 2002) after consultation with major stakeholders in client countries, including governments, transport operators and nongovernmental organisations, as well as with representatives of other international institutions. That review linked urban development and transport sector strategies with a strong poverty focus. It noted that sprawling cities are making the journey to work excessively long and costly and that throughout the per capita motor vehicle ownership continues to grow with adverse impacts on traffic congestion and air pollution. Public transport was being stifled by this congestion, and its relative performance tended to decline in comparison with the private modes. So the vicious circle of congestion and the decline of public transport were perpetuated. The safety and security of urban travellers were also major emerging problems worldwide.

The NUTP document begins with a basic contention that the mobility problem in our cities is a very formidable one and that it was not just hampering better growth possibilities but also threatening the basis for a reasonable standard of living. Accordingly, it was envisaged in the vision statement that liveability of our cities would be highlighted and emphasised with the basic objective of this policy being to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within our cities. With the states as the main facilitators in the process, the role of the central government, it was felt, would be to hasten it with the necessary financial support and technical expertise. We now look at the specifics.

6.3.2 Its Elements

6.3.2.1 Basic Guidelines

The issue of integrating land use and transport planning was taken up first. The connection between transportation and land use is a fundamental concept in transportation. Transportation and land use are inexorably connected. Everything that happens to land use has transportation implications, and every transportation action affects land use. Policymakers are required to help shape land use by providing infrastructure to improve accessibility and mobility. Accessibility can be measured by the number of travel opportunities or destinations within a particular travel radius, measured in terms of either travel time or distance. On the other hand, mobility is a measure of the ability to move efficiently between origins and these destinations. Thus, mobility is directly influenced by the layout of the transportation network and the level of service it offers. Land development generates travel, and travel generates the need for new facilities which, in turn, increases accessibility and attracts further development. The question of whether transportation influences development or whether land use dictates transportation has been a matter of ongoing concern among transportation professionals. Transportation's most significant impact on land development occurs when access is provided to land. Increased access to land raises its potential for development, and more development generates additional travel. Once access has been provided, land patterns begin to change over a period of time. In recent decades, concerns about urban sprawl have arisen. Several factors can be identified as contributing to sprawl, including the movement of jobs to suburbs, lower transportation costs versus lower housing costs, preference of many people to live in remote areas away from the problems of the city and the desire for larger lots. The concern about sprawl and transportation has led to a new debate about the relationship between transportation and urban sprawl.

The policy document recognises that a combination of transportation and land use measures is needed to address the transport problem. Both need to be developed together in a manner that serves the entire population and yet minimises travel needs. From a sector perspective, 'transport plans should, therefore, enable a city to take an urban form that best suits the geographical constraints of its location and also one that best supports the key social and economic activities of its residents. Unfortunately, however, transport planning has not received the extent of attention it should have in drawing up strategic development and land use plans' (GOI 2006, p. 5). And this is especially so in regard to the size of the urban area, its form and their interactions with the transport system. We now examine these aspects in some detail.

6.3.2.1.1 The Urban Size and Form and Its Interaction with Transport

While there are differences among various cities due to a variety of factors, the general pattern of urbanisation has been characterised by high population growth, the dominant emerging problem being the excessive growth of large cities especially metropolitan ones. This pattern is expected to prevail in the future as the basic economic and social forces, which encourage the growth of these cities, continue to dominate. Several times in the past, there has arisen an argument for policies to contain urbanisation (especially excessive growth) and thereby the size of cities. More specifically, the relevant question that has been (and continues to be) raised is: Is it not possible to restrict growth of cities to an optimum size? The concept of an optimal city is based on comparison of costs and benefits associated with city size (population measured on the horizontal axis). Adopting the common assumption of an S-shaped benefit curve and a U-shaped cost curve, it is expected that net benefits would become zero at some finite city size. Hence, this could indicate the optimal city size.

However, it is not easy as that since a bewildering set of optima can be identified. Moreover, the meaning of benefits and curves is rather obscure. The economic and social benefits of large relative to small cities appear stronger in developing than in developed economies. Furthermore, the social costs probably remain lower in developing countries despite increase in pollution, congestion, etc. Thus, there has been a basis for arguing that the hypothetical critical city size that provides maximum net benefits, if these could be measured, would be greater in developing countries (Richardson 1977). The question that arises then would be: how much more greater?

It must be recognised that the urbanisation process is very often accompanied by rapid growth in income and employment, and there is a commonly held view that it might not be in the interest of the concerned countries to stop economic growth of cities like Mumbai. Further, it is increasingly being realised that it is impossible to stop or arrest migration into cities even though it may be desirable to do so. It is more likely that it is possible to influence the growth pattern of urban areas in a desirable manner by a reorientation of land use policies in such a way that the city grows into an organic and vital agglomeration node.

The links between urban form and transport have been discussed by Thomson (1977), Owen (1998) and many others. The term 'urban form' is used broadly to refer to the various patterns of location, character and intensity of urban land uses and activities in an urban area. Transport patterns and infrastructure influence the urban form that evolves in any particular city, and, conversely, the urban form of a city influences its transport patterns and further infrastructure investments. The normally predicted generation of trips from particular land uses in any particular city is the basis for most modelling in transport planning. The effects of transport patterns and investments on the distribution of land uses are less predictable but are clearly significant over the long term. Transport appears in one form or another in all of the main theories which attempt to explain the spatial distribution of activities within regions, such as the variants of location theory and central place theory.

Historically, land use planning has been an important component of the urban planning process. However, in the traditional framework of policy making (based on standard economic theory), there are assumptions which no longer hold. Firstly, it is assumed that there is absence of space, as a result of which households, firms and governments choose only one location with the result that the role of land use planning has often been underplayed if not overlooked completely. But it is well recognised that space is not only an input in production, but it is also an important element for location planning of economic agents and also an important source of local authorities to finance city development. Land use decisions invariably introduce strong convexities in consumer preferences and production technologies. Secondly, the essence of urban areas is that there is an agglomeration of many people and firms in close quarters. This introduces an element of non-price competition which complicates the operation of the free-market process. Further, high densities of population, traffic congestion and provision of public services involve externalities. Besides, existence of space between locations means that producers of local goods (both public and private sectors) can be monopolies. All these problems suggest that urbanisation issues are complex and that an approach different from the past needs to be adopted to provide meaningful solutions.

To overcome this problem, it is stated that the Central Government would provide up to 50 % of the cost for the preparations of such integrated plans provided the local authorities demonstrate their willingness to act in accordance with these plans.

The issue is: how has and to what extent has this element been taken forward? Though studies have come with such approaches being recommended as part of their recommendations, there is very little evidence of attempting to examine these approaches and implementing them to the extent possible (MMRDA 2006).

6.3.2.2 The Need to Encourage Public Transport

The second significant element of the policy framework is the need to encourage public transport in a much bigger way. In fact, the emphasis is on ‘priority’ to such a system. Beginning with the issue of current position of inequitable allocation of road space in our cities, the key phrase is ‘movement of people rather than vehicles’. The importance of public transport to pollution and congestion reduction, poverty alleviation and economic empowerment cannot be overstated. In metropolitan areas where the distribution of land and social amenities mirrors high levels of income inequality, placing the poor furthest from economic opportunity and critical services, effective public transport provision is a critical element of development policy. Here, decades of persistent underinvestment in public transport, accompanied by sustained infrastructure spending in support of private car use, have resulted in a profoundly dualistic land passenger transport system which contributes significantly to the continuing economic and social exclusion of many. People whose mobility is constrained cannot exercise the other widely accepted human rights. Lack of mobility in low-income households is often a major factor in their economic and social exclusion. It can prevent the acceptance of employment, lead to failure in securing health appointments and severely reduce the ability to participate in daily activities. Most people who require these services are often the ones who are situated furthest from such services and are in most cases the ones who lack the necessary means to get to them. Over the past decade, driven by ongoing migration to cities, a period of strong economic growth, and the fact that the majority of new housing development programmes have been located in the suburbs, demand for passenger transport in metropolitan areas has increased sharply. As the standard and capacity of state-sponsored public transport systems have remained largely unchanged (in many middle- or lower-order cities they hardly exist), increased demand has been met predominantly by taxis and private cars. At the urban level, it is well recognised that responding to the inequality between core areas and periphery areas is difficult, but not impossible. The key is to bring back to life the vitality of struggling neighbourhoods and re-establish them as complements to the city. It takes knowledgeable foresight by city officials as well as action through the entire community to accomplish this. Each situation may require a different course of action whether it is a radical change (by introducing new public transport systems) or only a slight nudge in the right direction (reforming the existing ones). The emphasis on public transport cannot be made any clearer than what has been incorporated into the policy document. The question is: has this been taken seriously enough in the efforts that have been undertaken subsequently especially in the past 3 or 4 years? More specifically, we need to examine the extent to which measures outlined have been encouraged such as more allocation of road space for bus transport or, more generally, the priority given to public transport.

Equally important would be the aspect related to pricing. In this context, a very basic issue is whether there is an attempt by the policy document to encourage tariff reforms at all. While some indication relating to tariff fixation based on price discrimination is given, the basic question that remains refers to the sustainability of such pricing systems in the absence of an emphasis on norms of efficiency which serve as the basis for an understanding of effective provision of services.

6.3.2.3 Public–Private Partnerships in Bus Transport

The promotion of public–private partnerships (PPPs) has been an underlying objective of policy statements related to the transport sector that the central and state governments in India have been putting forward since the 1990s from time to time. However, in recent years, vigorous efforts have been made to promote the concept in the context of bus transport as part of the implementation of the National Urban Transport Policy (GOI 2006) while incorporating it as part of the central government-funded Jawaharlal Nehru National Urban Mission (JNNURM) that has prescribed model guidelines to the state governments and local governments. The emphasis has been on the need to promote public transport systems with a more directed initiative to promote the bus mode in the different cities for which funds for bus procurement are being liberally given within the framework of PPPs. JNNURM proposed to provide 50 % of the funds required to buy the buses for city transport to 63 cities if they adhere to those guidelines. As for the balance fund required, the state government would have to put in 20 % of the amount, and the balance 30 % of the amount would have to come from city municipal corporations or city transport corporations or a private party by way of a PPP.

6.3.2.4 Environmental Considerations

An overriding feature of the policy document appears to be the emphasis on the 'green' aspect of development of the urban transport system in terms of cleaner and more efficient technology and a more significant role for nonmotorised movement. Aimed at protecting the environment, these elements are today a necessary part of the policy framework worldwide with the EU countries leading the way in incorporating them in a very systematic way.

6.3.2.5 Institutional Capacity Building

The need for capacity building to handle urban transport related issues is also prominently put across not only in terms of institutional capabilities but also individual ones. The latter becomes significant in the face of efforts being attempted to promote public–private partnerships in which an individual or a few individuals are expected to play crucial roles in developing the concept of such a partnership and taking it forward to its logical end. However, the basic underlying issue in this regard is the proper understanding of the distinct roles of the public and private sectors and perspective of the general public regarding these roles.

6.3.2.6 Regulatory Framework

Above all, the emphasis on a unified metropolitan authority is significant. However, the details of such an authority especially in its role of a regulator have not been spelt out explicitly. We now turn to an approach to new urban transport policy framework which begins with a critique of some of the important above-mentioned elements of the current policy document.

6.4 Some Elements of a New Urban Transport Policy Framework

6.4.1 A Critique of Existing Policies

On the issue of integration of land use and transport policies, a good deal has already been said on the lack of such an integration or even an attempt towards this today especially in the context of developing countries. Fundamentally, it is well recognised that this move towards integration is very difficult since any economy is in a dynamic state all the time. The trouble is that it has not been possible to construct a comprehensive theory which fully reflects all the linkages in this interaction. The basic problem is that transport and land use changes are ongoing modification to the spatial economy. 'There are continual cycles of cause and effect, and it is impossible to decide upon a point where it is sensible to break into this continuum of change. Consequently, from a pragmatic standpoint, one has to make a rather careful judgment whether to treat land-use as influenced by transport or vice-versa' (Button 1993, p. 19). Historically, the practice was to accept a given land use pattern and attempt to provide least cost methods of providing transport services within this limitation. For example, Kain (1964) adopted this approach to travel decisions taken in a sequential type of framework which when considered closely involve assumptions which are very analogous to the ceteris paribus assumptions of conventional partial equilibrium microeconomics. While it is recognised that this approach suffers from the same limitations, they do provide a reasonable framework within which useful analysis can be conducted. However, over a period of time, this simplistic way of emphasising the causal link from land use to transport, i.e. where land use is predetermined, was found to be no longer useful in the presence of several dynamic elements relating to the economy. Accordingly, feedbacks from transport to land use began to be incorporated explicitly in models so that a more realistic picture emerged. However, it was found that the data requirements were enormous as a result of which a number of assumptions regarding parameters were made. Moreover, calibration of such models was complicated. The situation has not improved very much despite the use of information technology because data limitations continue to haunt planners and policymakers even in developed economies. Today, efforts at incorporating feedback effects are minimal with the sequential type of framework continuing to be used quite extensively. These can be effectively incorporated by developing limited realistic scenarios and planning accordingly.

The policy document touches only the generalities associated with integration of land use and transport planning in our urban areas. Transport and patterns of urban land use are so interconnected that all cities must make sure to plan their transport in harmony with the realities of their city's actual form. New land use trends associated with motorisation have begun to threaten the accessible and travel-minimising features of some Asian cities. Real estate developers increasingly build new developments with segregated land uses and in locations that are accessible only by private vehicle, even if this leaves them inaccessible by public transport and nonmotorised transport. New high-speed, high-capacity roads in some places have encouraged haphazard development in long corridors, resulting in longer trip distances for residents. No doubt, there is very little to say as far as transport planning practices go in most of our cities. On the other hand, the new trend in the West is to encourage more mixing together of different activities because it encourages more walking, cycling and convenience for residents and workers. The indication that central government support would be available to broad base current efforts is a welcome statement. It may be adequate for an urban area to prepare a long-term plan and also plan its transport facilities. Such plans are being made out in the bigger urban agglomerations. But even today, appropriate accessibility and mobility objectives are not well considered and defined in land development with the result that the current development themes tend to lengthen trips and lead to increased congestion. Further, there are no serious attempts to follow them. This weakness has been the single most limiting factor in our objective towards better transport facilities. Violation of zone laws is more often the rule than an exception which often results in a different land use pattern emerging and having an impact nowhere near the one that was expected as an outcome. Even with specialised agencies to deal with these issues, we have failed miserably on this count due to irrelevant considerations. A far more enlightened national- and state-level leadership is needed to help city governments integrate accessibility and mobility objectives and thereby land use and transport into urban development. The document is silent about the ways by which the central government as well as the state governments can play this role more effectively. Moreover, the role of the user in the planning process is almost nonexistent. Inclusive 'bottom-up' participatory approaches that incorporate community consultation and wide participation by all social groups including women and other disadvantaged groups can greatly enhance sustainable urban transport development. They are also more likely to win public support, especially when questions of difficult policy choices and public actions arise, for example, in the case of urban transport demand management. It has been observed that integrated approaches are based on methodologies that develop a broad-based consensus on an achievable vision of the future and clearly articulate the means by which the visions can be realised. A fundamental institutional change in the planning process is required to incorporate participatory approaches in decision-making and to seek interdisciplinary solutions to urban transportation problems. While the ways in which the involvement of all social groups is organised may be open to debate, its justification cannot be undermined.

The emphasis on the role of public transport has many dimensions. High-density cities are unsuited to high rates of private car use. It is physically impossible for a dense city to have a high level of road capacity per person. Cars take up a huge amount of space when in motion and for parking. In dense cities, space is a valuable commodity. Congestion and parking problems can therefore become very serious in dense cities even when only a few percent of people own cars. However, the failings of public transportation have become one of the major challenges faced by many cities. Dissatisfaction with the level and quality of public transportation services leads those people who can afford it to turn to private modes of transport. Another common problem in many cities is that women, people with disabilities and other disadvantaged groups have poor access to public transport services and that it is found difficult to meet their basic mobility needs. Historically, state transport undertakings (bus companies) have been the prime providers of public transport services in most Indian cities. Fares have traditionally been kept low by state authorities to permit travel by low-income citizens, especially those covering long distances. The chronic uncertainty regarding subsidisation of concessions by the state interacting with inefficiencies on the supply side stemming from the nature of public monopolies has resulted in public transport services being characterised by a low level of service necessarily operating at a low-priced equilibrium. A traditional and irrational focus on production rather than service, rigidities regarding staff levels and remuneration and low financial capacity to expand services have created almost an insurmountable barrier to change. While this approach is acceptable while a great majority of passengers are captive riders, interested mainly in low fares, it is no longer the case anymore especially with an increased affordability of motorised vehicles that resulted in a large loss of public transport passengers.

The solution to the complex urban transport problem thus lies in the development of an efficient and affordable public transport system. This has long been recognised by policymakers and transport planners and emphasised in every transport policy statement. But real actions have been far from adequate. In the early 1990s, public transport generally benefited from bus enterprise reform, increased investment in fleet capacity and implementation of some bus priority schemes, as well as urban population growth that helps maintain strong demand. Many cities have witnessed gains in both ridership and operating efficiency during the second half of the 1990s. These gains have disappeared due to the rapidly growing road congestion and the continuing shift to private cars. Most cities have failed to guide transit-oriented land use development. Peripheral-urban land development has not been planned in a way that could create a market for public transport. The road network—instead of the public transport network—is commonly used in urban master plans as an instrument to shape the urban land use structure. Bus operations and the future guided mass transit systems are given little consideration in road design. There are serious concerns regarding availability of road space especially for bus transport for smooth movement. Only one or two serious attempts have been made to provide more road capacity for bus systems in the Indian context. Others have been lackadaisical in their approach as a result of which such systems collapsed even before they had taken off properly due to lack of discipline on the part of road users. The policy suggests certain provisions in the Motor Vehicles Act to facilitate enforce such discipline. It is common knowledge that provisions in the absence of an effective implementation do not serve the purpose. Public transport, walking and cycling are very much more space efficient than private vehicles, especially cars. The most successful urban transport systems in Asia are those that have encouraged walking and cycling. The policy guideline assures support for such nonmotorised movement with an emphasis on the need to consider seriously the larger public perception regarding design and use of facilities for such movement. There is need for percolation of these ideas to the city level not only to merely gain the financial support being offered as incentive but also to convince the masses on the point that public transportation along with nonmotorised movement is most sustainable on economic, financial, social and environmental grounds.

The fare issue is yet to be tackled as a strategic matter in any urban area. Proposals to increase fares of public transport systems have always been made but never seriously taken let alone implemented. Moreover, these arguments for doing so were limited to the finances of public transport operators. A far more seasoned and mature argument would necessarily has to allow a full range of options to be considered, not just in the fare and service quality dimension but also regarding the regulatory framework and the approach to provision of explicit subsidies. The policy framework attempts to sideline this issue by considering only implicit subsidies which the operators themselves would have to provide. Also, in a world that is moving towards cash transfers, direct financial assistance to poor travellers may be a better option than keeping fares low. No doubt, it would be difficult to pursue this line of action since demand-related data are so inadequate and the relevant technical skills are in short supply in the state and local institutions (World Bank 2005).

An essential remaining question is this: can the current regulatory arrangement, a public sector monopoly, with an outsourcing complement, produce the cost efficiency and service levels to make this mode competitive with individually owned motor vehicles? A clear and promising option is to move towards a market-based arrangement, by separating regulatory and service planning functions from the provision of operations, organising the latter through the medium of competitively awarded service contracts.

6.4.2 Some Underlying Current Issues

Few cities have taken concrete steps to reform the sector structure as a basis for the development of even a viable mass transit industry. Consider, for example, the initiatives taken to promote bus transport under the JNNURM (a brief account of some experience is given in the next section). While incentives are being provided, very little attempt has been made to insist on tariff reforms which are badly required as far as many bus systems are concerned especially in the public sector. Mere insistence on recovery of costs through a process of implicit subsidies (price discrimination) is inadequate. This approach needs to be supplemented by effective benchmarking norms for provision of explicit subsidies—a need that arises in the case of most urban transit systems. According to Sivaramakrishnan (2010), it is quite likely that the bus purchase component of the JNNURM will not have the desired impact on the metropolitan cities. Hopefully, as JNNURM-assisted buses come on the streets, the contestation for allocation of road space for public transport will become more pressing. The issue is whether city and state governments would then be forced to intervene to resolve the conflict which they have avoided for long. This is doubtful since the new buses are by and large a replacement of the existing fleet and may not signify a meaningful addition to public transport capacity. Further, it is pointed out that one of the objectives of central government funding under the scheme was to enable some leveraging of funds by states and local bodies. It is now recognised that liberal provision of central funds can lead to crowding out of other sources which are normally expected to make up for the balance of the funds requirements. Local governments also have faced serious legal and capacity constraints on forming partnerships with the private sector. According to the policy document, ‘the Central Government would encourage the State Governments to involve the private sector in providing public transport services, but under well structured procurement contracts’ (GOI 2006, p. 19). The initiative taken under the JNNURM has been half-hearted with the government considering the venture as something beyond its monitoring and control (except for the start-up process) and the larger public considering it as purely private activity.

A common problem is fragmented responsibility for transportation between many agencies. Reflecting the state/local split, no city has vested the prime responsibility for all aspects of urban/metropolitan transport in one institution. Pieces of decision authority, control over resources and accountability are spread widely between state governments, local governments and state and national parastatals. It is readily acknowledged that some fragmentation is both necessary and unavoidable. But, at any given level of fragmentation, there should be stable umbrella arrangements to coordinate various institutions. This tends to encourage a sect oral approach to planning. Plans are prepared with different financing and implementation arrangements and lack effective institutional mechanisms to examine their mutual compatibility or interrelationships. Because of this unarticulated approach, urban transport development in many cities confronts serious difficulties, including delays in project implementation, wasteful investment and so on, and in many cases, transport interventions do not produce the desired effect. The presence of a unified metropolitan transport authority (UMTA) could solve many of these issues. But progress has been tardy, and in cases the authority has been set up such as Delhi, Bangalore, and Mumbai, it has been established by an executive order except in Hyderabad where it has been constituted under a special enactment. All UMTAs are essentially recommendatory since the thinking is that all coordination bodies must not be implementing agencies. They are only expected to be excellent platforms for coordinated thinking and planning.

The presence and growth of the spillover effects from the urban economies justifies a reconsideration of the present role of the central government in urban transport which is still confined to a few dimensions. At the local level, most large cities are able to make decisions and implement them. But they may not have the right incentives to make strategic decisions that do not compromise the long-term interests of the cities and the nation. Moreover, there need to be adequate checks and balances that would make sure a good strategic plan gets implemented. The responsibilities of the central government even under the NUTP are limited to the support of preparation of urban master plans and large urban transport investment projects, setting technical standards, giving some policy guidance, providing some financial incentives and maybe promoting knowledge exchange and facilitating capacity building. But under current decentralised arrangements, the state and municipal governments take primary responsibilities—both functional and fiscal—for urban infrastructure, including urban transport. Central monitoring and supervision are limited at the local level where planning and policy implementation is carried out. To a great extent, this situation has created an institutional gap in addressing the spill over effects of urban transport problems which is also reflected in the slow transfer of powers and resources from states to local governments. Further, the political constituencies of state and local institutions being different, the continuing dominance by the state produces transport policies, and investments are not properly aligned with local interests. Equally significant is the problem of proliferation of state and local institutions and parastatals which has been unusually high, resulting in diluted regulatory and funding authority and accountability for urban transport matters. Cities have not developed capacity for public transport regulation. The policy framework must provide specific guidelines on the institutional mechanism that is required for regulatory purposes especially when the paradigm of development of infrastructure and services is no longer the same as in the past.

Traditionally, the approach has been supply oriented, and traffic growth biased, and continues to be so. The resulting policy orientations and decisions on how to spend available funds have left large economic and spatial segments poorly served and have not been as effective as they could have to make these cities competitive. In the short term, it neglects the mobility of low-income and poor travellers, especially the nonmotorised ones. It does not involve any use of traffic restraint tools and hence leaves street-based public transport services to the mercy of unrestrained competition from individual motor vehicles. Moreover, it favours the most capital-intensive public transport modes (metros and other urban railways) which may not be warranted by either traffic density or passengers' ability to pay or their budget capacity to pay subsidies in perpetuity. In the longer term, the emphasis on increasing road capacity encourages car-based urban development patterns. The actual policies, as opposed to the statements in principle, thus appear to be both socially regressive and financially unsustainable. There is a conflict with the guidelines enunciated in the urban transport policy statement in a number of ways. In the short term, it neglects the mobility of low-income and poor travellers, especially the non-motorised ones. It does not involve any use of traffic restraint tools and hence leaves street-based public transport services to the mercy of unrestrained competition from individual motor vehicles. Moreover, it favours the most capital-intensive public transport modes (metros and other urban railways) which may not be warranted by either the traffic density or passengers' ability to pay or their budget capacity to pay subsidies in perpetuity. In the longer term the emphasis on increasing road capacity encourages car-based urban development patterns. The actual policies, as opposed to the statements in principle, thus appear to be both socially regressive and financially unsustainable.

Another aspect that is missing in the policy document, one which is a characteristic feature of urban transport systems, relates to a dedicated fund that needs to be made available for the purpose. According to World Bank (2005), the problem of underfunding is an inherent one due to the reduced link between what is paid by users and the funds brought back to bear on the local transport system. There are several ways to do this. The most common way is to escape budget funding and create a closed loop from road user fees via dedicated funds to cities. A less common way, highly successful where it has been implemented, is to introduce local road charging systems, aiming for both revenue generation as well as demand management. Either way, the challenge is to create not merely urban road funds but urban transport funds. Private sector funding has a potential to be a complement, but the prime source of funds should be public which should enable a crowding in of capital local.

6.5 Some Experiences with Elements Under the Current Policy Framework: JNNURM and Public Private Partnerships (PPPs)

6.5.1 The Vadodara (Baroda) Experience

Vadodara Municipal Corporation (VMSS) took up the initiative of organising a city bus service on the basis of public–private partnership. As the lead implementing agency, it defined the bus routes, bus stops and fare structure and also the quality of service in terms of frequency. It had to follow guidelines for city bus services as per urban development and urban housing development department, was responsible to get NOC (No Objection Certificate) from GSRTC for stoppage of current services with the RTA being responsible for sanction of stage carriage permits under

Motor Vehicles Act. The bus stops were made by VMSS on a build–operate–transfer (BOT) basis. In lieu of the rights given to the operators for collecting fare, VMSS got a premium on a yearly basis from the operators. On the other hand, the private partner procured, owned and maintained buses: took care of expenditure on rolling stock and operation and maintenance (including cost of driver and conductor, supervision, fuel). It also provided uniforms to drivers and conductors. Another private party built and operated 124 pick-up stands to give support to the bus services on basis of advertisements.

To begin with, 41 routes were operated with 100 buses. VMSS income increased from bus operations as also from bus stands. This income was to be used for the infrastructure development of the city. The success of this venture was due to:

1. Quick approvals from state government
2. Quick decisions regarding tariffs, routes and frequency
3. Overall monitoring by VMSS
4. Transparent selections of the operator
5. Continuous consultation with stakeholders—public, police, etc.
6. Provision of plots for setting up workshop and fuel station. Parking, cleaning, etc. on a token payment of Rs. 1 per square metre

VMSS has encountered several challenges in terms of the phenomenal growth of three wheelers and personalised vehicles (two wheelers and cars) which have created difficulties in bus movement. A move towards heavy occupancy vehicle lanes and then towards bus rapid transit system could pave the way for an improved system to emerge.

6.5.2 The Jalgaon Experience

The motivation behind the application of the PPP model in Jalgaon was provided by the poor services that the then existing public operator, Maharashtra State Road Transport Corporation (MSRTC), was providing. MSRTC sustained continued losses from the business, and its demand for compensation from the Jalgaon Municipal Corporation did not receive any response. As a result, operations were discontinued in August 2009. The municipal corporation wanted to provide bus services but had neither the resources nor the requisite expertise to do so, and hence there was no option but to go in for the PPP model.

A special purpose vehicle (SPV), JNTU, was formed for this purpose. The SPV floated the tender for bus services which then received one response from Prasanna bus links (PBL). 'ECOBUS' thus began operations with the fleet of buses fitted with EURO III diesel engines with rates being Rs. 3 for the first 2 km and Rs. 0.60 per km thereafter. This system adopted E-enabled measures such as GPRS fleet tracking system, electronic ticketing system, LED and LCD displays in buses and stops and smart card passes. The frequency on all routes was 15 min. As a result, the carrying capacity increased by 400 %, while average occupancy rose to 55 and a revenue increase of 500 %. All these were achieved due to sustained marketing efforts, more revenue from advertising and motivation of manpower, thereby providing high-quality services and above all achieving high level of operational efficiency.

However, a little more than a year later, the services have been withdrawn due to a number of reasons significant among them being the lack of infrastructure provision as provided in the agreement between the public and private partners. Noncooperation on the part of the MSRTC did not permit use of a terminal that has been lying unused ever since MSRTC stopped city operations. The absence of a bus terminus and depot space resulted in significant additional expenditure on diesel for bus turn around on every trip and empty movement at the start and close of the day. While the tendering process had specified 15 routes to be bid for only five were offered and the remaining not being offered at the instance of the MSRTC. It is our understanding that even the routes that were proposed were never planned which meant there is need for rationalisation of routes based on a comprehensive study that needs to be undertaken to examine origin–destination movements and also to categorise routes as trunks and feeder routes. This is a vital part of the urban planning and development department (or town and country) which is currently not being given any particular attention. Further, it is being realised that in the absence of model concession agreement prepared by the central government for use specifically for bus operations in urban areas (as was done for roads, ports, airports), there are no clear signals to the operators on what is expected from them. Addressing these issues of institutional weakness and the capacity-building constraints of urban local governments needs much more serious attention from national policymakers than what has been outlined in the policy framework.

6.6 Concluding Remarks

The central government has, no doubt, attempted to strengthen its role in urban transport under the NUTP to provide useful policy directions and reward good practices. However, since these attempts are advisory by nature, it is essential to realign the incentives of municipal governments in a far more strategic way so that the long-term objective interests of the cities and the nation are appropriately considered and incorporated into the local decision-making process. In relation to the incentives created by the central government, an urban transport performance benchmarking and evaluation system should be developed to monitor how cities are performing in city development including urban transport. It is well known that the absence of such benchmarking efforts has resulted in a decline of bus transport services in our cities especially those of public sector transport undertakings, almost all of which reflected most inefficient practices. More recently, the Ministry of Urban Development, Government of India, has attempted to provide comprehensive guidelines on service benchmarks (MOUD 2008). The crucial issue is whether these would ever be used in practice to encourage improvements.

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Chapter 7
Role of Nonmotorized Transport and Sustainable Transport in Indian Cities

Geetam Tiwari

Abstract A large number of trips are made by nonmotorized transport in Indian cites. However, majority of the users of nonmotorized transport are captive users, people who do not have any other choice of travel mode. The current state of infrastructure for nonmotorized transport is very poor, and city governments have paid very little attention to investment in developing appropriate infrastructure for nonmotorized transport. Therefore, with the increase in income and access to other motorized modes, these users will move to other modes of transport such as motorized two-wheelers or cars or bus. Improvement in NMT infrastructure can benefit current NMT users by reducing risk from other motorized vehicles. Improved NMT infrastructure is also expected to attract short trips from motorized two-wheelers and bus resulting in lower vehicular emissions. Increase use of NMT results in health benefits by increasing opportunities for active transport. Overall NMT-friendly infrastructure and policies can play a very important role in achieving sustainable transport – providing safe and clean mobility to all city residents.

7.1 Nonmotorized Transport in Indian Cities

Nonmotorized modes include walk and bicycle and cycle rickshaw. These modes are not dependent on fossil fuels and have minimal emissions. These are truly low carbon modes. Low-income households are dependent on these modes to access employment, education, and other essential services. The use of nonmotorized transport (NMT) has health benefits; however, with the rise in incomes and poor infrastructure, use of NMT has been declining. Often its users are captive users as they cannot afford other modes of transport. These users are dependent on walk and bicycle even for commuting longer distances (Mohan and Tiwari 1999). The use of nonmotorized modes of transport in Indian cities has been high and strongly correlated with low incomes (Jain and Tiwari 2009; Tiwari 1999; Replogle 1992). City

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authorities and state governments have not invested in upgrading NMT infrastructure resulting in degrading level of service and increasing risk to pedestrians and bicyclists. This has resulted in declining use of NMT with the increasing income levels in the past few years (Wilbur Smith Associates 2008). Despite this, NMT dominates the modal share of Indian cities. Even in megacities (population >8 million) modal share of NMT ranges between 40 and 50 % (walking and bicycling). This is attributed to the dense mixed land use patterns resulting in shorter trip lengths in Indian cities and availability of NMT as the only available mode of transport for low-income households.

NMT is also a major mode of transport to access public transport system especially by walk and cycle rickshaw. Primarily, a public transport (PT) user is a pedestrian for at least one part of the trip either during access or egress. Provision of an appropriate well-integrated infrastructure for the use of NMT along with PT improves the utility of the system and increases its catchment area. Approximately 97 % of the total bus commuters surveyed in Delhi walk to access bus service (Advani and Tiwari 2006). Though developing infrastructure for pedestrians does not have direct impact on their speeds, however, the improvement results in easy, comfortable, and safe access. The study shows that about 96 % of the bicycle owners walk to access public transport. By providing appropriate parking facility for bicycles at or near bus stop and safe bicycle paths, the number of bus users can increase as larger area around bus stops becomes accessible. To attain the sustainability goal within transport sector, it is required to promote the use of NMT. This would require changes in policies, plan implementations, and fund allocations to

- Retain the existing modal share of NMT and address the need of captive users
- Encourage potential users of NMT to use NMT

Provision of appropriate infrastructure for NMT provides equal access to all and is a major factor in determining the use of public transport in the city. Thus a complete network plan must be in place for promoting the use of NMT that is also well integrated with the existing and proposed PT system of the city.

7.2 Trends in the Use of Nonmotorized Transport (NMT)

Majority of urban trips are by NMT in Indian cities. However, the share of NMT has been reducing over the years. This section discusses changes in the use of NMT from 1980s to 2010 in Indian cities.

7.2.1 Modal Share of NMT

In the early 1980s, NMT in Indian cities, i.e., bicycles and walk, together accounted for approximately 40–60 % of the total trips. The share has been declining since then except in Chennai and Patna (Fig. 7.1). Bicycles and walk trips follow different trends.

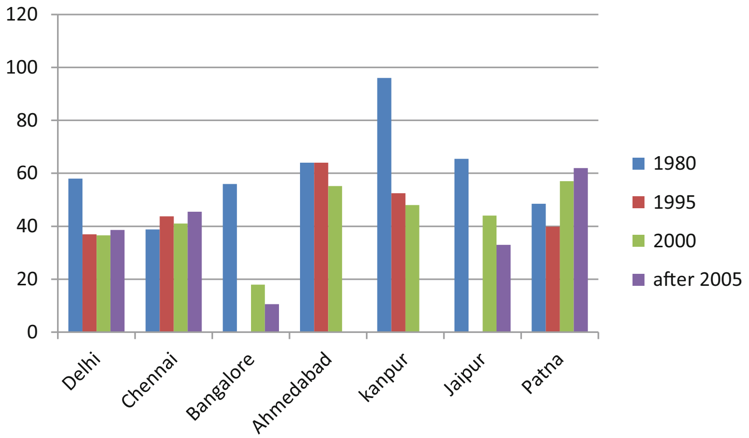

Fig. 7.1 Trends in modal share of NMT (walk and bicycle) from 1980s till date

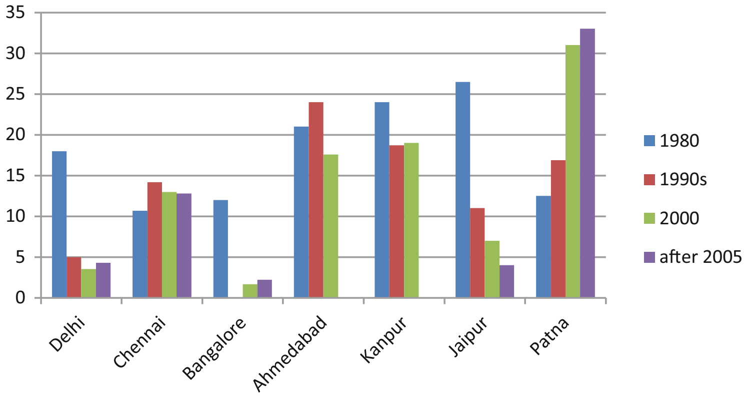

Fig. 7.2 Trends observed in modal share of bicycle trips since 1980s

Of the total trips, bicycle modal share accounted for approximately 10–30 %; bicycles started to lose patronage in the 1990s (Replogle 1992). For example, in Kanpur the modal share of bicycles declined by 22 % by 1995 as compared to Delhi, Jaipur, and Bangalore where the share of bicycles declined by 66 %, 58 %, and 86 %, respectively. The modal share of bicycles increased by 15 % till 1990s and then decreased by 27 % by 2000 in Ahmedabad. In Patna, modal share of bicycles increased by 83 % between 1990s and 2000s that can said to be stabilized resulting in increase by 6 % only from 2000 to 2008 (Fig. 7.2).

Trends observed in bicycle modal share are different from the trends observed in walk trips. Major changes have not taken place in the case of walk trips as compared to bicycle trips in Indian cities since 1980s; however, their share has also been declining. Of the total trips, walk trips still account for approximately 30–40 % of the total trips except in Bangalore where walk modal share has reduced to 8 % in

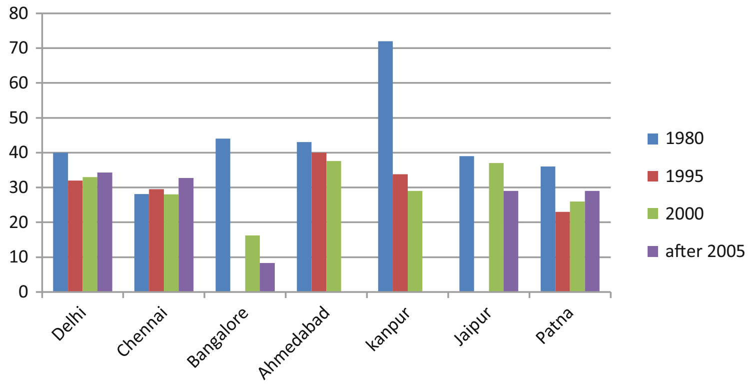

Fig. 7.3 Trend observed in modal share of walk trips since 1980s

2007 as compared to 44 % in 1984. Delhi and Patna have shown similar trends where the modal share of walk declined from 1980s to 1990s and then started to increase after 1995 (Fig. 7.3).

7.2.2 Bicycle Ownership

Bicycle ownership is high in all Indian cities. Most of the medium and large cities have 35–65 % households owning one or more bicycles as per Census 2001, whereas in the smaller cities, it varies between 33 and 48 %. There are 54 % households in Ahmedabad and 63 % households in Chandigarh owning one or more bicycle (Census of India 2001). In Delhi, 37 % of the households owned bicycles in 2001.

7.2.3 Cycle Rickshaw Trips in Indian Cities

Cycle rickshaws account for between 5 and 10 % trips in Indian cities (Kolkata, Chennai, Delhi, and Hyderabad). Apart from providing for passenger mobility, rickshaws have been developed as mobile carts selling perishable and other goods for daily use. They are also retrofitted as vans ferrying children to school. Driving cycle rickshaws is often the first job for many rural migrants in cities. The percentage of rickshaw trips is higher in smaller cities that do not have public transport and with traditional narrow streets inaccessible to buses (Un-Habitat 2013). Rickshaws carry goods for small traders and take children to schools. It is the most convenient form of transport for women to use between their homes and bus stops or shopping areas. Along with the large number of rickshaw drivers and the people traveling on rickshaws, a small community of rickshaw owners, rickshaw mechanics, and rickshaw makers are associated with this mode of transport (Ravi 2005). In spite of frequent harassment by local officials (Sood 2012), rickshaws continue to remain a popular, easily available, and cheap mode of transport for travel within a crowded locality, both for passengers and cargo. The amount of luggage they can carry versus the amount of space they occupy is comparatively high. Rickshaws also provide much-needed transport for people living in the old, congested areas, urbanized villages, illegal colonies, or peri-urban localities and provide connectivity to physically separated neighborhoods.

In 1998, the Ministry of Urban Development, Government of India, sponsored a study of 21 cities (Rites 1998). The study showed a substantial share of rickshaws in several cities (Table 7.1). The Ministry commissioned another study in 2008 to understand the mobility trends in Indian cities (Wilbur Smith Associates 2008). That study covered 31 cities. However, this time rickshaws were not counted as a separate mode and were combined with bicycles (Table 7.2). While the presence of cycle rickshaws is denied in data, there can be no discussion about their positive contribution to the city mobility system and required infrastructure. The National

Table 7.1 Share of trips by IPT modes across different cities (percentage)[a]

Cities	Year	Auto rickshaw	Taxi	Cycle rickshaw	Tonga	Contract buses
Bombay	1976		9			
	1981	2	9			
	1986	11.7	9.8			
Calcutta	1984					
Delhi	1957	12.2		16.4		1.4
	1969	5.2		2.2		
	1981	3.6		2.8		9
Madras	1984	0.35		1.06		
Bangalore	1982	4				
Hyderabad		2.75		6		
Pune	1970	2				
	1986	6.3				
Jaipur	1985			2.7		3.4
Kanpur		1		12		
Lucknow	1963			2.35	0.9	
	1987	4.31		20.03		0.66
Patna	1985			17.6		4.8
Vadodara	1985	5.8				2.2
Coimbatore		1.2			0.6	
Cuttack	1991	0.2		19.4		
Rajkot	1991	8.5				
Ranchi	1991	8.9		7.3		

Source: [a]Rites (1998)

Table 7.2 Estimated mode share for the selected cities for future (%)

		2007			2011			2021			2031		
City category	Population	PT	PV + IPT	NMT	PT	PV + IPT	NMT	PT	PV + IPT	NMT	PT	PV + IPT	NMT
Category – 1a	<0.5 million	5	57	38	4	59	36	3	66	31	2	72	26
Category – 1b	<0.5 million	8	34	58	7	37	56	5	47	48	3	57	40
Category – 2	0.5–1.0 million	9	39	53	8	42	50	6	51	43	5	58	36
Category – 3	1.0–2.0 million	13	43	44	12	46	43	10	52	38	9	57	34
Category – 4	2.0–4.0 million	10	47	43	9	49	42	8	51	41	8	52	40
Category – 5	4.0–8.0 million	22	42	36	21	45	35	15	51	34	12	54	34
Category – 6	>8.0 million	46	24	30	42	28	30	31	40	29	26	46	28

Source: Wilbur Smith Associates (2008)

Urban Transport Policy (NUTP) issued by the Ministry of Urban Development in 2006 is silent on the role and requirements for rickshaws (Ministry of Urban Development 2006). The comprehensive mobility plans prepared by different cities in the last decade do not discuss rickshaws (Itrans 2009; Rites 2009; Pune Municipal Corporation 2008).

Rickshaws are an important feeder mode for public transport systems. Advani (2010) presented estimates for Delhi metro for 2021. This study showed that at least 20 % of metro trips are currently (2011) dependent on rickshaws, and it is possible to estimate and plan for the necessary infrastructure required at the metro stops for bicycles and rickshaws. This suggests that in the future, too, rickshaws can be used as a feeder mode to metro and bus systems. The role of rickshaw as a feeder mode has been highlighted, especially its importance for metro rail trips. If the present policy of the Delhi government of restricting rickshaws in several parts of the city continues, metro ridership will be adversely affected. On the other hand, permitting rickshaws in all parts of Delhi will increase metro ridership.

Rickshaws are often blamed for creating congestion. However, Tiwari et al. (2007) show that if NMT is segregated from motorized traffic, road capacity can increase. Segregated lanes are possible on arterial roads where right of way is more than 30 m. Recognizing the role of cycle rickshaws not only as a mode of transport for short trips but also as an important feeder mode to public transport systems and adoption of favorable policies to integrate it in the overall transportation planning should be a requirement while planning a public transport system. At present, a number of cities in India are planning to implement either a Bus Rapid Transit system or metro system. All these cities have an opportunity to integrate rickshaw-friendly infrastructure at the planning stage of these systems.

7.2.4 Challenges Faced by NMT Users

NMT users such as pedestrians and bicyclists are exposed to high risk in all Indian cities. Generally, physical infrastructure is not planned for their convenience and safety, and most cities have restrictive policies for the use of cycle rickshaws.

7.2.4.1 Captive Users

Current NMT users are generally low-income people who do not have access to any other mode of transport because of economic constraints or social constraints. Even though modal share of NMT in Indian cities is high, however, the use of NMT by higher-income population who have access to motorized modes is low. In Indian cities, a large proportion of population lives in slums, for example, in Mumbai 54 % of the population lives in slums, in Kolkata 33 %, and in Delhi 19 %. This group of people cannot afford personal motorized vehicles (cars and two-wheelers) for transportation, and even subsidized bus systems are also too expensive for them for daily

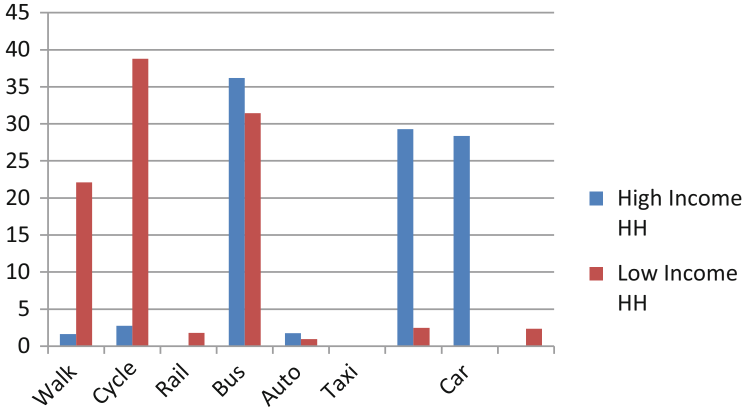

Fig. 7.4 Modal share by high-income and low-income households in Delhi (Source: Tiwari 2002)

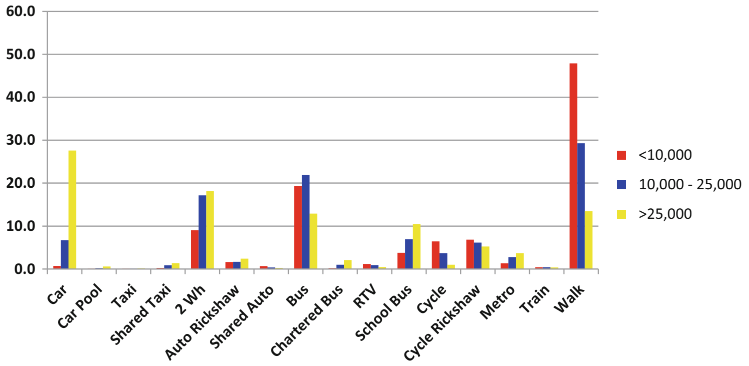

Fig. 7.5 Modal shares by income group in Delhi (Source RITES 2008)

commute (Tiwari 1999). Their transportation needs are thus dependent on nonmotorized transport (NMT) which includes walking or cycling. In Delhi, nearly 60 % of the trips made by low-income households were by walk and bicycle as compared to 4 % of the trips made by high-income households (Tiwari 2002). The proportions remained unchanged in 2008 (RITES 2008) (Figs. 7.4 and 7.5).

Table 7.3 shows travel modes used by different income groups and gender in Delhi and Fig. 7.6 in Vishakhapatnam. Both show higher share of walking and use of bicycles among lower-income households as compared to the higher-income households. Among poorer households, the share of NMT modes is higher among unemployed persons. Women are more dependent on walking. Figure 7.2 shows dominance of walk trips among women as compared to men; however, with the increase in income, this gap seems to reduce. Similarly with the increase in income, the gap in public transport trips among women and men seems to be narrowing; higher-income men and women have similar share of trips on public transport. Bicycle users are more among men as compared to women. These trends are similar

Table 7.3 Travel mode used by employed men and women

Mode of travel	Employed persons (%)	Unemployed persons (%)	Employed men (%)	Employed women (%)
Walk	49	87	34	86
Bicycle	15	2	22	1
Bus	23	8	27	13

Low-income households in Delhi (2012)

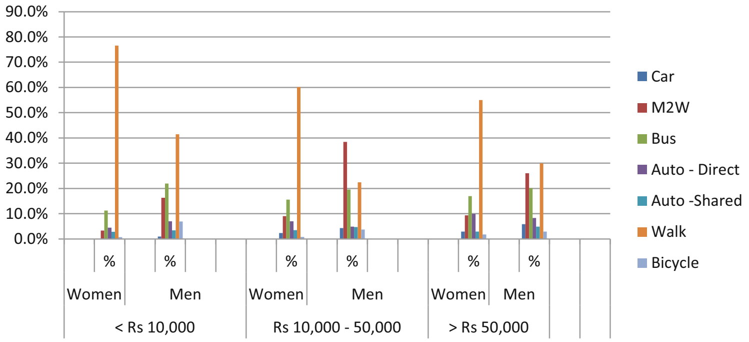

Fig. 7.6 Modal shares by income groups and gender

to those reported by earlier authors showing that 83 % of women trips were walking trips and 63 % of men trips were walking trips in Chennai, India (Srinivasan 2008). Anand and Tiwari (2007) reported similar trends observed in Delhi in 2001 of low-income households. Women either walk to work or use public transport. Share of women walking to work is much higher (52 %) than men (26 %).

A follow-up survey done in 2012 at TRIPP/Delhi of low-income households shows more women employed in informal employment as compared to men (86 % vs. 74 %). Among employed persons, women are more dependent on walking as compared to employed men. The use of bicycle is negligible among women, and bus use is much less than men. Differences in travel trends observed in 2001 remain unchanged after 10 years (Fig. 7.6).

7.3 Role and Impact of NMT in Future

7.3.1 Travel Behavior in Indian Cities

Indian cities have high density, mixed land use, and heterogeneous structure enabling shorter trip lengths. Even in the mega and large cities of India like Delhi and Hyderabad, 70 % of the trips are shorter than 5 km and 80 % of the trips are shorter than 10 km (Fig. 7.7). Average trip length in medium- and small-sized cities is less than 5 km.

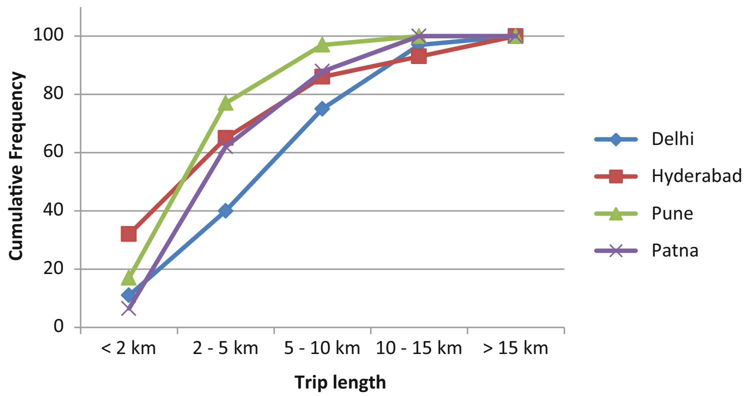

Fig. 7.7 Trip length frequency distribution for Delhi, Hyderabad, Pune, and Patna

Table 7.4 Modal share and average trip lengths in Delhi, Pune, and Patna

	Delhi[a]		Pune[b]		Patna[c]	
	Modal share	ATL	Modal share	ATL	Modal share	ATL
Walk	34.3	0.72	31	1	30.1	1.6
Cycle	10.7	4.5	13	4.3	36.7	4.9
Sc/Mc	14	9	28	6.47	13.2	5.8
Three-wheeler	2.29	9.67	7	3.14	9.5	7.1
Car	9.02	10.67	6	7.56	1.9	7.1
Bus	26.92	10.66	15	7.4	8.4	5.9
Metro	2.77		NA	NA	NA	NA

Source: [a]RITES (2008), [b]Pune Municipal Corporation (2006), and [c]Itrans (2009)

Even though the existing situation is hostile for the use of NMT, existing modal share is in favor of NMT being 45 %, 44 %, and 66.8 % in Delhi, Pune, and Patna, respectively (Table 7.4). In cities where formal bus service exists, PT (bus) dominates the motorized modal share. In other cities like Patna, three-wheelers dominate the motorized modal share.

The average trip length of walk and bicycle is nearly the same in Delhi and Pune, while in Patna people walk and cycle longer. The average trip length of motorized transport in Pune and Patna is similar except for three-wheelers. Three-wheelers cater to longer trip lengths serving 33 % of the total travel demand (passenger-km). This is attributed to the lack of bus service in Patna (Table 7.5). The average trip length in Delhi is approximately 10.6 km, and bus dominates the motorized transport share. Trip length frequency distribution and modal share for NMT and PT are correlated irrespective of infrastructure availability. Buses cater to 54 % of the total travel demand (by motorized modes) in terms of passenger-km in Delhi. Compared to this, buses cater to 31 % and 24 % of the total travel demand in Pune and Patna, respectively.

The existing infrastructure of NMT and PT in Indian cities is in poor condition resulting in increasing risk and distress to the users of the systems. The existing

Table 7.5 Passenger km (lakhs) for Delhi, Pune, and Patna by motorized modes

	Delhi		Pune		Patna	
	Passenger km (lakhs)	Percentage (%)	Passenger km (lakhs)	Percentage (%)	Passenger km (lakhs)	Percentage (%)
Bus	730	54	73	31	16	24
Car	245	18	30	13	4	7
MTW	321	24	119	51	24	36
IPT	56	4	14	6	22	33
Total	**1,352**		**236**		**66**	

users of the system are thus captive users as they cannot afford other modes of transport. These users are likely to shift to PMV as and when they can afford it. The trip length frequency distribution shows that there are a large number of potential users of NMT and PT.

7.3.2 Potential NMT Trips in Different Cities

Current NMT users in Indian cities are captive users (Jain and Tiwari 2011). These users do not have access to any other mode of travel and therefore are forced to use bicycles or depend on walking. At the same time, there are short trips (less than 6 km long) which are made by motorized two-wheelers or cars or buses. These can be termed as potential bicycle trips. Recent surveys in Delhi and Pune have shown poor quality of infrastructure, fear of traffic crash, and insecure street environment which forces people to avoid use of bicycles and instead use motorized modes for short trips. These trips can be shifted to bicycles if bicycle-friendly infrastructure is implemented in cities.

7.3.3 Impact of NMT Infrastructure

Travel pattern in a city not only depends upon transport infrastructure but also on cities' size and urban form defined by building density and land use mix intensity. Distances that people have to travel for various activities, defined as trip length, depend on the land use mix and density. Other than socioeconomic variables, trip length has a major influence on the choice of travel mode. NMT modes like walking and bicycle are likely to be used for shorter trips (shorter than 1 km for walking and 5 km for bicycles), provided that safe and convenient infrastructure is available. Longer trips are more likely to be made by motorized modes. This is well depicted in average trip length of various modes in different cities. Therefore, different types of transport infrastructure improvement projects are likely to have different outcomes in terms of modal shifts and hence energy consumption and emissions.

Impact of provision of NMT infrastructure is presented on modal shares and, therefore, emissions and fuel consumption for Delhi, Pune, and Patna. Based on the

Table 7.6 Scenario 1 description

Description		Share of trip shorter than 5 km shifting to NMT	Share of trips longer than 5 km shifting to bus
Improving only NMT infrastructure	MSS	30 % from MTW, three-wheelers, and bus	0 %
	LSS	10 % from MTW, three-wheelers, and bus	0 %

Table 7.7 Percentage change in modal share

	NMT		MTW		Three - wheelers		Bus	
	MSS(%)	LSS(%)	MSS(%)	LSS(%)	MSS(%)	LSS(%)	MSS(%)	LSS(%)
Delhi	7	2	–7	–2	–14	–4	–4	–1
Pune	12	4	–8	–3	–24	–8	–8	–3
Patna	3	1	–10	–3	–3	–1	–7	–2

understanding of correlation between mode choice and trip lengths, modal shifts from different modes to NMT are estimated considering trip length distribution of each mode. The results are further analyzed to determine impacts of improving NMT infrastructure on emissions and energy consumption. For the analysis, two extreme case scenarios are discussed – maximum shift scenario (MSS) and least shift scenario (LSS) as shown in Table 7.6. Modal shifts in MSS scenarios are based on stated preference surveys conducted in Indian cities by other researchers (Thamiz Arasan and Vedagiri 2011; Jain et al. 2010; Rastogi 2010; Vedagiri and Arasan 2009). LSS scenarios are developed to estimate the least plausible impact of improving NMT infrastructure on mode choice and hence emissions and energy consumption.

In MSS, improving NMT infrastructure in cities is likely to result in 30 % of the trips shorter than 5 km made by MTW, three-wheelers, and bus shift to NMT. While in LSS, only 10 % of the trips shorter than 5 km made by MTW, three-wheelers, and bus shift to NMT, and the modal share of the trips longer than 5 km is retained. In Indian cities, motor vehicle ownership is 58 per 1,000 persons which is likely to grow with the growing economy. Considering the low car ownership, net modal shift from cars to NMT modes is assumed to be negligible in both the scenarios.

7.3.4 Estimated Change in Modal Shares

Table 7.7 shows percentage change in modal share assuming NMT-friendly infrastructure is provided in Delhi, Pune, and Patna. Shaded cells within the table represent maximum shift from modes for each city. Even though same percentage shifts have been assumed for the three cities, resulting modal shares vary across cities.

Table 7.7 shows modal share of bus is not likely to change much in Delhi as compared to that of in Pune and Patna. Improving infrastructure for NMT in Delhi and Pune is likely to result in maximum shift from three-wheelers to NMT. As compared to this, improving NMT infrastructure in Patna may result in maximum shift from MTW to NMT.

7.3.5 Impact on Energy Consumption and CO_2 Emission

Estimated change in modal shifts from MTW, three-wheelers, and bus will result in change in energy consumption pattern across cities.

Improving only NMT infrastructure in Delhi results in overall reduction in fuel consumption by 6 % and equivalent CO_2 emissions by 1 %. This is attributed to a major shift from three-wheelers to NMT that has negligible contribution to CO_2 emissions. Whereas in Pune improving infrastructure for NMT results in reduced consumption of gasoline by 3 %, CNG by 22 %, and diesel by 12 %, in Patna, it results in reduced consumption of gasoline by 16 % and diesel by 46 %.

In terms of reduction in CO_2 emissions, maximum percentage reduction is achieved in Patna, i.e., 19 %. This is attributed to the shifts taking place from three-wheelers that are operating on gasoline. As compared to this, in Pune the percentage reduction in CO_2 emission is nearly 1 % when infrastructure for NMT is improved. Even though maximum percentage reduction is in Patna, quantitatively a large amount of CO_2 emission is reduced in Delhi, i.e., around 69,000 kg of CO_2 in MSS and 21,000 kg of CO_2 in LSS daily.

It is clear that provision of NMT infrastructure will benefit all city sizes and will result in reduction in fuel consumption and vehicular emissions.

7.4 Impact on Health

Transport system and resulting travel patterns impact human health in three different ways:

1. Vehicular emissions
2. Traffic crashes
3. Physical activity

NMT trips have direct impact on all three.

7.4.1 Vehicular Emissions

The harmful emissions from vehicles result in mortality and morbidity due to respiratory and cardiovascular diseases (Dora and Phillips 2000). Vehicular exhaust has the worst effect on those traveling on road, varying over different road users (Tsai et al. 2008), as well as those living in close proximity of traffic especially children (Kim et al. 2004). Pollutants, especially particulate matter (PM), from vehicular sources have been found to be much more toxic than those from other sources (Han and Naeher 2006). According to a study in three European countries, about half of all mortality caused by air pollution was attributed to motorized traffic (Dora and Phillips 2000). Cities in India have one of the highest pollution levels in the world. In 2010, annual average ambient concentration level of one of the criteria pollutants – PM10 – reached more than 25 times the standard set by the World Health Organization (WHO) (Guttikunda and Jawahar 2012).

7.4.2 Traffic Crashes

Injuries are an important public health problem in India, contributing to about 10 % of total deaths in urban and rural India. According to 2012 NCRB data, 0.14 million deaths have occurred due to road traffic injuries (RTI). This is among the three leading causes of death for people in the age group of 5 and 44 years. Nearly 15 % of RTI deaths in the country occurred in cities with a population of more than a million. Rest of the deaths and injuries occur in districts and rural areas of the country, predominantly on state and national highways. Traffic fatalities increased by about 5 % per year from 1980 to 2000 and since then have increased by about 8 % per year for the 4 years for which statistics are available.

Nonmotorized transport users such as pedestrians and bicyclists have the largest share in traffic crashes. Detailed analysis carried out in Delhi, Mumbai, Kota, and Vadodara showed pedestrians and bicyclists comprising of nearly 80 % fatal crash victims (Tiwari and Jain 2013). Another study which included Amritsar, Ludhiana, Bhopal, and Visakhapatnam showed similar trend (Fig. 7.8). Regardless of city size, involvement of pedestrians and bicyclists in fatal crashes is very high.

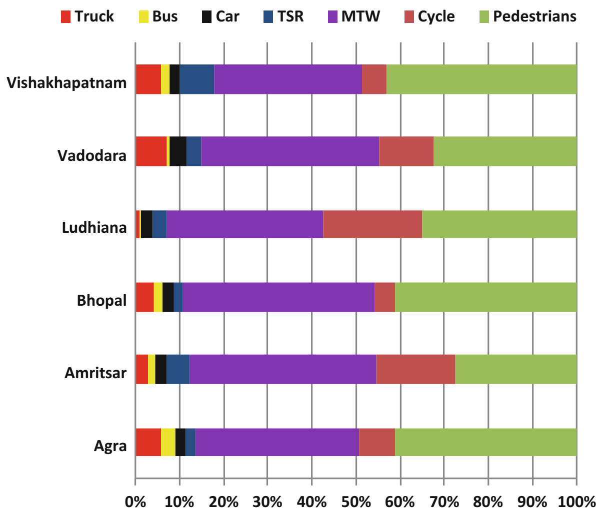

Fig. 7.8 Proportion of RTI fatalities by road user type in six study cities (*MTW* motorized two-wheelers, *TSR* three-wheeled scooter rickshaws) (Source: Mohan et al. 2014)

Provision of NMT infrastructure includes segregated pedestrian paths, exclusive bicycle tracks, and safe crossing facility for NMT users. This ensures that the conflict between NMT users and mortised vehicles is reduced. The data available from a 6 km long corridor in Delhi where segregated pedestrian and bicycle paths have been constructed shows reduction in bicycle and pedestrian crashes.

Safe NMT infrastructure results in increased NMT trips and reduces risk to NMT users from traffic crashes.

7.4.3 Physical Activity

Increasing dependence on motorized modes as opposed to walking or cycling also leads to reduced levels of physical activity. This, in turn, causes many chronic diseases like cancer, diabetes, and other mental health problems. In the United States, physical inactivity alone is responsible for a number of deaths which is four times the number of deaths attributed to traffic-related accidents and air pollution (Sallis et al. 2004).

Woodcock et al. (2009) have estimated health benefits of promoting active transport – walking and bicycles including all three impacts: vehicular emissions, traffic crashes, and physical activity in Delhi. The estimates are based on a reversal of present trends, i.e., investment in NMT infrastructure instead of expansion of road infrastructure which attracts more car and MTW trips. The estimates show a small increase in the distance walked and more than double increase in distance cycled, a large increase in rail use and small increase in bus use (Table 7.8 and Fig. 7.9). Various health impacts are shown in Table 7.8. Policy interventions include substantial investment in infrastructure designed for pedestrians and cyclists rather than for cars.

NMT infrastructure is expected to result in major health benefits to Delhi population. Similar trends are expected in other cities as well.

7.5 NMT Infrastructure Investments and Policies

The transport policies at urban and national level in India until 2006 did not focus on the improvement of infrastructure for nonmotorized transport (NMT). In 2006, National Urban Transport Policy (NUTP) was adopted by Ministry of Urban

Table 7.8 Health impacts of promoting active transport (Woodcock et al. 2009)

	Reduction in disease burden	Reduction in premature deaths
Ischaemic heart disease	11–25 %	2,490–7,140
Cerebrovascular disease	11–25 %	1,270–3,650
Road traffic crashes	27–69 %	1,170–2,990
Diabetes	6–17 %	180–460
Depression	2–7 %	NA

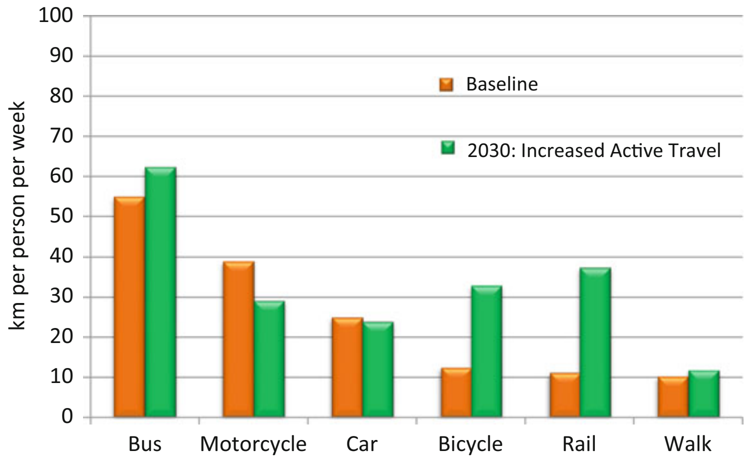

Fig. 7.9 Estimated change in travel patterns in Delhi due to NMT infrastructure provision (Woodcock et al. 2009)

Development (MoUD). The policy proposed a framework prioritizing the use of public transport systems and walking and use of bicycles in cities. The national government offered finances either as grant or loans to cities to invest in improving NMT infrastructure. However, improving infrastructure for NMT is restricted to the cities where Bus Rapid Transit (BRT) projects are under implementation and that too along the proposed BRT corridor only.

Tiwari and Jain (2013) analyzed city budgets of selected cities in India and found that of the four cities' budget, only Delhi specifies breakup of the expenditure made in transportation for different projects. The analysis showed that both Chennai and Surat have prioritized construction of bridges, flyovers, and subways. Greater Hyderabad is laying attention toward multimodal transport, and for Delhi no particular trend can be determined. As such, improvement of infrastructure for NMT is not accounted separately in city budgets.

In last 5 years, BRTS corridors have been planned and approved for 9 cities, bus procurement has been sanctioned for 53 cities, and other projects related to infrastructure expansion have been approved for 21 cities under JNNURM scheme. However, only Nanded and Bangalore have been exclusively taken for improvement of infrastructure for NMT users.

The study (Tiwari and Jain 2013) found that as per JNNURM strategy, transport infrastructure improvement projects should comply with the objectives of NUTP. However, in the sanctioned projects, the complete integration of multimodal systems including NMT is missing. Improving infrastructure for NMT requires provision of facilities extending to the city areas comprehensively that provide direct, safe, secure, and comfortable access to all NMT users. As compared to this, development of NMT infrastructure is restricted to the planned corridors of BRT. NUTP 2006 has not resulted in visible change in the investment pattern of local authorities and NMT continues to be ignored. This represents a gap between planning and implementation of a strategy, scheme, and policy.

7.6 Conclusion

Sustainable transport is often defined as one that meets the mobility needs of all users with least adverse effects on users as well as nonusers. Adverse effects are in the form of poor air quality, risk of traffic crashes, lack activity leading to obesity, and other related diseases. Least adverse effects on users and nonusers is possible when majority of the city residents have to travel short distances, thus reducing the exposure to air pollution as well as risk from traffic crashes. Short distances are conducive to travel by active (walking and bicycling) transport which is environment friendly along with giving health benefits to the users.

Walking, bicycling, and public transport have least adverse effects on environment both local and global. These are also known as active transport, because the users are involved in physical activity which results in health benefits. Provision of NMT infrastructure is expected to have substantial impact on travel patterns and reduction in adverse health impacts of transport. This paper shows the differences in modal shares and resulting impact on fuel consumption and emissions expected in different city sizes in India. NMT remains important regardless of city size.

However, NMT-friendly infrastructure continues to get low priority in city improvement plans and projects. NMT can contribute to the goals of sustainable transport only if we accept a different paradigm in transport planning. We have to accept that there is a hierarchy in transport planning with pedestrians and cyclists (the most vulnerable group) at the top and car users at the bottom. A city which is planned and designed keeping the needs of pedestrians and cyclists meets the environment, equity, and economic sustainability requirements as well.

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Chapter 8
Integrating Climate Change in City Planning: Framework and Case Studies

Minal Pathak, P.R. Shukla, Amit Garg, and Hem Dholakia

Abstract The relationship between cities and climate change has been under discussion by researchers and policy makers. It is an accepted fact that cities have a very important role to play in mitigating greenhouse gas emissions. This is especially true for rapidly growing cities in developing countries like India where urban population growth, spatial expansion, and economic development have resulted in increasing demand for energy. Future per capita CO_2 emissions are expected to increase by four times between now and 2050. At the same time, like many other cities in developing countries, Indian cities are experiencing simultaneous challenges including infrastructure scarcity, air quality deterioration, and inadequate water resources. Large populations, high densities, presence of informal settlements, and industries within these cities have made them vulnerable to climate extremes. Urban infrastructure also will be at risk from climate change events including intense precipitation, flooding, and heat events. Future growth in urban areas will exacerbate existing issues of infrastructure provision and environmental issues of air quality, water, and waste. Climate change will be an added dimension to these urban challenges. Current urban planning process does not mainstream climate concerns and therefore necessitates the search for alternate approaches. Using case studies of selected cities, the chapter briefly highlights mitigation and adaptation challenges for these selected Indian cities and suggests a framework for integrating climate change concerns in urban planning and management.

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8.1 Introduction

Globally, urban areas are expected to absorb the entire population growth in the next four decades and at the same time draw people from rural areas. Currently, over 3.6 billion people live in urban areas and by 2050 this number will be 6.3 billion. Nearly half of this population growth will happen in Asian cities (UN 2012). Within the next decade, there will be nearly 500 cities of more than a million people, including several megacities with a population exceeding 20 million. The role of the cities for global carbon mitigation is now increasingly being realized by research and policy communities (Dhakal 2010). Urban activities including transport, industry, solid waste disposal, domestic fuel use and power generation contribute to significant GHG emissions (Dhakal 2004, 2009). Cities also account for an estimated 67 % of global energy use and 71 % of global energy-related CO_2 emissions (OECD 2013).

In 2011, average per capita CO_2 emissions in EU-27 were 7 tons and 16.9 tons in United States. In the same year, India's per capita CO_2 emissions were 1.4 tons which are much lower than the 2011 global average of 4.5 tons and China's 5.9 tons (IEA 2013). However, India's total CO_2 emissions are the fourth largest globally (Oliver et al. 2012). Also, past trends show a significant increase in demand. For instance, between 1994 and 2007, emissions from electricity grew at a CAGR of 5.6 %, transport emissions increased at 4.5 %, and residential sector emissions increased by 4.4 % (GoI 2011). Population growth and economic development are important drivers of energy consumption and CO_2 emissions (Li et al. 2010). With increasing urban population and income, energy demand is expected to increase. It is now also clear that meeting global targets will require cooperation of large developing economies like India and China (Satterthwaite 2010).

Vulnerability to climate events presents a special challenge for these cities. With a large part of the population still residing in informal settlements, the damage from extreme events in the future can be significant for these city residents, particularly in large densely populated cities in India. Cities also face some other challenges related to climate change. These include air pollution, urban heat island effects, vulnerability from increasing population in coastal areas, high population density, and diversity (Rosenzweig et al. 2011).

Managing the future expansion of urban areas in India is already a significant challenge. The problem of climate change is an added dimension. The business-as-usual scenario will lead to highly populated cities with poor air quality, high GHG emissions, income disparities, and poor quality of life. Therefore, planning for the future will require consideration of the implications of economic growth while considering resource constraints and climate change impacts.

Three main reasons for Indian cities to look at climate change include the following: (1) A significant share of national population and high contribution to economic growth in the future will make these major energy consumers and therefore key players in national and global climate change mitigation, (2) inaction to integrate climate concerns could pose significant threats including high potential economic losses for cities, and (3) sectoral interventions in urban areas have significant potential to mitigate GHG emissions, minimize risk from climate change as well as generate a number of ancillary benefits.

The World Development Report (2009) emphasized the idea of harnessing the growth and development benefits of urbanization while proactively managing its negative effects (World Bank 2009). Cities have a key role to play in the global green economy transition, since they are centers of economic growth, job creation, and innovation as well as major contributors to global warming and environmental problems (Hammer et al. 2011). At the same time, these are also faced with environment and infrastructure issues. While emissions are rising rapidly, vulnerability to climate change is a more pressing issue. The long-term problems of climate change further compound the problem. Literature in the past decade converges on the fact that cities now need to look for solutions that address both mitigation and adaptation challenges simultaneously.

Indian cities need a vision that can align both development and climate change. City plans are usually made for short-term about 10–15 years. The idea of climate responsive urban development in this paper highlights the necessity to look at urban development that is low carbon and climate resilient. However, looking at the long-term vision of the city can be useful to align climate change into city development and receive both short-term environment benefits and achieve climate objectives.

The chapter is divided into five sections including the introduction. The second section looks at India's urbanization profile and the environmental issues in Indian cities. Sections 8.3 and 8.4 highlight the mitigation and adaptation challenges using case studies of selected Indian cities. The following section highlights the adaptation issues for Indian cities. Section 8.5 suggests an integrated framework for cities to deal with climate change. The framework presents all the considerations that cities need to develop a scenario both to reduce emissions and increase resilience. Finally, the paper addresses the core issue of making the city development more sustainable by integrating local environment, climate change, and social sustainability.

8.2 India's Urbanization Profile and Challenges

Presently, 377 million people live in the urban areas of the country, constituting 31.16 % of the total population (Census of India 2011). Between 2001 and 2011, the urban population grew by nearly 32 %, as compared to 12.3 % for the rural population. Delhi, Greater Mumbai and Kolkata are the three largest urban agglomerations in India with populations over 10 million. In the next category, there are five cities with populations between 5 and 10 million. In total, 53 cities with populations exceeding one million accommodate over 40 % of the total urban population of India (Census of India 2011). However, the larger part of India's urban population still live in small- and medium-sized towns with populations below one million. Figure 8.1 shows the population of major Indian cities.

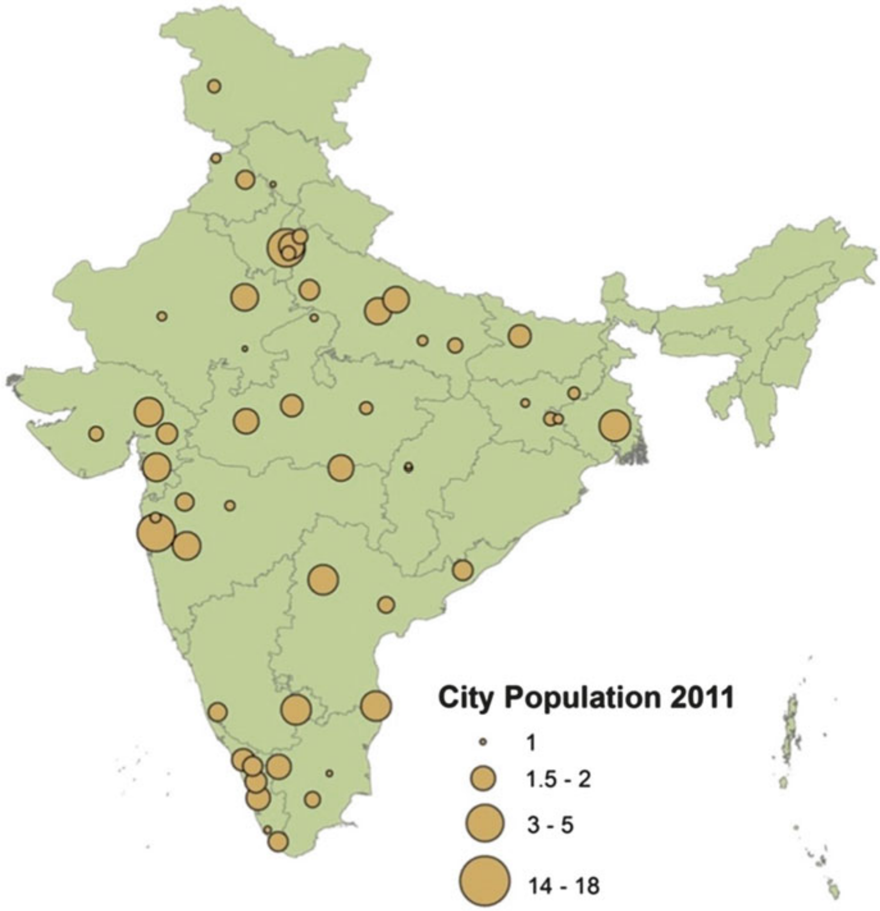

Fig. 8.1 Million plus cities in India in 2010 (by size) (Source: Data sourced from Census of India 2011)

It is projected that urbanization will continue in India till 2050, although the rate of urbanization will slow down after 2030. By 2050, India's urbanization level will cross the 50 % mark. Nearly 270 million people will be added to urban areas in India between 2030 and 2050 comprising one fifth of the total global urban population increase during the period (UN 2012). A large part of this growth will take place in cities with populations between 1 and 10 million.

Urbanization in India is accompanied by rapid economic growth. India's GDP (at constant prices) has nearly tripled from US $ 369 in 1996 to US $ 1,016 in 2008. In the financial year 2006–2007, India's real GDP grew at rate of over 7 % (WEO 2009). This growth is driven by cities which make a major contribution to the GDP of the country. Between now and 2030, India's GDP is projected to grow at an average annual rate of 7.4 % and cities are expected to account for 60 % of this growth

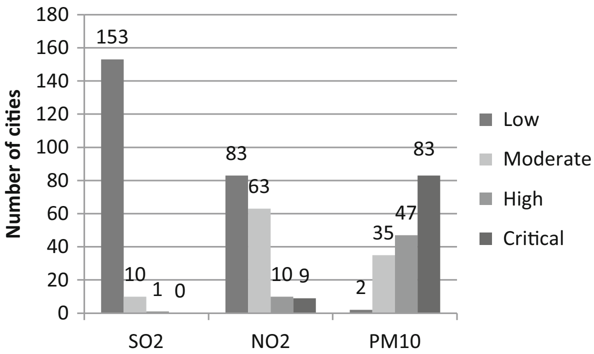

Fig. 8.2 Air quality in the cities (levels are classified into low, moderate, high, and critical based on exceedance factor which is observed mean concentration compared to annual standard. When exceedance factor is below 0.5, it is considered in low category while above 1.5 is classified as critical) (Source: CPCB 2012)

(MGI 2010). The trajectory of future growth in cities, especially with regard to local environmental problems like air quality, congestion, increasing risk from climate hazards, and poor quality of life, will have far-reaching implications on their global competitiveness, economic growth, livability, and overall well-being of citizens.

Environmental impacts in cities have resulted from increasing demand due to income effect, unguided growth, inadequate infrastructure, population density, and inefficient technologies. These are affecting the economic competitiveness and quality of life in the cities. According to a recent World Bank report, environmental degradation in India amounts to $80 billion annually or 5.7 % of annual GDP. This is mainly from health impacts of particulate matter from fossil fuels, inadequate access to clean water, sanitation, hygiene, and natural resource depletion (World Bank 2013a). Indian cities also face issues of poor water quality, threat to biodiversity, health impacts from inadequate solid waste disposal, and sanitation (Ramakrishna and Jayasheela 2010). Air quality is a serious issue in Indian cities. In recent years, rapid growth in vehicle populations coupled with industry and power plant emissions has resulted in very high levels of air pollution – especially particulate matter. At present, more than 50 % of the cities show critical levels of PM10 while nearly 30 % show high levels (Fig. 8.2). In case of sensitive areas, over 60 % of locations show critical levels of PM10. Levels of NOx are also a concern. 20 % of the cities showed high to critical levels of NOx (CPCB 2012).

Air pollution in India is a result of increasing travel demand, inadequate infrastructure, emissions from industries and power plants within the cities, combustion of household fuels, resuspension of road dust, and open burning of waste. Air pollution has significant human health implications as a large proportion of urban population lives in slums and squatter settlements without access to basic infrastructure and healthcare facilities. Direct exposure to air pollution and poor health status make this population more vulnerable to the toxic effects of air pollutants. A recent analysis showed that reduction in PM_{10} concentration levels of 25 μg/m^3 can result

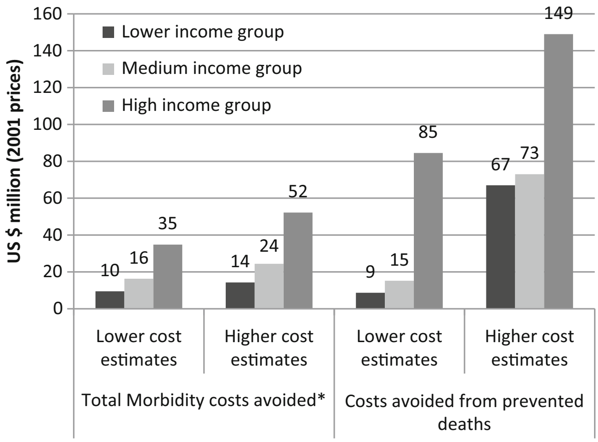

Fig. 8.3 Annual avoided health costs for different income groups from mortality and morbidity due to air pollution in Delhi (*when PM_{10} concentration levels in 2000 are reduced to 25 μg/m^3 throughout Delhi at higher mortality estimates) (Source: Garg 2011)

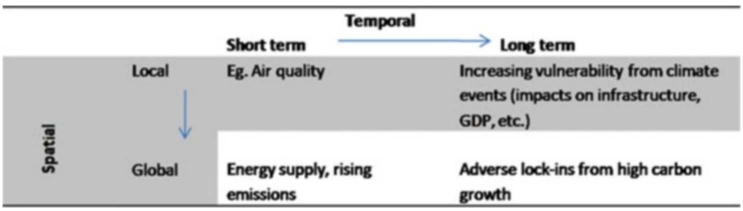

Fig. 8.4 Cities and environmental impacts (Source: Authors)

in cumulative savings ranging between US$ 23.5–101 million arising from improved health for all categories (Fig. 8.3). Cost savings from avoided deaths for the low-income group ranged from US $ 9 to 67 million while that for high-income group ranged from US$ 85 to 149 million at 2001 prices (Garg 2011).

Just as local activities in the cities contribute to environmental problems including air quality problems, water scarcity, and increasing emissions (Fig. 8.4), activities in the cities can also have regional and global impacts. There exists a complex relationship between the causal factors and impacts. Many of these problems arise from common sources and could have possible common solutions. At the same time, there could be tradeoffs between solutions for local short-term problems and long-term issues of climate change. Environmental impacts from cities can be temporally and spatially disaggregated.

8.3 Mitigation Challenges

There is a variation in per capita emissions among cities globally. Per capita GHG emissions for cities range from over 15 tons of carbon dioxide equivalent (tCO_2e) for several American cities to around less than half a ton for cities in developing

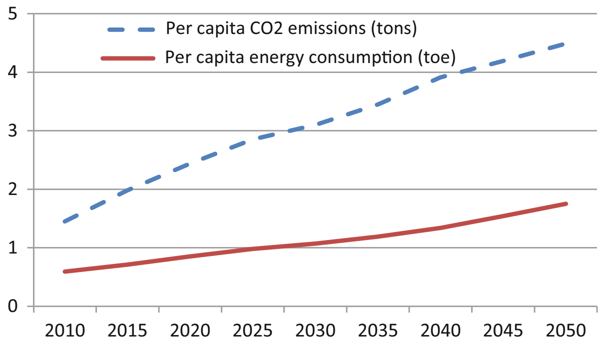

Fig. 8.5 Per capita energy consumption and CO_2 emissions for India in BAU scenario

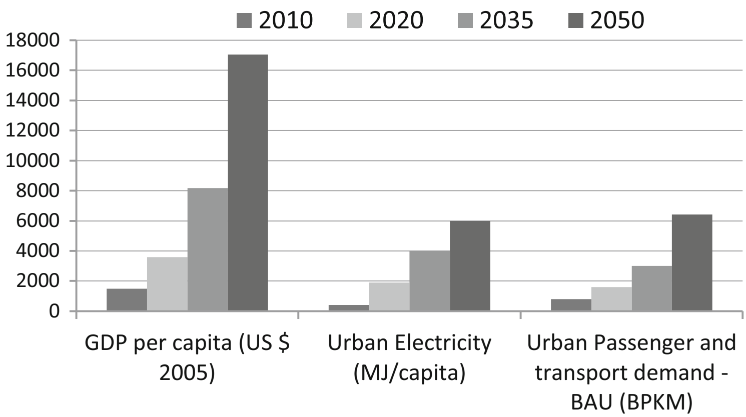

Fig. 8.6 Urban income and energy use projections for residential and transport

countries (Hoornweg et al. 2011; Dodman 2009). Although India's per capita emissions at 1.4 tons are low, India's total CO_2 emissions in 2012 reached about 2.0 billion tons, making it the fourth largest CO_2 emitting country globally (Oliver et al. 2012).

By 2060, the per capita income in India is projected to see a sevenfold increase (OECD 2012). This will drive the demand for energy for urban sectors – transport, building, industry, and urban services. In BAU scenario, energy use per capita will increase by three times between 2010 and 2050. During this period, per capita CO_2 emissions in India will increase by two and a half times and reach 4.5 tons by 2050 (Fig. 8.5). Urban population and income and consequent increase in urban floor space will result in a huge growth in energy demand for cooling, heating, appliances, and lighting, leading to significant electricity consumption in the buildings sector (Chaturvedi et al. 2012). Similarly, increase in income and population along with an increase in city size will lead to a significant increase in the total transport demand in the cities (Dhar et al. 2013) (Fig. 8.6). A study of three cities – Mumbai, Ahmedabad, and Surat – showed that total travel demand in the BAU scenario between 2005 and 2041 would increase five times in Mumbai, nearly six times in Ahmedabad, and ten times in Surat (Rayle and Pai 2009).

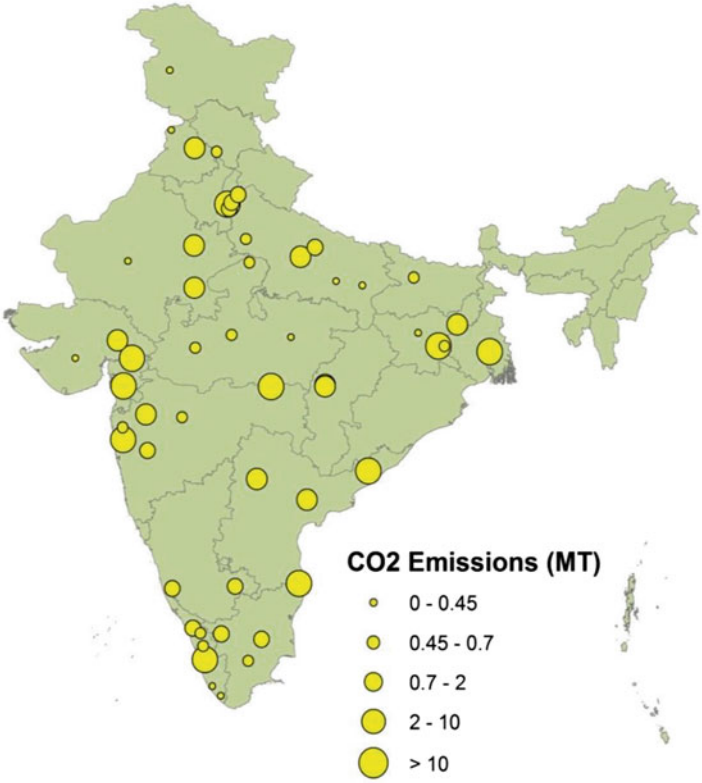

Fig. 8.7 CO_2 emissions for Indian cities (2010)

In the future, cities will house a large share of the country's population and will be the key drivers for economic growth and energy consumption. It is clear that meeting global targets will require cooperation of large developing economies like India and China (Satterthwaite 2010). Investments in infrastructure, urban planning and policies on building codes, and urban transportation will influence energy patterns of citizens in the future; therefore, decisions need to consider climate change to avoid getting into high carbon lock-ins.

Figure 8.7 shows the CO_2 emissions for major cities with the size of the bubble representing the amount of emissions. According to our analysis, total emissions from Indian cities range from 15 to 25 million tons. We analyzed the growth rates in emissions for these urban agglomerations for the period between 1990 and 2010. These ranged from 2 to 14 % with four cities showing a rate more than 8 % – Kochi, Vadodara, Surat and Kolkata. A large part of the emissions from these cities came from power plants and industries. Average per capita emissions from all million plus cities increased from 0.95 to 4.7 tons. A detailed modeling exercise for Ahmedabad City showed that a combination of low carbon interventions, if implemented can not only bring down CO_2 emissions but also deliver local environmental co-benefits. Box 8.1 gives a snapshot of the study.

Box 8.1: Future Energy and Emissions Projections for Ahmedabad

An exercise was carried out to understand the socioeconomic energy and emission parameters for Ahmedabad City. This data for the base year (2005) was methodically prepared using various approaches as enunciated in literature for various sectors. These parameters were used with the future energy service demands, energy technology assumptions, and socioeconomic assumptions for Ahmedabad to lead to assumptions for the target years (2035, 2050). This information was used to project future scenarios of energy and emissions in the future. This modeling was carried out using the Extended Snapshot Tool (ExSS) for two scenarios – business as usual and low carbon society (LCS) for 2035 and 2050.

Modeling results showed that the population of Ahmedabad would increase to 7.8 million in 2035 and would further rise to 12 million in 2050. Modeling results showed that the real GDP of Ahmedabad in 2050 is expected to be approximately INR 3,673 billion. Population and economic growth will result in increase in travel demand, increase in number of households, appliance ownership, and commercial floor area all, of which will result in increased energy consumption in all sectors. In the BAU scenario, primary energy consumption will increase nearly 10 times by 2035 and 15 times by 2050 compared to 2005 levels. Total CO_2 emissions increase from 10 million tons to 86 million tons by 2050. However, our analysis shows it is possible to bring down the BAU emissions with a combination of measures including lower energy intensity of economic activities, decarbonization of electricity-reduced energy demand in industrial and commercial sectors, fuel switch in power, transport and industrial sector, and measures promoting end-use device efficiency (Fig. 8.8).

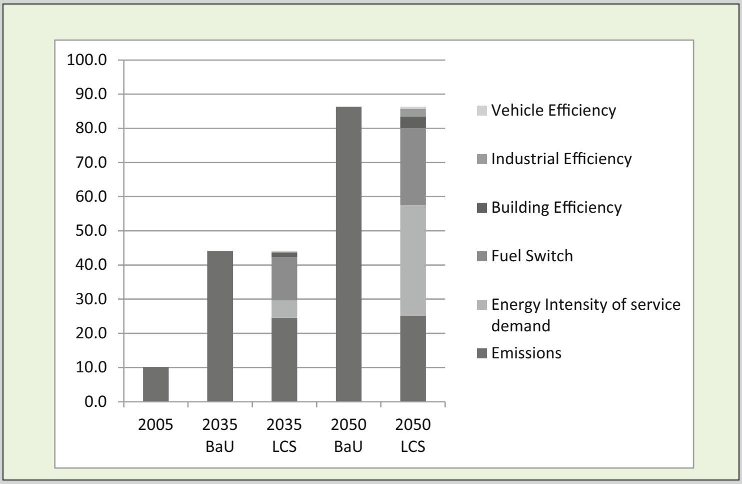

Fig. 8.8 Breakdown of emission reduction potential (million tons) (Source: IIMA 2010)

8.4 Adaptation Challenges

Vulnerability to climate events presents a special challenge for Indian cities. Climate change is projected to lead to temperature changes; higher variability in local conditions and changes in frequency, intensity, and location of precipitation and storms; sea level rise; river and inland flooding; and environmental health risks (Revi 2008). With a large part of the population still residing in informal settlements, the damage from extreme events in the future can be significant for these city residents, particularly in densely populated cities.

Climate change also impacts the physical assets used within cities for economic production, the costs of raw materials and inputs to economic production, the subsequent costs to businesses, and thus output and competitiveness (Sridhar 2010). Future urban growth will result in large populations in urban areas where many of these will live in informal settlements bringing forth the issues of managing equity, environment, urban development, and climate change. Going by the precautionary principle, in terms of preparedness, the city needs to remain prepared of a possibility of climate stabilization not achieving this target. Several of these cities, especially the small- and medium sized cities, do not have adequate resources to address the multiple challenges of environmental degradation, provision of basic services, urban poverty, and climate change.

PRECIS simulations show an all-round warming over the Indian subcontinent. A 3.5–4.3 °C rise in annual mean surface temperature is expected by the end of the century (MoEF 2012). Table 8.1 describes major impacts for climate change projected for India. For cities, this will exacerbate the heat island effects, water stress, impacts on infrastructure and major impacts from sea level rise coastal flooding and riverine flooding. This will be especially severe on densely populated cities.

Table 8.1 Impacts from climate change in India

Dimension	Projected impacts
Extreme heat	Increase in frequency of extreme heat events including more frequent warm days and nights
Changing rainfall patters	Change in rainfall pattern in terms of seasonal variations, frequency, and intensity
Water	Erratic monsoon patterns will lead to water shortages. These will also be exacerbated due to higher demand from increase in population, services, and industry
Food production	Increase in seasonal variability of rainfall, water shortages, and heat are all likely to impact agricultural production in the region
Energy security	Climate changed-induced water availability can affect power generation from thermal and hydro power
Health	Climate change impacts on human health could trigger or increase the incidence of vector-borne diseases and mortality and morbidity from heat stress

Source: Adapted from World Bank (2013b)

Climate risks differ for cities depending on their geographical features. For coastal cities, challenges of sea level rise will necessitate investments in particular infrastructure. Cities along rivers where higher precipitation is expected may face risks from floods. On the other hand, landlocked cities which have high built-up area and where climate change is expected to result in reduced precipitation will face risks from drought, reduced water tables, and food scarcity (UN Habitat 2009). An assessment of 59 Indian cities showed that Indian cities face a wide range of environmental risks including risks from climate change and lock-ins from high carbon infrastructure. The study estimated nearly 70 million people living in poverty and exposed to multiple stressors (CDKN 2013).

In another assessment, 14 cities in India on the basis of climate factors, altitude, and demographic, social and economic parameters highlighted different concerns for each of the cities. Mumbai ranked the highest on account of a very high population density exposed to cumulative risks from rise of temperature sea level and flooding. Temperature rise was a significant factor for Ahmedabad, while for Surat, it was flooding due to sea level rise (Parikh et al. 2011).

Kelkar et al. (2011) define vulnerability in terms of the loss of security provided by critical capitals that exist in the cities. These include natural capital, financial capital, human capital, infrastructure capital, built capital, social capital, governance capital, and technological capital. They concluded that economic status of the cities does not make them less vulnerable; however, cities with diversified economic profile had better adaptive capacity and those with poor local environment had a much higher risk of adapting to climate change.

The following are the specific climate change related risks for Indian cities.

8.4.1 Water Security

Population in cities and high demand for water have already put cities under water stress. Figure 8.9 shows the average per capita water supply and consumption in Indian cities. Assessments show that gross per capita water availability (including utilizable surface water and replenishable groundwater) is projected to decline from around 1,820 m^3 per year in 2001 to about 1,140 m^3 per year in 2050 due to population growth alone (World Bank 2013a). Climate change impacts on water sector could result in deterioration of water quality due to higher temperatures, from increase in sediment loads in rivers, land subsidence, and salt water intrusion from sea level rise (Major et al. 2011).

Indian cities face inadequate water supply, despite a significant effort and investments by urban local bodies. A number of cities do not meet national standards for water supply. Water stress in cities is likely to aggravate further due to increase in demand and deteriorating status of surface and groundwater resources. Impacts from climate change will affect the existing resources and therefore the availability of water in the cities. Box 8.2 shows climate change impacts on water availability for Delhi City.

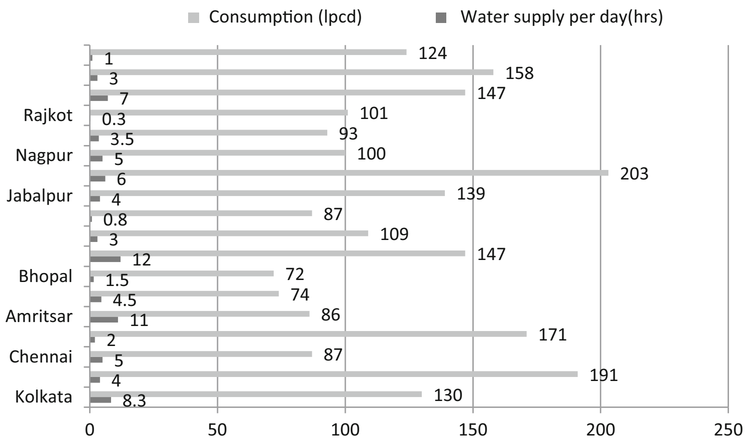

Fig. 8.9 Water supply in select Indian cities (2006) (Source: ADB 2007)

Box 8.2: Water Availability – Case of Delhi

Delhi depends largely on three river systems for its raw water supply, namely, Yamuna, Ganga, and the Beas. Other than the raw water from the rivers, a small proportion of supply is contributed by ground water. The current water supply stands at 225 liters per capita per day, however, its distribution is not uniform – some areas receive the supply 24-h supply, whereas some receive it for only 1–2 h (MPD – 2021). The major source of raw water is Yamuna River. Delhi gets 750 cusecs of water from the Western Yamuna Canal amounting to 310 MGD which is 48 % of Delhi's total water supply. Other sources include raw water from Upper Ganga Canal and Bhakra Beas Management Board (BBMB). At present, the contribution of raw water from the three sources is 84 % of the total. Currently about 100 MGD of the demand is met through groundwater extraction. Figure 8.10 shows the water supply from various sources till 2101. The assumption that there would be no further source of supply is based on the fact that the sources identified take into account the total groundwater potential of the national capital region and future dam projects envisaged.

Under climate change, it is assumed that the water availability from the Yamuna River would vary with the change in discharges. The availability from Beas and Ganga would vary according to 0.03 °C temperature rise scenario developed in the DFID study for Ganga discharge at Haridwar. Beas River carries more glacial content compared to Ganga River, and therefore, it is expected that the discharges would change more rapidly in case of Beas. The water supply from various sources was revised based on the assumptions made regarding existing sources, availability of water from Beas and Ganga, as well as rainfall changes, and the surplus deficit sensitivity analysis was carried

(continued)

Box 8.2 (continued)
out. It was found that under climate change, there is an increase in water availability till 2041 and then a sharp decline in the latter part of the century. The highest impact is experienced by the water availability under additional plan which is to be procured from the three dam projects. Owing to their location in the Himalayas, these sources would be able to add only 692 MGD in 2041 against the envisaged 865 MGD. This would further decline to 501 MGD by the end of the century. Existing riverine sources will also be impacted and would decline from approximately 828 MGD in 2011 to approximately 550 MGD in 2101. Figure 8.11 shows the water supply from various sources under climate change.

There would be a surplus of water for the next few decades, and Delhi would be in a position to meet its water demand as a result of additional discharges in the existing and additionally planned water from riverine sources. This would be followed by a steep decline in the post-2041 period as a result of depletion of glacier systems. By 2101 there will be a deficit of 631 MGD for a population stabilization of 40 million as against 130 MGD in the case without taking into account the climate change impacts. This would create even more severe water shortages than experienced now. The current analysis is conducted considering the Delhi Jal Board recommended norm of 60 gallons per capita per day. But as the population increases, this norm would increase further and the shortages could be much higher than what is being displayed by the current analysis.

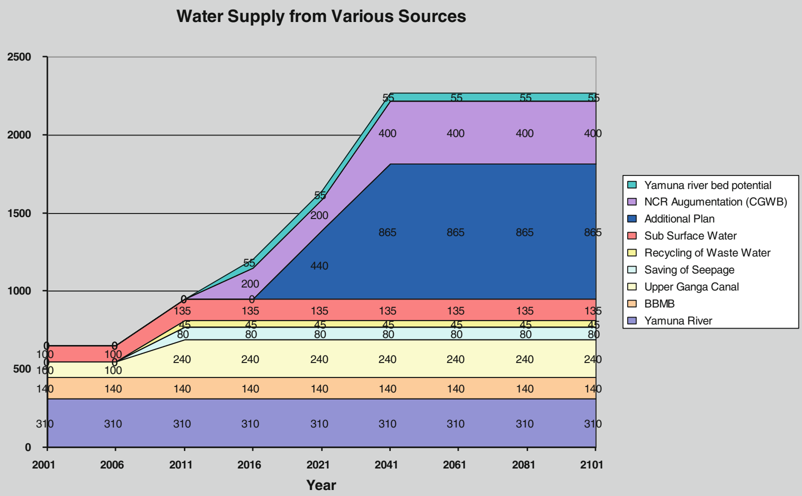

Fig. 8.10 Existing and envisaged water sources for Delhi

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Box 8.2 (continued)

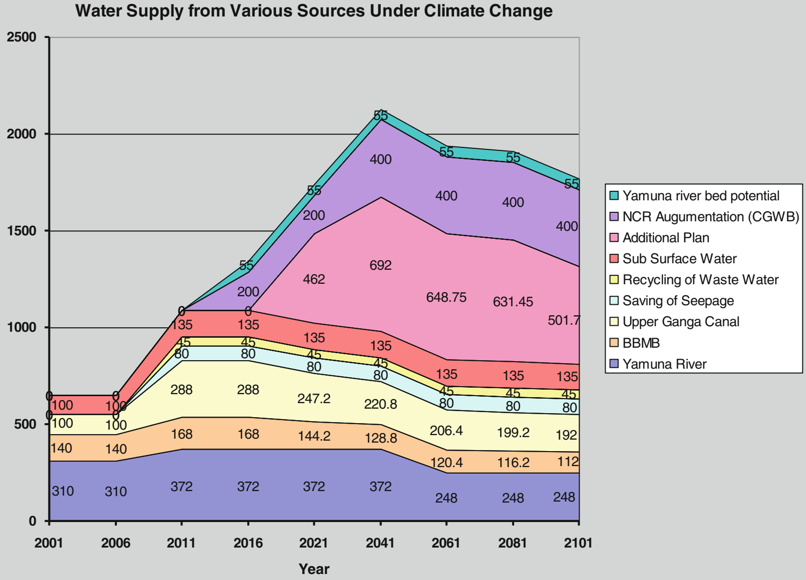

Fig. 8.11 Existing and envisaged sources of water for Delhi under climate change (Source: IIMA 2009)

8.4.2 Flood Risk

For city planners, floods pose a major problem as the most expensive and damaging climate disasters. Evidences show an increase in the frequency and severity of floods in recent years. A recent World Bank study highlights the case study of two large cities – Mumbai and Kolkata – where large populations are vulnerable to sea level rise, tropical cyclones, and riverine flooding.

With a high population density and a large part of the city in low-lying areas, Mumbai is extremely vulnerable to coastal flooding (World Bank 2013b). Another OECD study found that by 2080 in a SRES A2 scenario, the likelihood of a 2005-like flood event for Mumbai could double in the upper-bound climate scenario. This will result in tripling of the total losses for a 1-in-100-year event compared to current costs. The analysis also showed that the losses would amount to $250 million for the poor marginalized population, which could be a significant figure for these households (Hallegatte et al. 2010).

The current annual rainfall in Mumbai is 2,809 mm. An assessment carried out at IIMA (2009) showed that under B2 scenario, the average would increase to 3,200 mm with a standard deviation of 627 mm and under A2 scenario, the average is likely to increase even further to 3,476 mm with a standard deviation of 687 mm. The study revealed that the probability of 100–200 mm rainfall in a day would increase by 18 times and 13 times approximately for the A2 and B2 scenarios. Flood-prone low-lying areas of Mumbai would expect a price decline of more than 15 % with no prospects of price recovery owing to recurring characteristic of flash floods in the climate change scenario (IIMA 2009).

8.4.3 Heat Stress

Mean temperatures are increasing around the world, and it is expected that rising temperatures will lead to an increase in frequency and severity of extreme heat and heat wave events (Tebaldi et al. 2006). According to IPCC, climate change can affect human health directly from extreme events and cause indirect impacts by disrupting social and economic systems (IPCC 2007). Urban heat island impacts caused to reduced green cover, higher concrete, and asphalt and urban heat sources further aggravate heat waves (Barata et al. 2011). Direct threat to health from heat stress is more likely to affect the vulnerable groups including the elderly, young children, and those with preexisting health problems.

We studied the impacts of temperature on mortality for the cities of Ahmedabad and Mumbai (Figs. 8.12 and 8.13). These are among the largest cities in India and are representative of a hot and dry (Ahmedabad) and warm and humid (Mumbai) climate. For the summer (March to July) season, the relationship between daily deaths and daily maximum temperature (from 2005 to 2012) was modeled using standard time-series approaches described in public health literature. The outcome of interest was the percentage change in mortality between the 99th and 95th percentile of temperature distribution (called heat effect). A similar analysis was carried

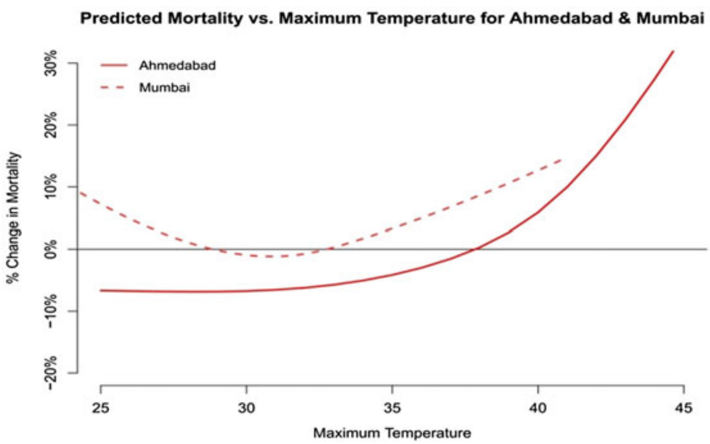

Fig. 8.12 Temperature and mortality relationship in summer season (Source: Dholakia 2014)

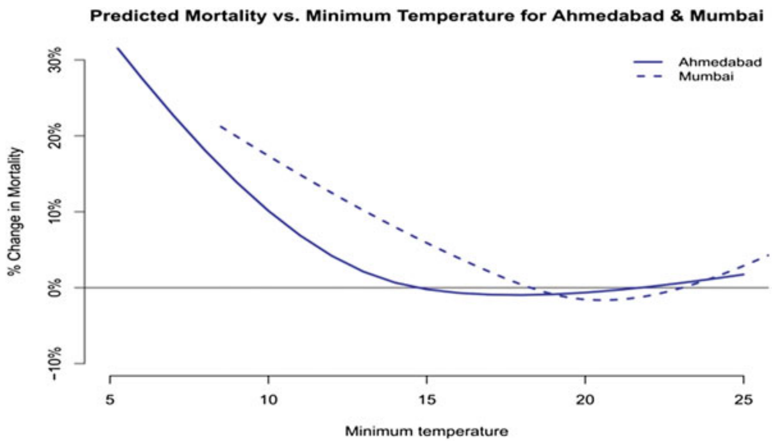

Fig. 8.13 Temperature and mortality relationship in winter season (Source: Dholakia 2014)

Table 8.2 City characteristics and heat and cold effects for Ahmedabad and Mumbai

City	Temperature (°C)		Daily deaths	PM_{10} (μg/m^3)	Population (millions)	Heat effect (%)	Cold effect (%)
	Max.	Min.					
Ahmedabad	34 ± 4.6	21.5 ± 5.6	100 ± 18	93.9 ± 58.7	6.3	6.56	7.09
Mumbai	32 ± 2.4	22.7 ± 4	225 ± 30.7	174 ± 86.6	18.4	3.53	5.33

Sources: Central Pollution Control Board; Indian Meteorological Department; Ahmedabad & Mumbai Municipal Corporations; Census of India 2011

out for the winter season (November to February) to understand the cold effect, i.e., percentage change in mortality between the 1st and 5th percentile of minimum temperature distribution.

For each city, we find a "U-" or "J"-shaped relationship between temperature and mortality which have been described previously for other cities in Europe and United States. In the summer season, mortality increases significantly above 32.2 °C for Ahmedabad and 30.9 °C for Mumbai. The corresponding values for winter season are 20.6 °C for Mumbai and 17.8 °C for Ahmedabad. However, mortality is determined by the rate of increase as well as the temperature range that a city experiences.

The heat effect was found to be 3.53 % (95 % CI: 1.69, 5.4) for Mumbai and 6.56 % (95 % CI: 4.84, 8.31) for Ahmedabad. The respective cold effects for Mumbai and Ahmedabad were found to be 5.33 % (95 % CI: 2.6, 8.12) and 7.1 (95 % CI: 4.3, 9.96). These effects were robust to a range of alternate model specifications and were independent of effects of air pollution (Table 8.2).

The differences in heat and cold effects can be explained by the fact that being a coastal city, Mumbai has less extreme weather (moderation due to land and sea breeze). Ahmedabad on the other hand is located in the interior of the Indian landmass and is subject to a more extreme form of weather. Thus, Ahmedabad has higher heat and cold effects in comparison to Mumbai. In addition, higher cold effects for Ahmedabad could be explained by population acclimatization to the hot and dry climate.

Projections of mortality show that heat-related mortality is set to increase in the future while cold-related mortality will reduce. However, decreases in cold-related mortality will not offset the increases in heat-related mortality – thus, there will be a net increase in future temperature-related mortality. Under the RCP 4.5 scenario, in the 2050s, we estimate 38 % excess deaths (~5,700 deaths) due to heat for Ahmedabad and 40 % excess (~4,200 deaths) for Mumbai compared to the baseline period of 2000–2009. The corresponding reductions for cold related mortality are 63 % (~900 deaths) for Ahmedabad and 37 % (~3,800 deaths) for Mumbai. The magnitude of death is much higher under an extreme climate change scenario such as RCP 8.5. Acclimatization will likely have only modest impacts in reducing future mortality, thereby underscoring the need for planned adaptation.

Planned adaptation measures could potentially include but are not limited to public awareness through information, education, and communication programs; city-level heat-health warning systems; efficient functioning of emergency medical services; shelters to reduce exposure for the poor, children, and elderly; greening of urban landscapes; and district level heating or cooling measures. Implementing these involves a comprehensive, coordinated approach at multiple levels that include various stakeholders as well as a dedicated pool of financial and other resources. Ahmedabad City has recently initiated a Heat Action Plan which is the first comprehensive early warning system and preparedness plan for extreme heat events in India. The plan creates immediate and longer-term actions to increase preparedness, information sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations (AMC 2013).

8.4.4 Urban Infrastructure

Urban infrastructure includes energy infrastructure including power plants, gas supply, transport infrastructure, water supply, housing, and waste water systems. Increased growth and development of cities has led to increasing demand for urban infrastructure. Currently, India spends $17 per capita per year in urban infrastructure, whereas the most benchmarks suggest a requirement of $100. The investment required for building urban infrastructure in India, over the next 20 years, is estimated at approximately US$1 trillion (Planning Commission 2013).

Infrastructure in the cities is influenced by the changing dynamics in the future – population, economic growth, availability of financial resources, and capacity of local governments. Infrastructure are long-life assets that are exposed to nature and therefore face uncertainties of weather parameters such as rainfall, temperature and other extreme weather events Garg et al. 2013. This exposure uncertainty creates risks for their economic performance, for instance, rainfall pattern in the catchment areas of a hydroelectric dam could drastically reduce in the future, making the dam a stranded economic asset. Different sectors and assets exhibit different levels of sensitivity to climate change because of varying vulnerability and adaptive capabilities (Garg et al. 2007).

There are complex dimensions to infrastructure and climate change in the cities. One is that inadequate infrastructure in the cities including sewerage, storm water drains, and water supply can exacerbate climate risk, and therefore, investments in infrastructure can reduce vulnerability to climate change. Hallegatte et al. (2010) found that investment in drainage systems in Mumbai could result in reduced vulnerability of the population from flood risk. Climate change impacts can cause significant damage to urban infrastructure including transport, water supply, and sewage and energy infrastructure leading to huge losses for the cities. Finally, urban infrastructure choices will determine the consumption patterns and contribute to GHG emissions. The city form and infrastructure influences the way energy is consumed and therefore has bearing on the future emission patterns. For instance, the choice of building mass transit infrastructure or choice of energy infrastructure would facilitate low carbon choices for citizens in the future and support transition to a low carbon society. In addition to high carbon technology lock-ins, infrastructure also influences choices of the citizens. This could also lead to preference lock-ins, which could influence people's behavior in a certain pattern (Mukhopadhyay 2010).

Figure 8.14 shows the infrastructure investments in public transport for large Indian cities. Mass transit infrastructure including BRTS and Metro is already operational or planned for 21 cities in India. However, this planning has not integrated the environment and climate change considerations. Out of the 21 cities where Metro is operational or planned (Figure), nearly half of these cities have already been identified as being highly vulnerable to flooding risk due to a combination of climate-induced risk coupled with inadequate infrastructure (Parikh et al. 2013). Six of these cities face threats from cyclones in the future.

For climate proofing infrastructure assets, it is important to identify system dynamics, climate change parameters, and developmental parameters affecting the

Fig. 8.14 Mass transit infrastructure investments (existing and planned)

system under consideration and capture various impact parameters. This is normally done based on the past data, and a damage function is created that captures the adverse impacts of all the variables on the system. While creating this damage function, future climatological projections must be incorporated to adjust for increased frequency and variability of relevant critical climate parameters.

8.5 Strategies for Synergizing Climate and Development Goals in the Cities

Cities have environment and social priorities – increasing the percentage of green cover, improving local air quality, and reducing congestion. This necessitates the search for delineating win-win options that deliver multiple benefits – of better local environment like cleaner air, more green spaces, and water bodies, improved energy access, reduced congestion in the transport system, and reduced risks from residual climate change. The business-as-usual approach does not integrate climate objectives into development priorities. Therefore, alternate frameworks are necessary.

The framework (Fig. 8.15) suggested here uses an integrated assessment framework which aligns global climate change concerns and issues within the urban development agenda. The three stages include identifying climate risks, constructing future scenarios, and assessing synergies to prioritize actions.

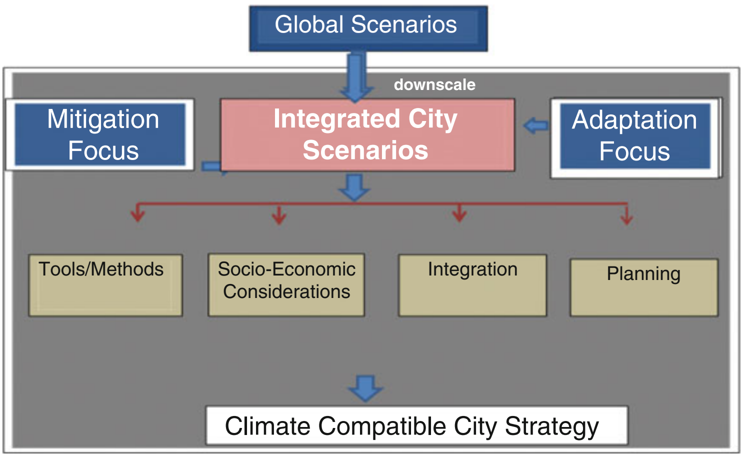

Fig. 8.15 Integrated framework for climate compatible development for the cities

8.5.1 Identification of Climate Risks

Action on climate change starts with reliable comprehensive information on climate change. For example, for a city, the impacts from meteorological events such as rainfall, extremes of water such as heat stress enhanced by the urban heat island effect, as well as long-term impacts of building design, role of transportation design on air quality and health (WMO 2010). Climate modeling over Asia is complex due to its unique topography. As a result, global climate models (GCMs) fail to properly represent physical processes. Also climate change impacts may vary significantly among regions within the country as well as locally due to the unique features of the cities. There is a need to improve the resolution by downscaling using models and tools (Salinger et al. 2014).

Urban meteorological networks can be set up within and around the cities to study vertical profiles of temperature, rainfall, wind humidity, turbulence, air quality, particles, reflectivity, and refractivity. There is a need to improve the understanding of the impacts of atmospheric data over complex urban surfaces through observations and to delineate the impact of urban areas on climate from natural processes (WMO 2010). Cities do not operate in isolation. Therefore, it is important to consider global scenarios. At the same time, global scenarios are insufficient to understand impacts at the local level. Global and regional conditions must be downscaled using statistical relationships or physical methods that take into account specificities of the urban context.

Local socioeconomic scenarios and environment information are used to understand a city's vulnerability. It is necessary to take a broad view and understand all components of socioeconomic activity and their interactions to comprehend direct and indirect impacts from climate change on a city (Hallegate et al. 2008).

Similarly, planning for climate change mitigation requires comparable, consistent and robust information on energy use and emissions. Greenhouse gas inventory is a necessary first step for planning for mitigation actions. Cities need a robust inventory that tells them what the emissions are and which sectors they come from (Hoornweg et al. 2011). There is currently little information on urban energy use and emissions in Indian cities in recent years. Since emissions are greatly influenced by the activities at a spatial scale, it is important to link emission inventories with information on land use and activities.

8.5.2 Constructing City Scenarios

A city scenario will require alignment of both top-down and bottom up information. Top-down information includes information on the risks and uncertainties at the global level, national policies and targets, climate change information, and assessment of future technologies. Integration of global storylines is essential for the cities as it will influence many key choices like infrastructures, technologies and behavior.

For example, key elements for climate resilient developments like technology sharing may differ between a fragmented future global world versus a cooperative society. Similarly, cities need to look at global climate projections, emission pathways, and mitigation goals. Global scenarios have to be downscaled to regional or local level and fitted within the policy time frame.

This has to be integrated with bottom-up information including an understanding of the city's form, activities that influence energy use and emissions, and vulnerability within the city. Since urban form influences future emissions and vulnerabilities, it is important to include this information while constructing city scenarios. Other challenges with respect to implementation of plans include old city lock-ins, density and land use lock-ins, inertia of public behavior, and life of the city infrastructure. Prioritizing climate change will require an understanding of these spatial impacts. A city's capacity to act (mitigation and adaptation) and the socioeconomic status of its population are also important to consider in developing city scenarios.

8.5.3 Integrated Assessment

Climate change is influenced by a several complex interactions among several factors; therefore, understanding complexities would require a more comprehensive approach. Integrated assessment is a process that combines knowledge from various disciplines including natural and social sciences to examine and comprehend the interactions between these complex systems (IPCC 1996).

The integrated assessment methodology for GHG emissions and climate impacts developed by the Tyndall Center for Climate Change Research provides an approach for analysis at the local level. These parameters influence regional economy and land use. The approach ensures that though the land use modeling is spatially explicit at the local level, it integrates regional and global parameters (Dawson et al. 2009).

It is now increasingly becoming clear that urban development in India will have to be compatible with the changing climate. However, cities have environment and social priorities – increasing the percentage of green cover, improving local air quality, and reducing congestion. Literature in the past decade converges on the fact that cities now need to look for solutions that address both mitigation and adaptation challenges simultaneously. Recognizing that urban centers will play a key role in implementing national and development goals, cities need to be energy and resource efficient, reduce environmental externalities, and at the same time achieve social and economic goals. Looking at these challenges, cities will have to delineate win-win options that deliver multiple co-benefits, besides climate change benefits, of better local environment like cleaner air, more green spaces and water bodies, improved energy access, reduced congestion in the transport system, and improved resilience.

On the mitigation side, effective sectoral mitigation opportunities exist in the cities. Local governments control policies on land use, transport, water, and energy efficiency which are keys to mitigation responses. These include public transport, land use planning, water supply, zoning, building codes, energy conservation, taxation, waste management, etc.

At the same time, cities will have to stay prepared to mitigate impacts from residual climate change. Unmitigated climate risks impose huge costs, for instance, insurance payments from not addressing adaptation (Sathaye et al. 2006). Different cities have different priorities. There is a mismatch between needs and responses are occurring in regard to who should mitigate, how much to adapt, and why. Cities need to look at climate risks and mitigation options simultaneously in order to balance adaptation and mitigation. (Mehrotra et al. 2011). For instance, rapidly growing cities will need to prioritize investments in low carbon infrastructure. On the other hand, small and medium coastal towns which have very low emissions will need to prioritize adaptation.

Synergies between mitigation and adaptation actions have been reported for cities. For example, urban design to include climate safe citing, building codes, and transportation requirements could reduce energy use and emissions while at the same time reduce the negative impacts of climate change such as for low-lying coastal areas or areas prone to flooding (Swart and Raes 2007). Decision makers can integrate climate change into plans if clear information is available on quantified climate benefits and other benefits that include cost savings in the long run from damage due to extreme events, avoided deaths from air quality improvements, mobility benefits, etc.

The integrated assessment framework suggested below suggests several important areas of integration for effectively addressing the issue of mainstreaming climate change concerns in urban planning. These include a vertical integration from global to local, spatial and temporal integration, integration of scientific information with policies, and finally integration of mitigation and adaptation into city plans.

8.5.4 Mainstreaming Climate Change Concerns in Development Plans

The period of 2007–2012 witnessed high growth rate, however, it also witnessed impoverishment and exclusion of large sections of population from the benefits of development (Hussain 2012). The Government of India recognizes that development should be equitable and environmentally sustainable. The central theme of India's 12th Five-Year Plan (2012–2017) is Inclusive Green Growth (GoI 2012). The stated vision is that "of India moving forward in a way that would ensure a broad-based improvement in living standards of all sections of the people through a growth process which is faster than in the past, more inclusive and also more environmentally sustainable." Similarly, the eight submissions under India's National Action Plan on Climate Change, (2008) emphasize development and environment objectives including protecting ecosystems, agricultural sustainability, biodiversity, and quality of life in addition to climate change mitigation and adaptation measures (GoI 2008).

There are several existing programs focusing on urban areas including the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), the National Mission on Sustainable Habitat, and the latest National Urban Livelihood Mission. The National Environment Policy (2006) of the Government of India emphasizes the simultaneous goals of mainstreaming environment protection and livelihoods while promoting economic growth (MoEF 2006). The local Agenda for Environment Management by the Government of India underlines that urban environment management tasks should be appreciated in terms of the linkages between the city economy, infrastructure, productivity, poverty, and environmental health (GoI 2013). Similarly, several policies have been introduced at the state and central level to promote renewable energy with the objective of achieving energy security, improving air quality, reducing GHG emissions, and providing local jobs (MNRE 2013).

In other words, cities need to grow, attract skill and knowledge, and increase competitiveness. This will require robust infrastructure systems – housing, transport, and services which are efficient and accessible to all sections of the society. Within this urban growth and development strategy, cities will need to embed low carbon and climate resilience. A way to start would be to integrate climate strategies into existing urban redevelopment programs such as the JnNURM and bottom-up mobilization with the help of NGOs, CBOs, and stakeholder participation (Revi 2008).

In this context, the concepts of co-benefits and ancillary benefits play an important role in aligning climate change concerns into sector-specific developmental goals. Also, co-benefits provide the necessary bridge for the alignment of climate change concerns with national development objectives (Yedla and Park 2009). Urban planning decisions could offer synergies of development, infrastructure supply, low carbon development, and climate resilience. A more sustainable-oriented urban planning approach offers significant opportunities for cost savings and environmental benefits. For instance, efficient, fast, and reliable public transport systems can reduce local pollution and promote low carbon transport (Sathaye et al. 2006).

A structured approach for low carbon growth requires integration of an urban Environmental Management Plan to be integrated with sectoral policies including energy, transport, and infrastructure. This usually begins with establishing the baseline environmental conditions in urban areas by assessment of major environmental components including air quality, water, land, energy, biota, socioeconomic, and built environment (Nallathiga 2010).

Instead of a climate centric approach, Indian cities can work on incorporating climate goals into the planning exercise. Some potential areas could include integrating climate risks in urban infrastructure projects, local development control regulations, energy and mobility plans.

The importance of states and cities in achieving national objectives is being recognized. Increasingly, more and more subnational governments are making a significant contribution in energy efficiency, climate governance, and environmental actions. Actions initiated at the city level have a good chance of succeeding because city governments are in a better position to comprehend local issues, can address these through locally specific solutions, and engage local businesses and citizens more effectively. The formulation and implementation of climate action in cities poses governance challenges for the cities. In developing countries, local governments lack the capacity and power to implement these (McCarney et al. 2011). Some technology and infrastructure choices still remain out of control for city governments. For instance, the electricity mix is dependent on the energy mix of the regional grid and state policies.

Local low carbon actions including solid waste management systems and efficient public transport which can be implemented in the short term are being successfully executed by several cities. However, the implementation of a long-term action plan requires a comprehensive multi-sectoral approach as well as a good vertical coherence between the local and national government institutions and between local-state governments.

8.6 Conclusion

Results from several studies clearly show the need for an integrated approach to urban planning. Indian cities continue to battle local problems – of air pollution, water scarcity, and inadequate infrastructure. Climate change challenges – of curbing the rising energy use and emissions and reducing vulnerability from extreme events – have added to these. While it is recognized that future development will need to be low carbon and climate resilient, climate change does not figure prominently on the policy agenda for local governments. This entails the need for a framework that aligns climate change – both the issue of reducing emissions and coping with these. Integrating climate change into city plans at the developmental stage can help avoid costs in the long run and prevent adverse impacts arising due to lock-ins. The framework presented in this chapter is a starting point. There are several gaps regarding information on climate systems at the urban level and their interactions with the urban profiles both current and in the future. In the overall, the chapter argues for (1) robust information for cities on short-term and long-term risks for cities (2) a quantitative assessment of co-benefits and risks to delineate the roadmap, and, finally, (3) an integrated strategy that aligns mitigation, adaptation, and urban sustainability goals.

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Chapter 9
Securing Cities for Energy Needs

Rangan Banerjee

Abstract Cities are critical for the development of any country. For cities to grow, securing energy supply is important. This chapter reviews the energy needs of Indian cities based on end uses (cooking, lighting, motive power, transport) and source (LPG, electricity, diesel, kerosene, biomass). Electricity accounts for more than 50 % of the supply mix in terms of primary energy for most cities. Daily and seasonal variations in the demand for electricity for Indian cities show morning and evening peaks (6 pm to 10 pm). The growth rates for electricity demand range between 5.1 and 10.6 % for a sample of 12 Indian cities. Most Indian cities face electricity shortages often dealt with by load shedding (curtailment of supply). The threats to energy security for cities include supply–demand mismatch, supply disruptions, market volatility, climate variations, etc. Possible responses to ensure energy security involve enhancement of renewable supply, energy efficiency and demand side management (DSM), smart grids, mass transit, zero energy buildings and sustainable urban design. Tracking the energy and carbon performance of cities in a transparent fashion is a prerequisite for planning future sustainable energy services for the city. Securing energy needs for cities would need changes in our approach to planning cities and implementing projects.

9.1 Introduction

Cities are critical for the development of any country. There is a global trend of increasing urbanisation (UN Habitat 2013; UNEP 2011). Figure 9.1 shows the Human Development Index (HDI) for different cities in the world and the corresponding HDI for the country in which it is located. It is clear from the figure that HDI for the cities is higher than the average HDI of the country in which it is located. This difference is more pronounced in the developing countries. Cities also have a higher energy intensity per capita and emissions per capita than the rest of

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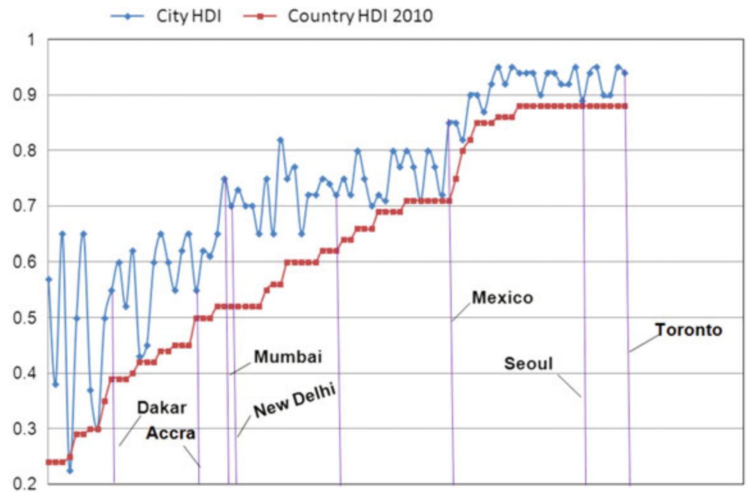

Fig. 9.1 Human Development Index (HDI) for different cities in the world (Source: UN Habitat 2013)

the country. Cities account for a larger proportion of the income of the country resulting in a higher gross domestic product (GDP)/capita than the rest of the country. In 2008, 30 % of India's population lived in cities but accounted for about 58 % of the country's GDP.

India's urban population grew from 290 million in 2001 to 340 million in 2008 (a compound annual growth rate of 2.3 %). A Mckinsey study (McKinsey 2010) projects growth of urban population to 580 million in 2030 and a total share of 40 % of the country's population. India has 42 cities with population greater than one million. The number of cities with more than a million population is expected to grow rapidly in the future.

Cities are clearly important for India's development and growth. They are a source of prosperity and GDP growth and provide employment opportunities for the population. The challenge of securing energy needs for growing cities is important for their growth.

9.2 Energy Security

What is energy security? Cherp and Jewell (2011) provide a definition and a perspective of energy security. This is depicted in Fig. 9.2. Energy security is normally a priority at a national level. The objective is to provide uninterrupted energy services. The three elements of energy security identified are sovereignty, resilience and robustness. Sovereignty indicates the protection from external threats. Robustness implies adequacy of resources, affordable energy prices and reliable energy infrastructure. Resilience of the energy system is defined as the ability of the

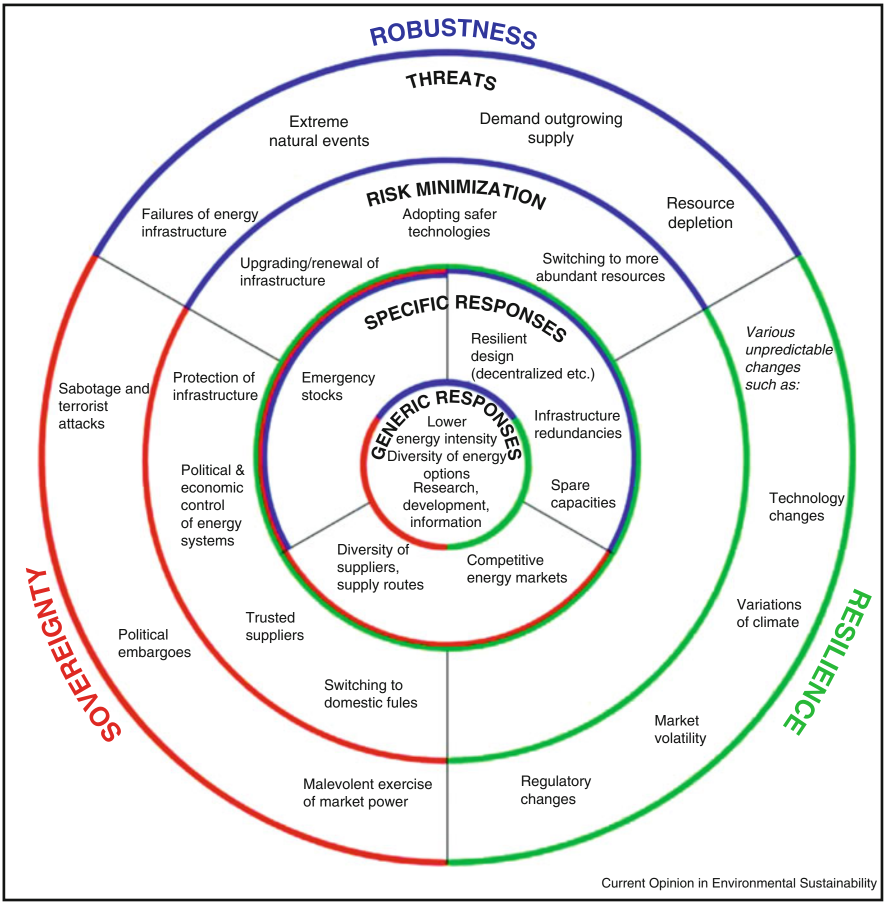

Fig. 9.2 Perspectives on energy security (Source: Cherp and Jewell 2011)

system to withstand disruptions. The threats and responses possible for each of these measures are shown in the figure.

This framework can be used to understand the basis for securing cities for future energy needs. In order to understand this, it is essential to analyse the energy needs of cities. This is done in the context of Indian cities.

9.2.1 *Energy Needs of the City*

What are the energy needs of cities? Figure 9.3 shows the energy flow diagram showing the chain from primary energy that is available in nature (coal, oil, natural gas, solar energy) to secondary energy to the final energy or the delivered energy that is bought by the consumers. Each of the conversion steps or processes has

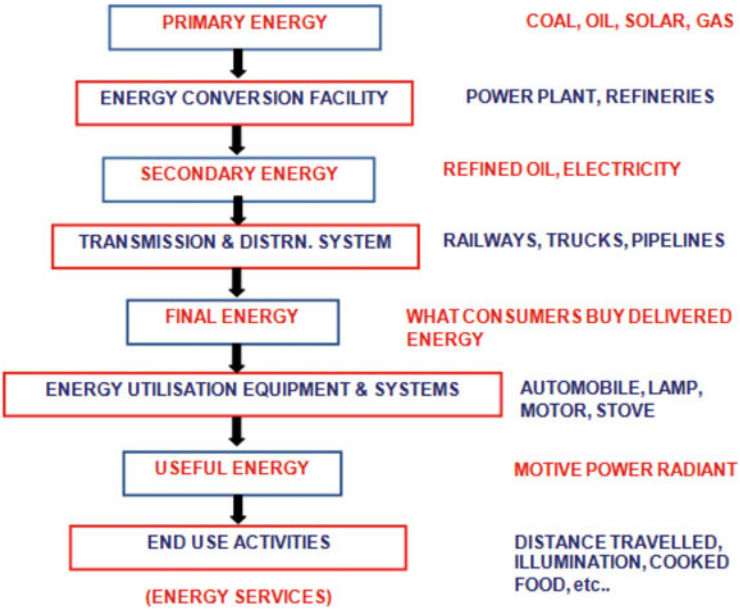

Fig. 9.3 Energy flow diagram (Source: Developed by the author)

associated with it some losses. The final energy bought by consumers is utilised in end-use equipment to provide energy services.

In cities the different sectors where energy is used are the residential, transport, industry commercial and municipality sectors. The major end uses are cooking, cooling, heating, appliances, motors and water pumping. Most cities are driven by fossil fuels. This includes diesel, petrol and compressed natural gas (CNG) for transport; LPG, kerosene and fuelwood for cooking; and electricity for lighting, appliances and motive power. Normally aggregate energy balances are not available for cities and have to be compiled from different sources and are subject to uncertainties. Figure 9.4 shows the share of final energy used in Mumbai in 2010 as estimated by Reddy (2013). The direct final energy use was 14.7 GJ/capita for Mumbai. In terms of primary energy, the share of electricity would be higher (as the electricity delivered would be divided by the conversion efficiency of about 30 %). For Mumbai in 2010 in terms of primary energy, the electricity share would be more than 60 %. Agra's energy balance has been estimated by ICLEI (2011).

Among the energy supply option, electricity is particularly important since it is a convenient energy source and tends to substitute other sources with increasing income. Electricity supply needs investment in generation, transmission and distribution infrastructure. Table 9.1 shows a comparison of the four large metros in terms of area, income, energy use and carbon dioxide footprint. Some of the differences in the indices can be accounted for – e.g. Bengaluru has a lower carbon dioxide footprint since the electricity generation has a larger share of hydro. However, Kolkata's larger carbon footprint seems to be caused by data inconsistency and

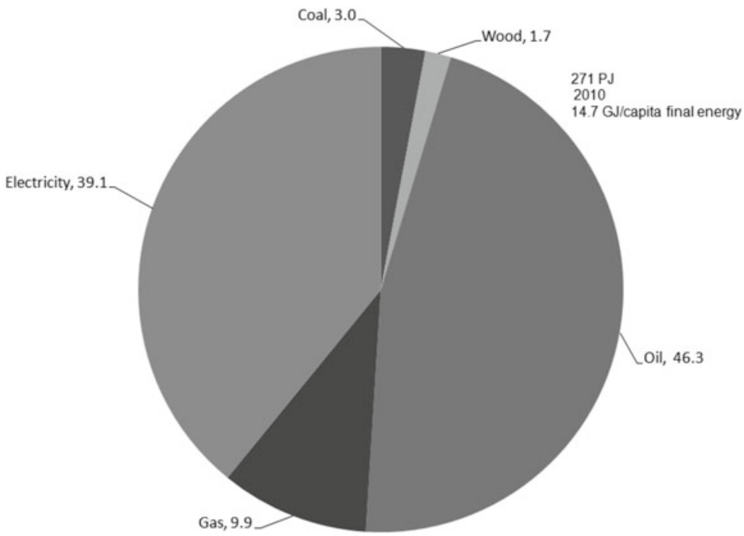

Fig. 9.4 Mumbai – final energy mix (Source: Reddy 2013)

Table 9.1 Comparison of large metros in India

	Population million	Area (km^2)	GDP/capita US$	Energy/capita	CO_2 emissions/ capita
Mumbai	12.7 (24)	468	2,184	14.2	1.0
Delhi	17.4	1,483	2,004	15.4	1.1
Kolkata	15.6	1,851	1,414	5.65	1.5
Bengaluru	7.1	710	2,066	9.5	0.5

Source: Asia Green City Index (2011)

uncertainty. It is important to be able to accurately quantify and benchmark the energy use by sector and end use for different Indian cities.

The energy use for the transport sector of a city would depend on the share of mass transport, share of the mode of transport, layout and design of the city and income of the city. Using data from Reddy and Balachandra (2010) for the transport use and income for Indian cities in 2005, a scatter plot is shown in Fig. 9.5. It is seen that the transport energy use varies from 0.5 to 2 GJ/capita/year and does not show any clear correlation with income.

9.2.2 Variation in Energy Demand and Growth Rates

Aggregate load profiles of different cities are available from the load dispatch centres for each state. Figure 9.6 (MSLDC 2013) shows the sample load curve for Mumbai in the summer of 2013. Most Indian cities have their maximum period of

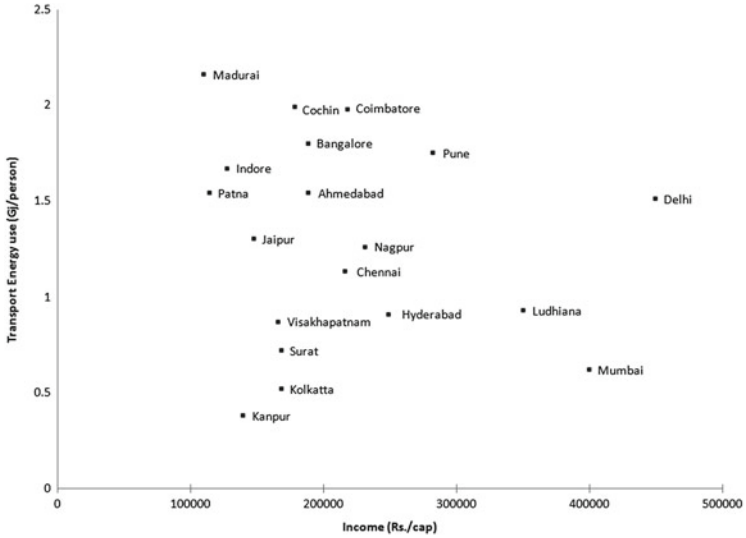

Fig. 9.5 Transport energy use per capita and income in Indian cities in 2005 (Source: Reddy and Balachandra 2010)

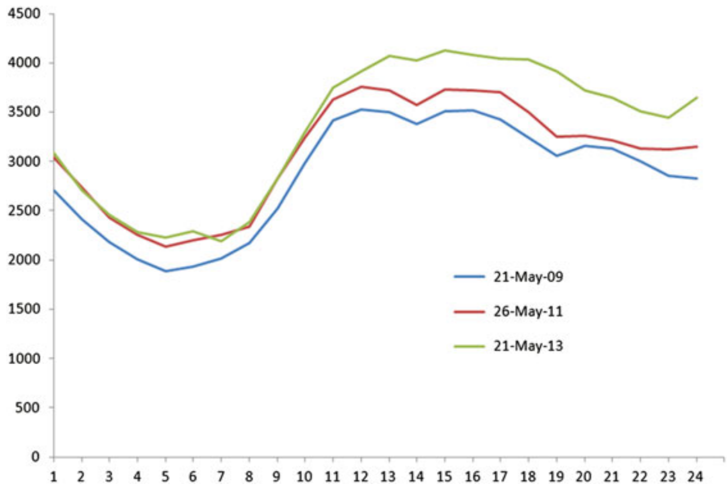

Fig. 9.6 Mumbai electricity load profile (Source: MSLDC 2013)

electricity consumption (peak) during the evening and night (7–10 p.m.) when the residential and commercial lighting and appliances loads come onto the system. The morning peak is caused by the office loads and air-conditioning coming onto the system. Between the morning and the evening peaks is a period of high consumption (partial peak) or shoulder region. During the night, there is a period of low consumption (11 p.m. to 6 a.m.). In some cities, there is a significant seasonal

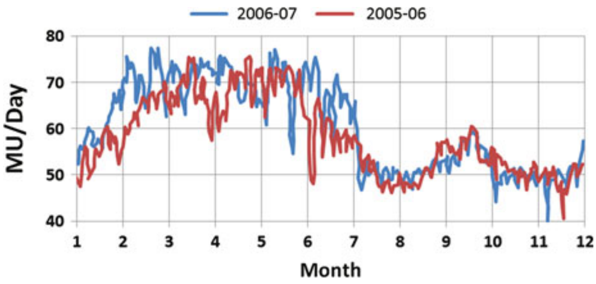

Fig. 9.7 Seasonal variations – Delhi (Source: NRLDC 2006)

Table 9.2 Electricity supply – Indian cities

	Average MW	Peak MW	Average/peak	Annual growth rate
Lucknow	553	750	0.73	6.5
Kanpur	348	580	0.6	5.4
Jaipur	446	771	0.58	10.6
Ahmedabad	897	1,320	0.68	7.4
Surat	917	1,309	0.7	6.6
Nagpur	264	315	0.83	7.6
Indore	229	391	0.59	10.2
Pune	886	1,173	0.76	10.5
Mumbai	2,524	3,605	0.7	6.9
Hyderabad	1,544	2,134	0.72	8.2
Chennai	1,743	2,291	0.76	5.6
Bengaluru	1,404	2,090	0.67	5.6
Kolkata	1,773	2,577	0.69	5.1

Source: CEA (2013)

variation in the cities' electricity use pattern. Figure 9.7 shows the seasonal variation in the electricity use for Delhi (NRLDC 2006). It is clear that electricity demand in summer is significantly higher than the winter demand mainly due to the increased demand for air-conditioning.

Table 9.2 shows the average system power demand (MW) and the peak power demand (MW) for select India cities and the annual growth rates. It is seen that the annual growth rates are high ranging from 5.1 to 10.6 % per year. CEA projects these growth rates as the expected growth continuing for the next decade. This implies significant increases in the electricity supply and investments in the transmission and distribution infrastructure. The average demand to the peak demand depends on the nature of the load variation and the share of industrial and commercial loads.

Most cities in India have a shortage of electricity supply. This is managed by load shedding (curtailment of supply). A study by Wartsila in 2009 surveyed the load shedding in different cities in India. In most international power systems, supply and demand match and loss of load expectation is low and rare. In many Indian cities,

Table 9.3 Load shedding seasons

S.No.	City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Bangalore												
2	Bhopal												
3	Chennai												
4	Coimbatore												
5	Delhi												
6	Faridabad												
7	Gurgaon												
8	Hyderabad												
9	Indore												
10	Kanpur												
11	Lucknow												
12	Ludhiana												
13	Madurai												
14	Mumbai												
15	Mysore												
16	Navi Mumbai												
17	Noida												
18	Pune												
19	Rajkot												
20	Vadodara												
21	Vishakapatnam												
Severity of daily outage			No outage				Non peak months				Peak months		

Source: Wartsila (2009)

Table 9.4 Load shedding estimates – Indian cities

Severity of power outage across the weak - peak & non -peak season															
		Peak season							Non-peak season						
No	City	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	Bangalore	1.5	1.5	1.5	1.5	1.5	1.5	1.5							
2	Bhopal	2.5	2.5	2.5	2.5	2.5	2.5	2.5							
3	Chennai	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4	Coimbatore	2	2	2	2	2	2	2	1	1	1	1	1	1	1
5	Delhi	2	2	2	2	2	2	2							
6	Faridabad	5	5	5	5	5	5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
7	Gurgaon	5	5	5	5	5	5	5	4	4	4	4	4	4	4
8	Hyderabad	1	1	1	1	1	1	1							
9	Indore	2	2	2	2	2	2	2	2	2	2	2	2	2	2
10	Kanpur	7	7	7	7	7	7	7	6	6	6	6	6	6	6
11	Lucknow	3.5	3.5	3.5	3.5	3.5	3.5	3.5	1	1	1	1	1	1	1
12	Ludhiana	4	4	4	4	4	4	4	4	4	4	4	4	4	4
13	Madurai	2	2	2	2	2	2	2	1	1	1	1	1	1	1
14	Mumbai														
15	Mysore	2.5	2.5	2.5	2.5	2.5	2.5	2.5							
16	Navi Mumbai	2	2	2	2	2	2	2	1	1	1	1	1	1	1
17	Noida	5	5	5	5	5	5	5	2	2	2	2	2	2	2
18	Pune	3	3	3	7	3	3	3	Infrequent upto 1h			5	Infrequent upto 1 h		
19	Rajkot	Infrequent upto 3 h. No fixed pattern							Infrequent upto 1 h. No fixed pattern						
20	Vadodra	Infrequent upto 3 h. No fixed pattern							Infrequent upto 1 h. No fixed pattern						
21	Vishakapatnam	2	2	2	2	2	2	2							
Severity of daily outage			No outage			>0<3 h			>=3<6 h			>=6 h			
Note: Numbers in the table indicate the average daily outage hours															

Source: Wartsila (2009)

the supply demand mismatch persists over years. There are often load shedding schedules. However, there are no accurate methods of quantification of load shed and the losses due to the non-availability of electricity supply. Tables 9.3 and 9.4 provide an estimation of load shedding seasons and the number of hours of load shed during these seasons for some Indian cities in 2008. It can be seen that load shedding is a widespread phenomena in most Indian cities with the summer months seeing more load shedding.

Unlike electricity, the variability in transport or cooking energy does not need to be planned for in terms of storage or capacity. The growth in personal transport vehicles in cities poses a problem in terms of congestion of roads, local emissions, lack of parking space and increased travel times.

9.3 Threats to Energy Security

(a) *Demand outgrowing supply* – The rapidly growing demand makes it difficult for investments in new supply to keep pace with the demand. This often results in peak and energy shortages.
(b) *Non-availability of fossil supply* – Non-availability coal supply to power plants on LPG supply to cities can also result in shortages. Resource depletion is a key threat for fossil fuel supplies to cities.
(c) *Disruptions/failures in supply network* – There have often been cascaded failures in the electricity grid due to overdrawal and poor grid management that have resulted in outages of the electricity supply to cities.
(d) *Variations in climate* – Changes in the climate patterns resulting in extreme temperatures may impose increases in the electricity demand that are difficult to meet. Changes in the rainfall pattern can affect the availability of water to the cities and may need a higher energy cost in transporting/pumping water from other locations.
(e) *Extreme natural events* – Floods, cyclones, and other extreme natural events can disrupt the energy infrastructure of cities and result in prolonged energy shortages.
(f) *Market volatility* – Often cities are depending on procuring energy from other suppliers. Fluctuations in market prices and demands of energy may affect the cities' ability to secure its energy supply.
(g) *Sabotage* – The energy infrastructure is susceptible to sabotage and terrorist attacks. Blockages of roads and ports and disruptions in pipelines and transmission networks can disrupt the energy supply and the functioning of cities.
(h) *Environmental impacts and health* – The adverse impacts of vehicular fuels and solid cooking fuels can result in poor indoor and outdoor air quality and have an impact on increased respiratory diseases in the city.

9.4 Responses

9.4.1 Renewable Energy Supply

Figure 9.8 shows a schematic of possible renewable energy sources for the different end uses required for the residential sector. Renewable energy technology is available and can provide reliable supply. The costs are higher than existing fossil sources but costs are rapidly coming down. The commercial sector and high-usage

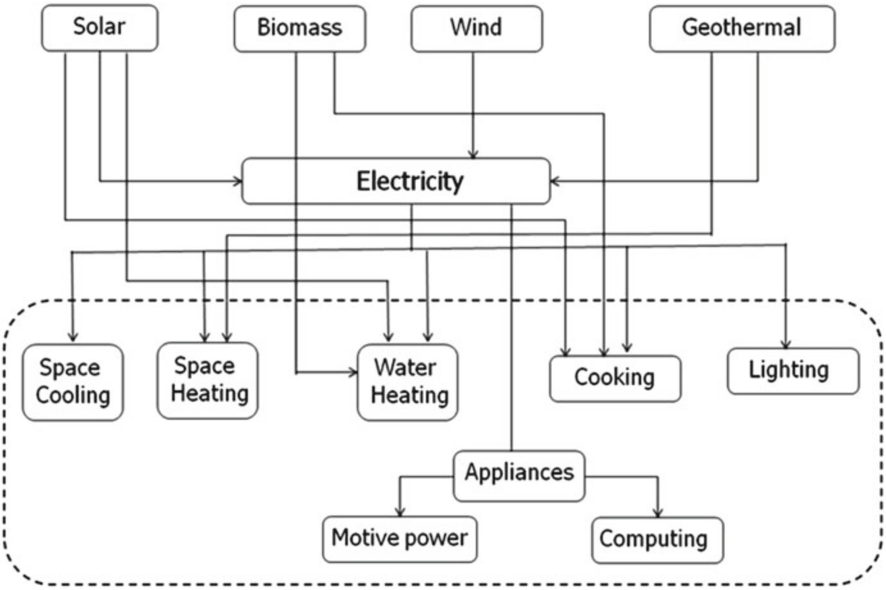

Fig. 9.8 Schematic of renewable energy options for buildings (Source: Developed by the author)

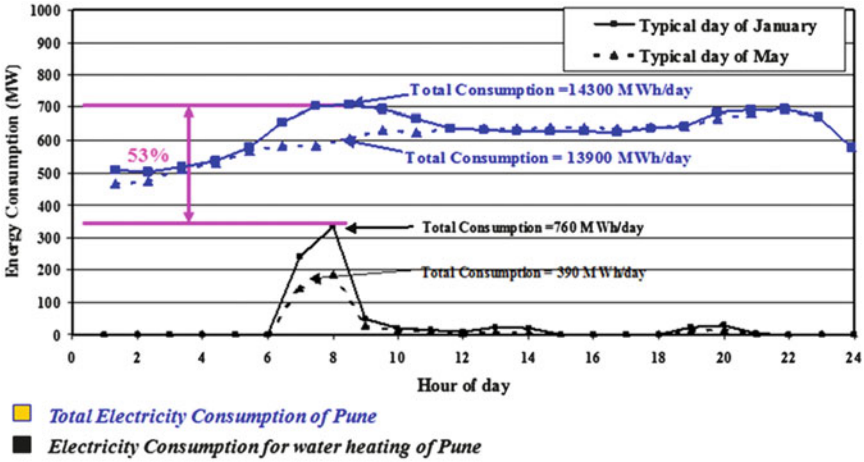

Fig. 9.9 Load profile and electric water heating share for Pune (Source: Pillai and Banerjee 2006)

residential sector pay significantly high tariffs for electricity (Rs. 8–10/kWh) in some cities in India (e.g. Mumbai). At current prices, solar water heaters are cost-effective as replacements for electric geysers with payback periods less than 3 years.

Solar water heaters have significant penetration in cities like Bangalore and Pune. Figure 9.9 shows the potential for morning peak reduction through a solar water heating programme for Pune. It is seen that electric water heaters contribute significantly to the morning peak load.

Solar photovoltaic modules on the rooftop can supply the cities' electricity requirement during the day. A study for Delhi indicated a potential of 2 GW of PV peak in the national capital region. The National Solar Mission emphasised large-scale MW-based grid-connected PV power at preferential tariffs. Similar incentives should be made available to rooftop-based PV systems for cities. Distribution companies should facilitate the connection of rooftop PV systems with net metering and buy-back schemes.

9.4.2 Energy Efficiency and Demand Side Management

Distribution and energy supply companies need to invest in demand side management – modifications of the customer load profiles to provide benefits to the utility and society. Energy-efficient lighting (incandescent to compact fluorescents (CFLs) and light-emitting diodes (LED), efficient fluorescents, lighting controls, etc.), replacement of conventional ceiling fans of rating 70 W by Brushless DC fans (BLDC fans) of rating 36 W, efficient appliances and efficient air-conditioning systems and controls are cost-effective as retrofits for many commercial and high-usage residential consumers.

A study of an office building in Mumbai (Puradbhat and Banerjee 2014) illustrates the potential of DSM in modifying the electricity load profile as shown in Fig. 9.10. DSM programmes like energy-efficient fans, efficient lighting and air-conditioning are cost-effective and can result in a reduction of electricity consumption and peak demand. Cool storage (chilled water or ice storage) can be used in large central air-conditioning systems as a technique for load shifting. This is viable under the differentials provided by time-of-use tariffs.

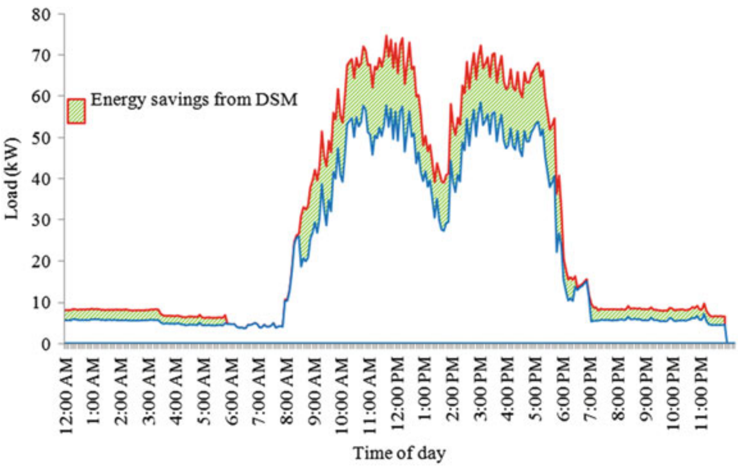

Fig. 9.10 Load profile of an office building (Source: Puradbhat and Banerjee 2014)

Some urban distribution utilities have invested in pilot DSM programmes. In order for future electricity systems to be affordable and more secure, large-scale implementation of DSM programmes should be supported.

9.4.3 Captive and Industrial Power Plants

An option to mitigate load shedding is the use of surplus captive and industrial power plant capacity. In 2006, the Confederation of Indian Industries (CII) estimated that 90 MW of load shedding was being imposed on Pune. CII identified 100 MW of captive generators in the industrial sector of Pune. A special tariff of the regulatory commission (MERC) was provided for the variable cost of generation from captive power plants ranging from Rs. 8.24 to 11/kWh. In Pune, Tata Power took on the responsibility of a distribution franchisee. This demonstrates that local solution to mitigate load shedding is possible with industry's help.

9.4.4 ICT, Smart Grids and Demand Response

Flexibility and control of loads in urban grids through improved use of ICT can be used for demand response and help electricity grids become more resilient and cost-effective. The key issue for affordability is the transaction costs of hardware and software solutions. One of the solutions that Mumbai has used has been islanding – where sensors detect conditions in the rest of the grid and isolate (or island) the Mumbai grid from the rest of the national grid in the face of impending grid failures.

9.4.5 Mass Transit

Policies of cities must encourage mass transit systems – metros, high-speed bus transits and suburban railway systems. Prioritising investments for these systems and providing accurate timetabling and information about mass transit systems can enable larger shares of passenger-kms in these systems and reduced energy intensities.

9.4.6 Benchmarking Energy and Emission Performance of Cities and Localities

Energy and emission balances for cities need to be computed and the performance of different cities compared on an equivalent basis. The direct primary energy and final energy use per person per year or per GDP can be compared. The electricity used per unit area per year or the electricity used per person per year can also be used as an indicator. The share of renewable energy in the cities' final energy or primary energy mix can also be tracked along with the carbon footprint of the city.

9.4.7 Zero Energy Buildings and Energy Plus Houses

It is possible to design houses with solar passive concepts to maximise the use of daylighting and minimise the needs for air-conditioning. The use of efficient appliances can contribute to a reduction of the electricity requirement per unit area to barely 10–20 % of the present averages. This reduced energy requirement can be provided by rooftop solar thermal and solar photovoltaics.

9.4.8 Bikable, Walkable Cities and Sustainable Urban Design

Integrated planning of cities to reduce the need for travel and provide special paths for biking and walking along with access to mass transit systems can transform the energy profile of cities. Rainwater harvesting and converting wastes to energy can help make cities more sustainable. Retrofit solutions can reduce the energy and carbon footprints of existing cities. Innovations and new design coupled with detailed computer simulations and analytical models can help evolve more sustainable urban design for future cities of India.

9.5 Conclusions

Cities are likely to provide the impetus for growth in India. The share of urban population is likely to increase in the future. Creating energy security for cities is critical to enable their growth. In order to do this, it is important to understand the existing energy use patterns in the cities. The adoption of energy efficiency and renewables can help improve the energy security and sustainability of cities. Tracking the energy and carbon performance of cities in a transparent fashion is a prerequisite for planning future sustainable energy services for the city. Several technological and design solutions exist and may be cost-effective if financed appropriately. Appropriate policies are needed to examine the city's future energy, water and waste removal needs in an integrated fashion. Securing energy needs for cities would need changes in our approach to planning cities and implementing projects.

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Chapter 10
Challenges and Opportunities in SWM in India: A Perspective

Sunil Kumar and Avick Sil

Abstract Solid waste management (SWM) is one of the important tasks managed by local municipal bodies. Currently, it is one of the most neglected fields in the society. Unscientific management of waste leads to emission of methane, carbon dioxide, mercaptans, hydrogen sulfide, etc. Also, through transportation, various vehicular pollutants are released. In developing countries, waste is treated as a resource, and valuable products are obtained from them. This paper highlights about scientific management of waste and potential for Mumbai to earn about 33 lakhs per day through scientific management of waste. The challenges and opportunities are being discussed in this paper.

10.1 Introduction

The primary purposes of solid waste management (SWM) strategies are primarily to address the health, environmental, aesthetic, land use, resource, and economic concerns associated with the proper disposal of waste with least menace of pollution and cost. These issues are discussing elements for nations, municipalities, and corporations around the world (Marshall and Farahbakhsh 2013). It is the most challenging task in India mainly because of its complexity related with segregation, transportation, and disposal issues (Goyal et al. 2014). It is associated with generation, segregation, storage, collection, transfer and transport, processing, and disposal of the solid waste. This must be carried out in accordance with best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations with a common goal of effective reduction of solid waste production which leads to minimization of pollution. Traditionally, SWM is accomplished through generation, segregation, collection, transportation, and

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disposal. Now, at few cities, scientific treatments, such as waste to energy, composting, biomethanation, etc., are observed (Goyal et al. 2014). Still, municipal bodies are facing tremendous challenges in terms of management of MSW. Rapid population growth coupled with industrialization has dramatically impacted traditional waste management system. In the last 20 years, India has witnessed an explosion of non-biodegradable waste materials like plastics, e-waste, and household hazardous and biomedical wastes. With the introduction and rapid spread of these nonbiodegradable wastes, particularly plastic, the traditional practices for waste disposal are no longer an effective solution. Municipal (or local) authorities are responsible for providing conservation (waste evacuation). This chapter reviews the challenges faced by municipal bodies in terms of management of waste. Finally, this paper highlights opportunities in terms of scientific waste management.

10.2 Waste Generation Rates Among Indian Cities

India is a vast country, and its waste generation varies with behavioral pattern. The waste generation depends on various factors like household size, number of people residing in the household, their living style, and others. This influenced the rate of generation of several categories of waste, including packaging wastes, putrescible kitchen waste, miscellaneous plastic waste, and miscellaneous combustible waste. Waste generation does not follow a linear graph in terms of the number of household and population growth. It is totally dependent on behavioral pattern. Jones et al. (2008) have conducted a study in which they found that as household size increased, the rate of increase in waste generation itself declined. They also found the relationship between per capita waste generation and household size, illustrating the rapid fall that occurs in the amount of waste produced by each family member as the size of the family increases. In India, major cities produce 0.2 to 0.6 kg of waste per day per person. In terms of income groups, the variation of higher- to lower-income group population varies from 800 to 180 g per person per day (Toxiclink 2014). The waste generation from different cities is represented in Table 10.1.

As per Table 10.1, most of the cities showed substantial increase in waste generation. In some cities, waste generation doubled, and some cities showed even a decrease in waste generation. These cities must be assessed and mapped in terms of waste management, and the reason for waste reduction needs to be found out. Also, some of the big cities like Mumbai, Delhi, Bangalore, Ahmedabad, Chennai, etc. need to implement decreased or ward-wise scheme for waste management. This would lead to the betterment of the country and aid in the progress of the country.

Table 10.1 Waste generation in different cities (in tons/day)

Cities	1999–2000	2004–2005	2010–2011	Remarks
Agartala	–	77	102	Waste generation increased with time
Agra	–	654	520	Waste generation decreased. But no justification is provided for the same
Ahmadabad	1,683	1,302	2,300	It is one of the most populated cities in India, and its waste generation showed fluctuation
Aizawl	–	57	107	Waste generation increased tremendously in this city
Allahabad	–	509	350	There is huge reduction in waste generation. One needs to investigate more about this status
Amritsar	–	438	550	Waste generation increased
Asansol	–	207	210	Waste generation remained more or less similar
Bangalore	2,000	1,669	3,700	This city showed fluctuation, and waste generation increased very rapidly. One needs to look for more assessment for better understanding
Bhopal	546	574	350	This showed fluctuation, thereby leading to a reduction of waste generation
Bhubaneswar	–	234	400	Exponential waste generation was observed
Chandigarh	–	326	264	Waste generation rate decreased tremendously
Chennai	3,124	3,036	4,500	Exponential increased in waste generation was observed
Coimbatore	350	530	700	Exponential increased in waste generation was observed
Daman	–	15	25	Slight increase in waste generation was observed
Dehradun	–	131	220	Increased in waste generation was observed
Delhi	4,000	5,922	6,800	Exponential increase in waste generation was observed
Dhanbad	–	77	150	Waste generation almost doubled
Faridabad	–	448	700	Exponential increased in waste generation was observed
Gandhinagar	–	44	97	Waste generation almost doubled
Gangtok	–	13	26	Waste generation almost doubled
Guwahati	–	166	204	Increased in waste generation was observed
Hyderabad	1,566	2,187	4,200	Waste generation almost doubled
Imphal	–	43	120	Exponential increased in waste generation was observed
Indore	350	557	720	Every assessment showed increased in waste generation

(continued)

Table 10.1 (continued)

Cities	1999–2000	2004–2005	2010–2011	Remarks
Itanagar	–	12	102	Exponential increased in waste generation was observed
Jabalpur	–	216	400	Waste generation almost doubled
Jaipur	580	904	310	There is a tremendous decrease in waste generation
Jammu	–	215	300	Slight increase in waste generation is observed
Kanpur	1,200	1,100	1,600	Exponential increase in waste generation was observed
Kochi	347	400	150	Waste generation decreased
Kohima	–	13	45	Exponential increase in waste generation was observed
Kolkata	3,692	2,653	3,670	Waste generation showed fluctuation, and it remained almost constant as compared with the 2000 and 2011 data
Lucknow	1,010	475	1,200	Waste generation remained almost constant as compared with the 2000 and 2011 data
Ludhiana	400	735	850	Substantial increase in waste generation was observed
Madurai	370	275	450	Increase in waste generation was observed
Mumbai	5,355	5,320	6,500	Exponential increase in waste generation was observed
Nagpur	443	504	650	Waste generation increased constantly
Patna	330	511	220	There is a tremendous decrease in waste generation
Puducherry	–	130	250	There is an exponential increase in waste generation
Port Blair	–	76	45	There is a reduction in waste generation
Pune	700	1,175	1,300	Constant increase in waste generation was observed
Raipur	–	184	224	Substantial increase in waste generation was observed
Ranchi	–	208	140	Decrease in waste generation
Shimla	–	39	50	There is an increase in waste generation
Srinagar	–	428	550	There is an increase in waste generation
Surat	900	1,000	1,200	There is an increase in waste generation
Thiruvananthapuram	–	171	250	There is an increase in waste generation
Vadodara	400	357	600	Waste generation increased with time
Varanasi	412	425	450	Waste generation increased with time
Vijayawada	–	374	600	There was substantial increase in waste generation
Visakhapatnam	300	584	–	Waste generation doubled

Source: Modified from CPCB (2012)

10.3 Waste Collection Efficiency

In India, waste management is mainly carried out by the local municipality. Mostly unsegregated waste is being collected from the household by sweepers and then disposed into the community bins. These sweepers are mainly employed by individual households or societies. Waste from the community bins is then collected and transported by the local municipal authorities to open dumping sites. They are disposed without any prior scientific treatment. The detail of waste management is given in Fig. 10.1.

As per CPCB, 2012, the overall waste collection efficiency in India is about 70.1 %. Among the various states and union territories, Bihar, Maharashtra, and Lakshadweep show 100 % collection efficiency. In terms of treatment of waste, Sikkim has the highest percentage with 80 % and Chandigarh is next with 78 %. The overall treatment percent for India is merely about 12 %. Some of the states and union territories like Andaman and Nicobar, Bihar, Daman and Diu, Mizoram, Nagaland, Puducherry, Haryana, Punjab, Rajasthan, Uttar Pradesh, and Uttarakhand have 0 % treatment of waste. The detail of waste collection and treatment percent is given in Table 10.2.

Thus, there is a tremendous scope for improvement in waste management especially in terms of improving collection efficiency and waste treatment. Collection efficiency can be improved by awareness campaign, better door-to-door collection frequencies, understanding the value of waste, and human resource management. In terms of treatment, some of the cities have installed treatment plants like composting, waste to energy, biogas plants, etc. Some of the running biogas plants in India are given in Table 10.3.

Thus, from Tables 10.1 to 10.2, it can be concluded that mostly untreated waste is disposed off into the open dumping sites. The unscientific management of waste at open dumping sites leads to emission of various pollutants (Fig. 10.2).

The leachate generated from unscientific disposal contaminates the ground and surface water quality. Reyes-Lopez et al. (2008) has reported in their geographical studies that leachate contaminated groundwater quality up to the depth of 80 m from ground level. Also, the zone of influence varied from 20 to 40 m depending on season and other climatic conditions (Reyes-López et al. 2008). Varying levels of heavy metals are reported in landfill leachate like Cl, Al, Zn, Pb, Ni, Cr, etc. They could have significant health and ecological impacts (Rapti-Caputo and Vaccaro

Fig. 10.1 Current waste disposal mechanism in India

Table 10.2 Waste collection efficiency and treatment percent in Indian states

States	Waste generated	Waste collected	Waste treated	Collection efficiency	Treatment (%)
Andaman and Nicobar	50	43	0	86	0
Andhra Pradesh	11,500	10,655	3,656	92.7	31.8
Arunachal Pradesh	94	0	0	0.0	0.0
Assam	1,146	807	72.65	70.4	6.3
Bihar	1,670	1,670	0	100.0	0.0
Chandigarh	380	370	300	97.4	78.9
Chhattisgarh	1,167	1,069	250	91.6	21.4
Daman and Diu	41	0	0	0.0	0.0
Delhi	7,384	6,796	1,927	92.0	26.1
Goa	193	0	0	0.0	0.0
Gujarat	7,397	6,744	873	91.2	11.8
Haryana	537	0	0	0.0	0.0
Himachal Pradesh	304	275	153	90.5	50.3
Jharkhand	1,710	869	50	50.8	2.9
Jammu and Kashmir	1,792	1,322	320	73.8	17.9
Karnataka	6,500	2,100	2,100	32.3	32.3
Kerala	8,338	1,739	1,739	20.9	20.9
Lakshadweep	21	21	4.2	100.0	20.0
Madhya Pradesh	4,500	2,700	975	60.0	21.7
Maharashtra	19,204	19,204	2,080	100.0	10.8
Manipur	113	93	2.5	82.3	2.2
Meghalaya	285	238	100	83.5	35.1
Mizoram	4,742	3,122	0	65.8	0.0
Nagaland	188	140	0	74.5	0.0
Orissa	2,239	1,837	33	82.0	1.5
Puducherry	380	0	0	0.0	0.0
Punjab	2,794	0	0	0.0	0.0
Rajasthan	5,037	0	0	0.0	0.0
Sikkim	40	32	32	80.0	80.0
Tamil Nadu	12,504	11,626	603	93.0	4.8
Tripura	360	246	40	68.3	11.1
Uttar Pradesh	11,585	10,563	0	91.2	0.0
Uttarakhand	752	0	0	0.0	0.0
West Bengal	12,557	5,054	606.5	40.2	4.8
Total	**127,504**	**89,335**	**15,916.85**	**70.1**	**12.5**

Source: Modified from CPCB (2012)

Table 10.3 Biogas plants for treatment of waste

State	Organization	Capacity (m^3/day)
Gujarat	P.N. Desai Aranyak Foundation, Valsad, Gujarat	1,000
Maharashtra	Ashoka Biogreen Pvt. Ltd. at Talawade Village, Tahasil Trimbak, Nasik District	500
	Mrs. Chhaya Vilas Kudale, Malad Village, Daund Taluka, Pune	1,000
	Global Bioenergy, Kherdi Village, Buldhana Taluka, Buldhana District	600
	SEEPZ SEZ, Andheri, Mumbai	300
Karnataka	M/s Terra Firma Biotechnologies Ltd., Bangalore	1,000
Chhattisgarh	R.G. Organics, Raipur, Chhattisgarh	1,000

Source: MNRE (2014)

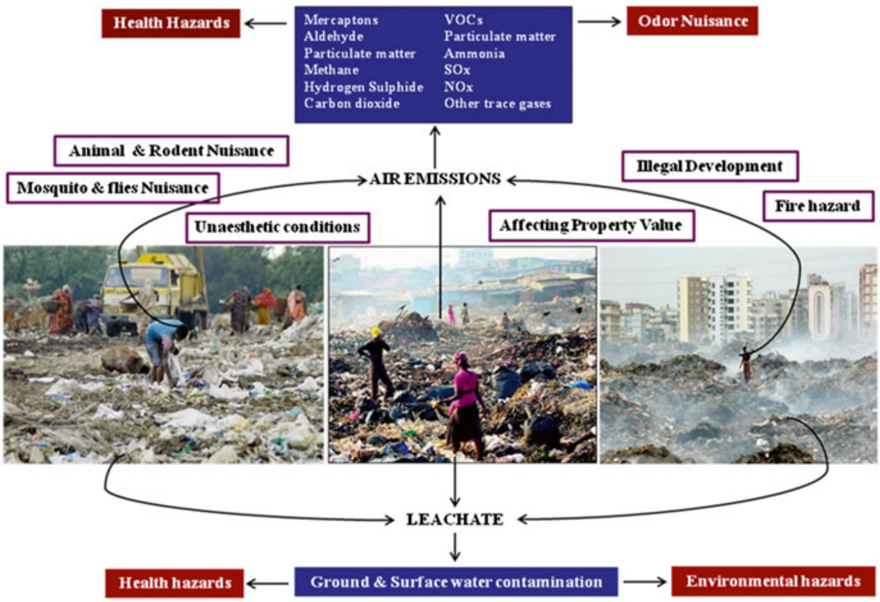

Fig. 10.2 Challenges and emissions from open dumping sites

2006). Open dumping sites are the major contributor of greenhouse gas (GHG) emissions. One such GHG is methane which has 21 times more global warming potential than carbon dioxide (Pattnaik and Reddy 2010). GHG and landfill gas emissions from Mulund and Deonar site are given in Fig. 10.3.

Most of the Indian municipalities are facing challenges in terms of waste management. Lack of awareness, technological knowledge, and human resource challenges together with population explosion is making it the most challenging task. Mumbai is the financial capital of India, and it harbors about 15 million of population.

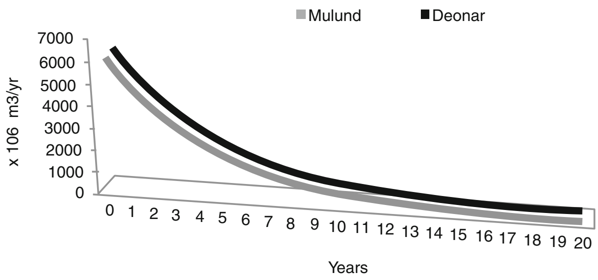

Fig. 10.3 Emission of methane from landfill sites (Sil et al. 2014)

More than 55 % of this population lives in slums (Census 2011). Waste management is the most challenging task in Mumbai. It generates about 8,500 tons of waste per day, 55 % of which is biodegradable waste, while the remaining is nonbiodegradable and inert. More than 800 vehicles (Sil et al. 2011) operate in the city for transportation of waste, while more than 1,000 workers are involved in this activity. Currently, unsegregated waste is collected and disposed off to the open dumping sites. In Mumbai, there are two operating waste disposal sites, namely, Deonar and Mulund. A new site at Kanjurmarg has been recently started. It is designed as a sanitary landfill site. But due to the lack of management, this site has also been converted into an open dumping site. Emission from transportation is another important aspect from SWM. About 800 vehicles make about 1,600–1,700 trips per day for the collection and disposal of waste (Sil et al. 2011). The emission from waste transportation vehicles is given in Fig. 10.4. All these aspects could lead to tremendous challenge in the near future, as waste generation increases with population explosion.

10.4 Treatment Methods

Rapid modernization and urbanization has lead to change the lifestyle of urban population thus increasing the waste generation. Due to this, there is a constant disposal of garbage in the dumping sites, and this has flooded the sites and cannot further bear the burden. This also creates illegal dumping of waste at different locations. This contributes to the spreading of pollution, foul odor, communicable diseases, etc. (Fig. 10.2). Waste can be treated as a resource, and it can be used for the production of energy and compost. The technology options available for processing the MSW are based on either bioconversion or thermal conversion (Petric et al. 2012). The bioconversion process is applicable to the organic fraction of wastes, to form compost or to generate biogas such as methane (waste to energy) and residual sludge (manure). Various technologies are available for composting such as aerobic, anaerobic, and vermicomposting. The thermal conversion technologies are incineration with or without heat recovery, pyrolysis and gasification, plasma pyrolysis and pelletization, or the production of refuse-derived fuel (RDF). The two leading

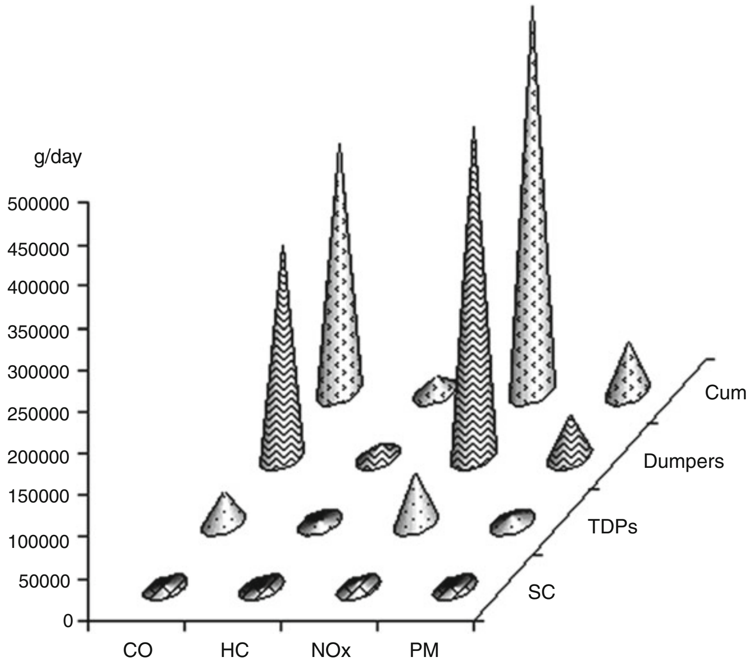

Fig. 10.4 Emission from waste transportation vehicles in Mumbai (Sil et al. 2011)

innovative mechanisms of waste disposal being adopted in India include composting (aerobic composting and vermicomposting) and waste to energy (WTE) (incineration, pelletization, biomethanation). WTE projects for disposal of MSW are a relatively new concept in India. Although these have been tried and tested in developed countries with positive results, these are yet to get off the ground in India largely because of the fact that financial viability and sustainability is still being tested. Different methods for the disposal and treatment of MSW have been discussed in the subsequent sections.

10.4.1 Thermal

Thermal technologies either use or produce significant quantity of heat during the course of treatment. In general, thermal processes take place at high temperature in reaction vessel. Common types of thermal technologies include gasification, pyrolysis, cracking, and plasma. These technologies are similar, in that exothermic or endothermic chemical reactions occur during the processes that change the composition of the organic fraction of the MSW. Air or oxygen may or may not be added to the reactor to influence the composition of the resulting products. The inorganic fraction of MSW may be sorted out prior to treatment or may be treated along with the organic fraction.

Types of products resulting from the processing of the organic fraction of MSW are syngas (i.e., synthesis gas composed of hydrogen, carbon monoxide, and carbon dioxide), char (a carbon-based solid residue), and organic liquids (e.g., light hydrocarbons). These products represent unoxidized or incompletely oxidized compounds, which in most cases differentiate the innovative thermal technologies from more complete combustion implemented in traditional waste-to-energy projects. If the inorganic fraction of MSW is also processed, additional by-products such as vitrified silica and mixed metals are produced.

The syngas is used in traditional combustors (boilers, reciprocating engines, and combustion turbines) to produce energy. Impurities like chlorides, heavy metals, etc. need to be removed from syngas prior to its combustion or usage. Syngas cleanup is achieved using standard, commercially available technology. Instead of combustion for energy/electricity production, the syngas gas may be chemically processed to produce other chemicals, such as methanol. In cases where organic liquids are produced, these may also be used as fuels or as chemical feedstocks for currently unspecified commodity or specialty chemicals.

10.4.2 Incineration

Incineration is the process of control and complete combustion, for burning solid wastes. It leads to energy recovery and destruction of toxic wastes, for example, waste from hospitals. The temperature in the incinerators varies between 980 and 2,000 °C. One of the most attractive features of the incineration process is that it can be used to reduce the original volume of combustible solid waste by 80–90 %. Unfortunately, in Indian cities, incineration is not very much practiced. This may be due to the high organic material (40–60 %), high moisture content (40–60 %), high inert content (30–50 %), and low calorific value content (800–1,100 kcal/kg) in MSW (Villeneuve et al. 2009). The first large-scale MSW incineration plant was constructed at Timarpur, New Delhi, in 1987 with a capacity of 300 tons/day and a cost of INR. 250 million (US$5.7 million) by Miljotecknik volunteer, Denmark. The plant was out of operation after 6 months, and the Municipal Corporation of Delhi was forced to shut down the plant due to its poor performance. Another incineration plant was constructed at BARC, Trombay (near Mumbai), for burning only the institutional waste, which includes mostly paper, and it is working as of this writing. In many cities, small incinerators are used for burning hospital waste (Sil et al. 2014).

10.4.3 Pyrolysis

Pyrolysis is a thermal process where organic materials present in the waste are broken down under pressure and at temperatures greater than 925 °F in the absence of oxygen to produce syngas; char and oil are also produced. Then, syngas is cleaned and burned in internal combustion (IC) engine generator sets or turbines to produce electricity.

10.4.4 Digestion (Anaerobic and Aerobic)

Digestion is the reduction of organic waste materials through microbial decomposition. It is a biological process of digestion which may be aerobic or anaerobic, depending on whether air (oxygen) is introduced into the process or not. *Anaerobic digestion* is a biological process by which microorganisms digest organic material in the absence of oxygen, producing a solid by-product (digestate) and a gas (biogas). Anaerobic digestion has been used extensively to stabilize sewage sludge and has been adapted more recently to process the organic fraction of MSW. The biogas produced from anaerobic digestion is primarily methane and carbon dioxide. Biogas is commonly burned in an internal combustion engine to generate electricity. Biogas also has other potential end uses. For example, biogas can be scrubbed of carbon dioxide, hydrogen sulfide, and water to obtain usable methane, which can be compressed and used as an alternative fuel in light- and heavy-duty vehicles. Digested material may be used as a soil conditioner, or compost, after a period of aerobic stabilization. *Anaerobic digestion* process may be either "wet" or "dry," depending on the percent of solids in the reactor. The process temperature may also be controlled in order to promote the growth of a specific population of microorganisms. Mesophilic anaerobic digestion occurs at temperatures of approximately 35 °C (95 °F). Thermophilic anaerobic digestion occurs at temperatures of approximately 55 °C (131 °F). The wet anaerobic digestion process starts with the organic fraction of MSW, which is mixed with water and pulped. The pulp is fed into a reactor vessel, where optimal heat and moisture conditions are promoted to enhance microbial development and decomposition. The process may be conducted in a single-stage or two-stage reactor vessel. Some of the technologies use a dry anaerobic digestion process, in which no added water is utilized. For dry anaerobic digestion, the incoming shredded organic solid waste is "inoculated" with previously digested material prior to introduction into the reactor vessel. Material in the digester has a retention time of 15–17 days and moves through the digester in a plug flow manner.

In the *aerobic digestion* process, the organic fraction of MSW is metabolized by microorganisms in the presence of oxygen. During the process, temperature and pH increase, carbon dioxide and water are liberated (reducing the mass of material), and pathogens are destroyed. The digested material may be used as a soil amendment or fertilizer (i.e., compost). Unlike anaerobic digestion, no methane gas is produced in the aerobic digestion process.

The aerobic digestion process may be either "wet" or "dry." Dry aerobic digestion is similar to in-vessel aerobic composting where MSW is put through an enclosed, intensive aerobic digestion phase, screened to remove nonorganic material, and then further stabilized in aerated piles. Wet aerobic digestion is considered "new and emerging" and was included in the evaluation. The wet aerobic digestion process consists of the following steps: pulping the organic fraction of MSW; mixing, heating, aeration, and inoculation with microbes; and separating the material into solid and liquid fertilizer products.

10.4.5 Anaerobic Digestion (Biomethanation)

If the organic waste is buried in pits under partially anaerobic conditions, it will be acted upon by anaerobic microorganisms with the release of methane and carbon dioxide; the organic residue left is good manure. This process is slower than aerobic composting and occurs in fact naturally in landfills. However, thermophilic digestion for biomethanation is much faster and has been commercialized. Anaerobic digestion leads to energy recovery through biogas generation. The biogas, which has 55–60 % methane, can be used directly as a fuel or for power generation. It is estimated that by controlled anaerobic digestion, 1 t of MSW produces 2–4 times as much methane in 3 weeks in comparison to what 1 ton of waste in landfill will produce in 6–7 years (Jha et al. 2008). In India, Western Paques have tested the anaerobic digestion process to produce methane gas. The results of the pilot plant show that 150 tons/day of MSW produce 14,000 m^3 of biogas with a methane content of 55–65 %, which can generate 1.2 MW of power. The government is looking forward to biomethanation technology as a secondary source of energy by utilizing industrial, agricultural, and municipal wastes. A great deal of experience with biomethanation systems exists in Delhi, Bangalore, Lucknow, and many other cities. There is little experience in the treatment of solid organic waste, except with sewage sludge and animal manure (e.g., cow dung). Several schemes for biomethanation of MSW, vegetable market, and yard wastes are currently being planned for some cities (Kumar and Gaikwad 2004).

The study reveals that in all situations (rural, urban or city, etc.) where space is available, composting or waste to energy is the better option because it prevents the load on municipalities for collection and transport of MSW and then reduces the pressure on the landfills. It also provides a valuable by-product for agriculture.

10.4.6 Composting

Composting is an organic method of producing compost manure by decomposition and stabilization of organic matter. Composting process is a commonly used method and results in the production of stable compost product reduced in size (when compared to initial size) and free from odors. Compost is particularly useful as organic manure which contains plant nutrients (nitrogen, phosphorous, and potassium) as well as micronutrients which can be utilized for the growth of plants. Composting can be carried out in two ways – aerobically (with the presence of oxygen) or anaerobically (without the presence of oxygen) or vermicomposting or by any other biological mechanism. Controlling some of the composting influencing factors, natural composting process could be accelerated. These influencing factors also have impact on the quality of compost produced. Some of the important factors in the composting process are temperature, C/N ratio, phosphorous, sulfur, moisture, particle size, oxygen flow, etc.

Table 10.4 Comparative table for solid waste management technologies

	Composting	Biomethanation	Incineration	Pelletization	Pyrolysis
Requirement for segregation	Very high	Very high	Low	High	High
Potential for direct energy recovery	No	Yes	Yes	No	Yes
Overall efficiency in case of a small setup	High	High	Low	Low	Moderate
Efficiency in case of high moisture	High	High	Very low	Low	Low
Land requirement	High	Low to moderate	Low	Low	Moderate
Leachate pollution	High, if not routed properly	Moderate to high in case effluent is not properly none	None	None	None
Toxicity	None	None	Moderate	None	None

Source: Barlaz et al. (2004) and Goyal et al. (2014)

Though so much of technologies are being available, still, open, uncontrolled, and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation. More than 90 % of MSW in cities and towns are directly disposed of on land in an unsatisfactory manner. Such dumping activity in many coastal towns has led to heavy metals rapidly leaching into the coastal waters. In the majority of urban centers, MSW is disposed of by depositing it in low-lying areas outside the city without following the principles of sanitary landfilling. Compaction and leveling of waste and final covering by earth are rarely observed practices at most disposal sites, and these low-lying disposal sites are devoid of a leachate collection system or landfill gas monitoring and collection equipment. As no segregation of MSW at the source takes place, all of the wastes including infectious waste from hospitals generally find its way to the disposal site. Quite often, industrial waste is also deposited at the landfill sites meant for domestic waste. Sanitary landfilling is an acceptable and recommended method for ultimate disposal of MSW. It is a necessary component of MSWM, since all other options produce some residue that must be disposed of through landfilling. However, it appears that landfilling would continue to be the most widely adopted practice in India in the coming few years, during which certain improvements will have to be made to ensure the sanitary landfilling. Comparative review of different technologies is given in Table 10.4.

Similarly, advantages and disadvantages of various technologies are given in Table 10.5.

Thus, overall looking at the moisture content and colorific value of waste, waste to energy is the most suitable technology for Jabalpur City. In order to have the proper design, one needs to access the waste collection efficiency. Waste collection

Table 10.5 Influencing parameters and constraints of various MSW technologies

Technologies	Influencing parameters	Limitations	Benefits	Environmental concerns
Composting	Segregation Organic matter Moisture content Market demand Location of the facility	Unsegregated waste No yield consistency (varying compost quality) Slow process Sound marketing arrangements are required Limited acceptance by the farmers and sometimes even by the city parks and gardens department	Reduces volume of organic waste fraction of MSW by 50–75 % Stabilizes organic fraction of MSW Highly useful product for crop improvement Value addition to waste resource	Can contaminate the soil if not tested for toxic elements before sale Emissions of particulate matter when moving/handling the waste Odor problems
Biomethanation or anaerobic digestion	Moisture content Organic/volatile matter C/N ratio Segregation Market demand	Higher capital costs Not suitable for wastes containing less biodegradable matter Requires waste segregation for improving digestion efficiency	Recovery of energy and production of fully stabilized organic manure Control/reduction of greenhouse gas emissions like methane Complete destruction of pathogens through anaerobic digestion – no transmission of disease through vectors Only preprocessing rejects – no post processing rejects Conversion efficiency: 60–70 %	Gas handling Fire and safety measures Proper operation of drying beds Leachate collection and treatment

Incineration	Calorific value Moisture content Organic/volatile matter Total inerts	Excessive moisture and inert content in waste affects net energy recovery Auxiliary fuel support may be necessary to sustain combustion High capital and O&M costs Residual ash and metal waste require disposal Overall efficiency is low for small plants Indian MSW has low calorific value; hence, supplementary fuel is required for combustion and hence high fuel costs	Achieves maximum volume reduction Incineration is a standard hygienic operation compared to open burning Heat generated can be utilized for production of steam/hot water/electricity Less land is required Most suitable for high calorific value waste. Can be located within city limits, reducing cost of waste transportation	Emissions – particulates SOx and NOx emissions, chlorinated compounds, ranging from HCl to organo-compounds such as dioxins, and heavy metals Toxic metals may concentrate in ash

Source: Barlaz et al. (2004) and Goyal et al. (2014)

is the most important aspect. If they are not collected effectively, it can lead to inefficiency in design parameters. Also, the level of segregation is very poor at this city. WTE does not require properly segregated wastes. It can function even with unsegregated or poorly segregated level of wastes.

10.5 Way Forward

Waste can be treated as a resource. There are various technologies (Fig. 10.5) available to treat the waste and produce valuable products.

Biodegradable waste can be treated through composting, vermicomposting, in-vessel composting (IVC), and biogas as decentralized treatment unit (Goyal et al. 2014). Under centralized manner, waste to energy (WTE) and biomethanation/biogas can be implemented. Biodegradable waste can be converted into compost. Mass balance ratio shows that about 12–15 % of the total biodegradable waste could be converted into compost (EPRI 2012). Thus, compost potential for Mumbai is 561 tons per day. Sale value of compost varies from INR. 5–10 per kilogram (data obtained from local vendor). Keeping the lower estimates, the amount that could be generated from the sale of compost would be INR. 28,05,000 per day. Similarly, dry waste could be converted into refused-derived fuel (Cui et al. 2011) of briquettes. Mass balance ratio for conversion rate for dry waste to briquettes or RDF is 10 % (EPRI 2012). Thus, about 250 tons per day of briquettes would be produced from

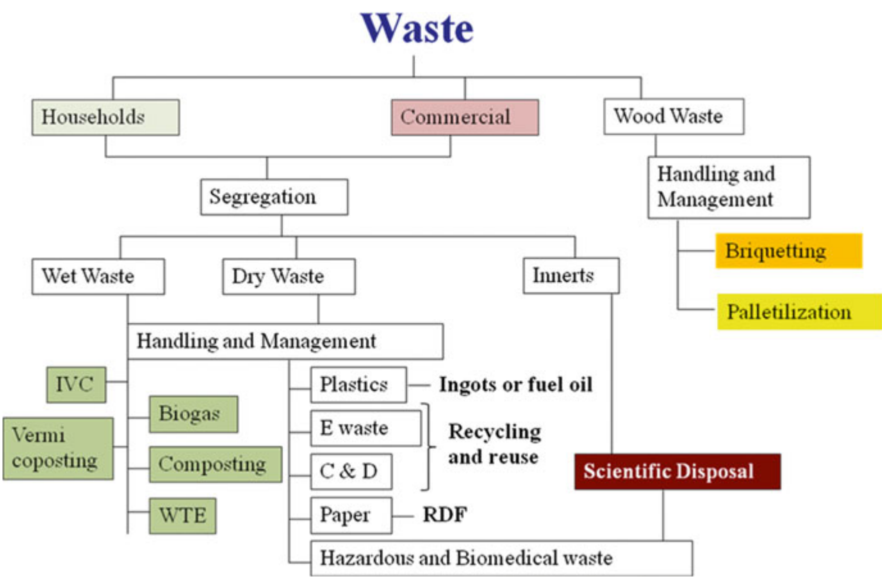

Fig. 10.5 Technologies for management of wastes (*IVC* in-vessel composting, *WTE* waste to energy, *e-waste* electronic waste, *C & D* construction and demolition waste)

Table 10.6 Incentive schemes of waste-to-energy projects in India

Project description	Incentives
Power generation from MSW with RDF	INR. 15 million per MW
Power generation from biomethanation	INR. 20 million per MW
Power from MSW on gasification, pyrolysis, and plasma	INR. 39 million per MW

Source: MNRE

Mumbai. The selling price of briquettes ranges from INR. 2,000–4,000 per ton (data obtained from local vendor). Keeping the lower estimates, the amount that could be generated from the sale of compost would be INR. 5,00,000 per day.

Thus, waste that could be treated as a resource can generate a large quantity of profit. Also, this would lead to overall improvement of the environment and social heath. Emission from transportation of waste could be reduced to a great extent with decentralized management of waste. This would also lead to green jobs and business and entrepreneurship opportunities. Similarly, there are various incentive schemes available for solid waste treatment units. The detail of such incentive schemes is given in Table 10.6.

Based on the above, many companies are getting into waste management as business opportunities. Some of the companies working in India are Hitachi Zosen, Ramky, Hanjer Biotech, Essel Groups, etc., in waste management sector. This has opened up a new branch of opportunity and entrepreneurships. Now, many small-scale companies and NGOs are also working in this sector of waste management. Finally, waste management is getting much more attention and it is moving toward scientific management option through waste as energy.

10.6 Conclusion

Waste or garbage is the most neglected aspect in Indian society. But it has a tremendous potential to be used as a resource and source of energy. Mumbai alone can generate about 33 lakhs per day from scientific management of waste. This cost only includes the valuable products that could be obtained from MSW. Also, there would be a tremendous improvement in social health and reduction in environmental pollution. Hence, it is the need of the hour to encourage local communities in terms of scientific management of waste.

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Chapter 11
E-Waste in Indian Cities, Menace, Resource, and Strategies for Sustainable Management

Amit Jain

Abstract E-waste in India, which may exceed three million tons by 2020, contributes significantly to solid waste generation in cities. Indian e-waste recycling is a subset of metal scrap industry consisting of formal and informal collectors, transporters, dismantlers, and recyclers. Class 1 and 2 cities act as major e-waste suppliers where informal sector collects and supplies 95 % e-waste to informal recycling hubs in metros resulting in toxic emissions and stress on civic services. The formal sector just accounts 5 % with 14 % of their capacity utilization. India's projected material requirements, up to 2030, are around 14.2 billion tons (46 % minerals and 6 % metals). India imports 95 % copper; 100 % molybdenum, nickel, antimony, cobalt, and magnesite; 90 % phosphate; and 87 % fluorite. Current e-waste inventory estimates from PC projected till 2020 indicate recovery potential of silver (6 tons to 11 tons), gold (1.4 tons to 2.4 tons), palladium (0.5 tons to 0.89 tons), copper (3.14 tons to 5.6 tons), and cobalt (0.4 tons to 0.73 tons) with GHG emissions ranging from 2 to 35 % of the GHG emissions due to primary mining of these metals. SWOT analysis indicates that despite potential strengths and opportunities, weakness exists due to sluggish enforcement of regulations without targets, economic instrument, and take back mechanism increasing illegal leakage of material. Therefore, under 3R strategy, usage of economic instrument, collection targets, and viability gap financing through PPP can lead to successful demonstration of e-waste management in metros. This can be scaled up to waste management parks, ecotowns, and their integration with smart cities.

11.1 Introduction

E-waste in India is one of the new waste streams, which is growing exponentially and contributing significantly to solid waste generation in cities. As per Central Pollution Control Board (CPCB) estimates, ten major cities contribute more than 60 % of total e-waste generation in India (Guidelines for Environmentally Sound Management of E-waste 2008). This new waste stream not only poses health and

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environmental challenge but also offers business opportunity. The estimated revenue potential from e-waste recycling is expected to double from US$ 1.5 billion in 2013 (Markets 2013) by 2018. The major objective of this chapter is to assess and describe the scale and structure of e-waste management in Indian cities, associated health and environmental impacts, and metal resource potential so that a road map for a number of interventions can be prepared to scale up its management and resource recovery.

11.2 Approach and Methodology

At first, a sector review was carried out based on secondary data analysis, followed by an assessment of environmental and health footprint in geographical context by formulating e-waste material flow chain using tracer technique and geographically mapping it using geographical information system (GIS) technique in metros, class 1 and class 2 Indian cities (Jain and Sareen 2006). Further, inventory projections have been computed by using the modified version of the "market supply method" with usage of "average life cycle" of electrical and electronic equipment (EEE) as per Indian conditions (E-waste Volume 1 and Inventory Assessment 2007). Macrolevel environmental and health impacts in Indian cities were evaluated using global-, regional-, and country-level ranking of waste management services and associated health impacts (Waste Atlas 2012). An assessment of e-waste versus natural resource has been carried out based on global material extraction versus consumption pattern and evaluation of its geographical implication. Further, metal reserves from e-waste generation in India have been estimated using e-waste inventory estimates (Jain and Sareen 2006; Dittrich et al. 2012). Finally, gap analysis of policy and regulatory framework under EPR has been carried out with overall scenario analysis using strategic evaluation technique of strength, weakness, opportunities, and threat (SWOT) to identify the strategies for developing the future road map for its sustainable management.

11.3 Results and Discussions

As per industry estimates, India generated more than 0.8 million tons of e-waste in year 2012 up from about 0.15 million tons in 2005 (Implementation of E-waste Rules 2011). It is estimated that the e-waste inventory from six major items (PCs, TVs, mobile phones, air conditioners, washing machines, refrigerators) will surpass 2.15 million tons by 2018 and 3 million tons by 2020. Per capita e-waste generation per year in India increased from 0.14 kg in 2005 to 0.7 kg in 2012. Therefore, the process of e-waste generation has accelerated, and in recent times it has nearly doubled the waste level year over year. Geographically, it is expected to exceed 587,824 tons in the east zone, 874,900 tons in the north zone, 984,000 tons in the south zone, and 1,030,000 tons in the west zone by 2020.

Indian e-waste recycling industry material flow analysis mapped through tracer technique indicates that e-waste recycling infrastructure consists of e-waste collectors, transporters, dismantlers, and recyclers in both formal and informal sectors. However, informal sector stakeholders are dominant which are linked to each other as part of the trade value chain. This mapping of scrap recycling industry is shown in Fig. 11.1. It indicates that the e-waste dismantling/recycling industry is a subset, where e-waste goes to the informal sector (Kojima and Promoting 3Rs in Developing Countries Lessons from the Japanese Experience 2008). This sector draws material from the major e-waste hubs in the country.

Spatial mapping of e-waste material flow chain in Indian cities (metros, Class 1 and Class 2) is shown in Fig. 11.2.

Figure 11.2 depicts natural and man-made features of the cities and their proximity to informal sector hot spots (Jain and Sareen 2006; Report on Assessment of Electronic Wastes in Mumbai-Pune Area 2007). Metrocities act as the hubs where the informal sector collects, manually dismantles, and practises open burning/acid leaching to recover/concentrate metals as part of the e-waste recycling chain (Report on Assessment of Electronic Wastes in Mumbai-Pune Area 2007). Other operations performed are de-soldering of printed circuit boards and open dumping as part of the recycling chain. These recycling operations in the informal sector are leading to "emissions of toxins" and are potential health and environmental risks (Puckett and Smith 2002). Mapping of current e-waste material flow chain in Indian cities is shown in Fig. 11.3.

The total licensed e-waste dismantling/recycling capacity in India as of January 2014 is 342,907 metric tons per annum (MTA) (List of E-waste Dismantlers/ Recycler in the country 2014). As per industry estimates, only 5 % of the generation potential goes into the formal dismantling and recycling sector, which indicates that the existing level of dismantling/recycling capacity utilization is around 14 %. Analysis of current inventory estimates versus dismantling/recycling capacity

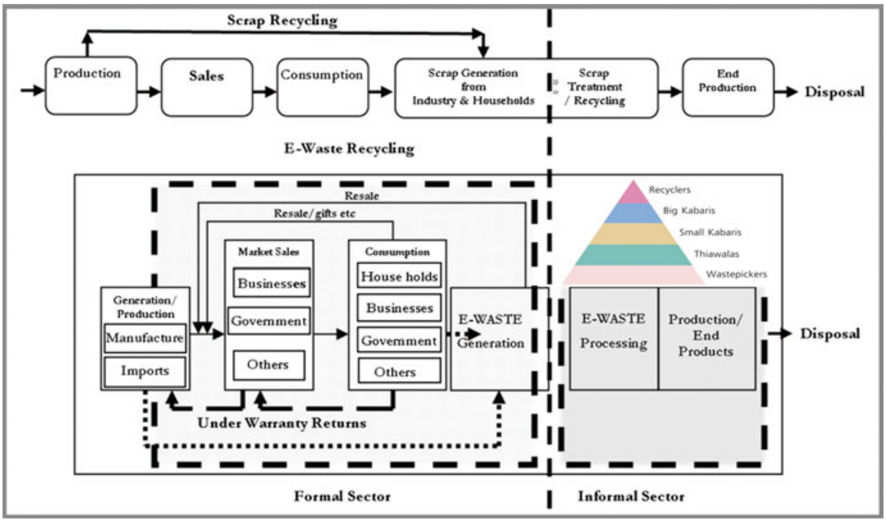
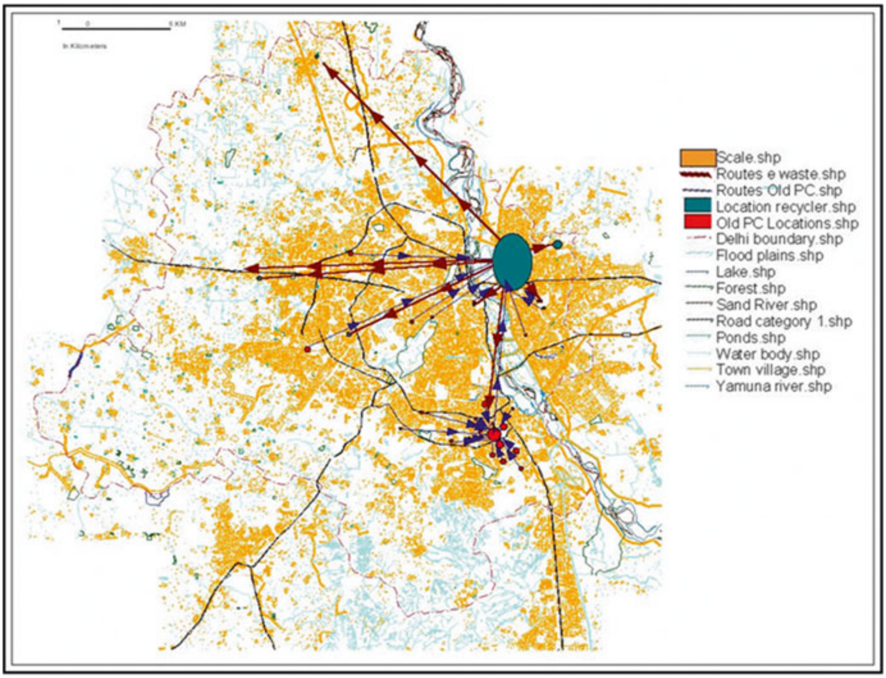


Fig. 11.1 Scrap recycling versus e-waste dismantling/recycling industry (Developed by author using data from field survey in metros, Class 1 and 2 cities)

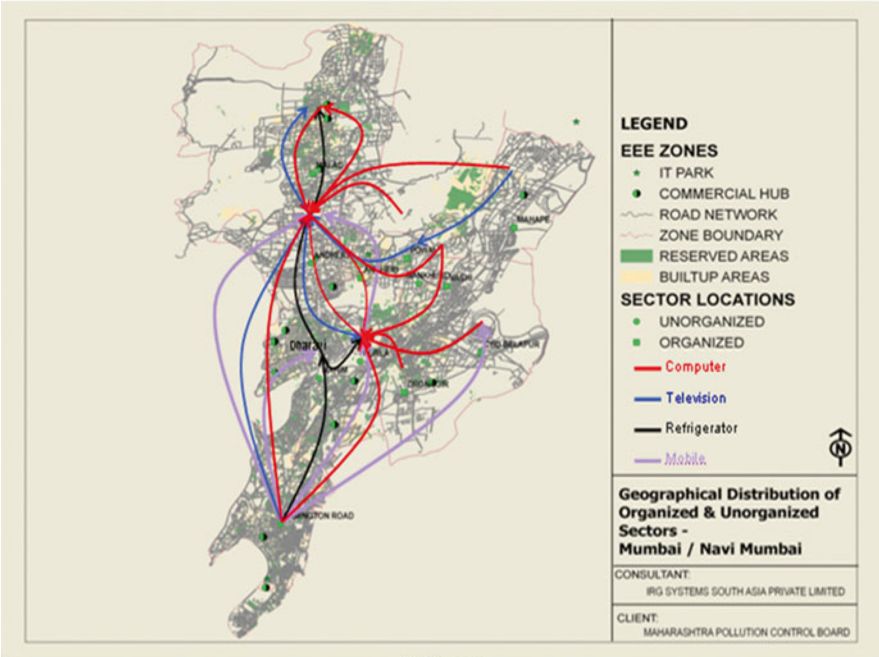
indicates that India has an e-waste recycling installed base, which is 35 % of the total e-waste generation potential in the country. Class 1 and 2 cities act as major suppliers of e-waste where the informal sector collects and supplies e-waste to recycling hubs in metros. The emergence of this new waste stream, 95 % of which goes into the informal sector, exerts stress on the existing civic infrastructure in Indian cities as well as increases its toxic footprint. At macrolevel, Fig. 11.4 describes the status of waste management services in India and health impact. India ranks close to poor in "collection coverage" versus "access to improved sanitation." Further, India also ranks poor in terms of "health indicator versus unsound disposal" (Waste Atlas 2012).

Natural resource availability and their consumption indicate that their consumption by humans has increased to 125 % of global carrying capacity and could rise to 170 % by 2040. North America, the EU, and the Asia-Pacific region currently consume at rates well beyond their available natural resources (Living Planet 2006). The need for these resources leads to higher global material extraction, trade, and

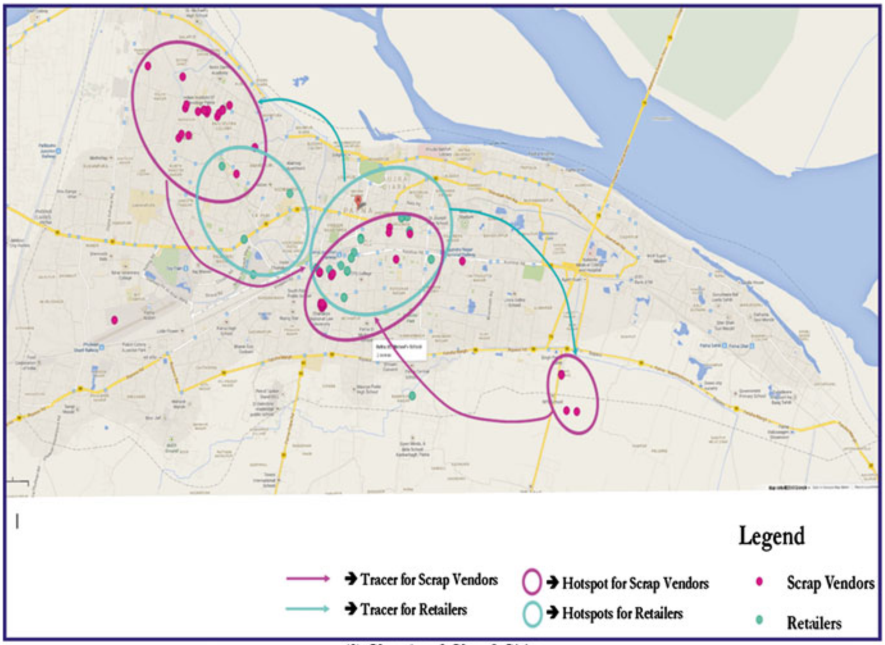


(1) Metros: Delhi

Fig. 11.2 Spatial mapping of e-waste material flow chain in Indian cities (Developed by author using data from field survey in metros, Class 1 and 2 cities) *Developed by author using data from (1) Pilot Assessment in Delhi: Management, Handling and Practices of E-waste Recycling in Delhi; (2) Reproduced from E-waste Assessment Study for MMR, Pune, and PCMC Region, Maharashtra Pollution Control Board (MPCB); (3) Developed by author from field survey of Class 1 and Class 2 cities*



(2) Mumbai



(3) Class 1 and Class 2 Cities

Fig. 11.2 (continued)

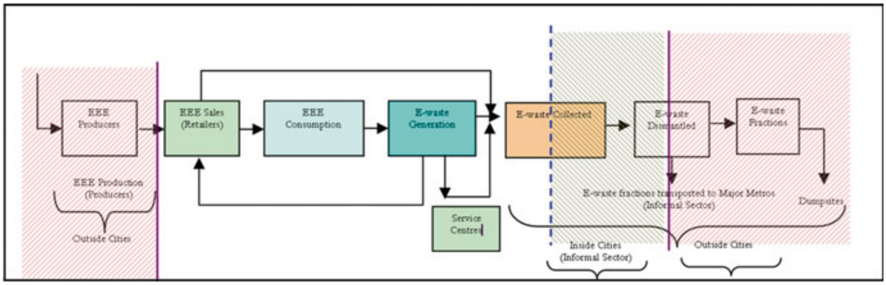
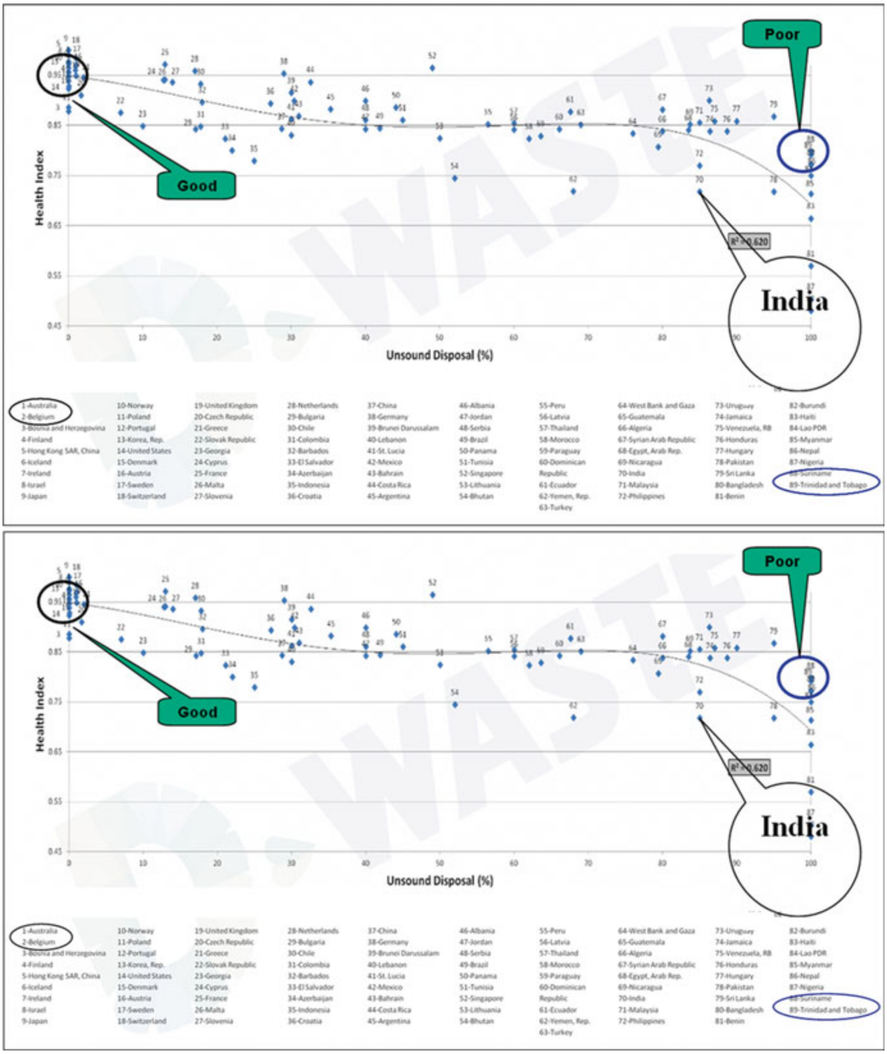


Fig. 11.3 Geographical mapping of e-waste material flow chain (Developed by author using data from field survey in metros, Class 1 and 2 cities)



Poor
Good
India
Health Index
Unsound Disposal (%)

Fig. 11.4 Waste management services and health impacts (Developed by author using data from Waste Atlas, 2012) consumption. Literature cites that since 1980, global extraction which equals global consumption has been growing by an average of 2.8 % annually and physical trade by 5.6 %. Asia extracts, exports, imports, and consumes around 50 % of all globally used materials. Trends indicate that Asia will continue to consume at rates well beyond their available natural resources. In Asia, India is expected to be one of the major drivers of this trend (Living Planet 2006).

In India, per capita consumption of material has changed during the past few decades. It increased from less than 3 tons per capita a year in 1980 to 4.2 tons per capita in 2009. India ranked 151st out of 193 countries in the world in 2009, consuming less than half of the global average of around 10.0 tons. In India, material consumption amounted to 4.83 billion tons in 2009, compared to 1.70 billion tons in 1980 (+184 %). In 2009, India accounted for 7.1 % of global material consumption, 5.8 % of global nonmetal mineral consumption and 2.3 % of global metal consumption, while hosting 17 % of global population. Consumption of metals increased at a compounded annual growth rate (CAGR) of 10 % between 2006 and 2011, while nonmetals increased by a CAGR of more than 6 %. Literature further cites India's requirements up to around 14.2 billion tons until 2030, out of which 46 % will be of minerals and 6 % will be of metals. Per capita consumption is expected to reach around 9.6 tons in 2030, which is nearly the current global average (India's Future Needs for Resources Dimensions and Possible Solutions 2013).

On the supply side, India is import dependent in nonrenewable materials, e.g., petroleum and specific minerals and metals. India imports 70 % of its petroleum and 95 % of its copper; 100 % of molybdenum, nickel, antimony, cobalt, and magnesite; 90 % of phosphate; and 87 % of fluorite. In this context, e-waste generated in India can be a source of materials and metal which are currently being imported by India. E-waste may contain up to 60 elements, e.g., a mobile phone may contain over 40 elements like copper (Cu), tin (Sn), cobalt (Co), indium (In), antimony (Sb), precious metals, and rare earth elements as shown in Fig. 11.5 (Resources and Technology Transfer Industrial Sector Studies 2009). The precious metal content in mobile phone may consist of 250 mg Ag (silver), 24 mg Au (gold), 9 mg Pd

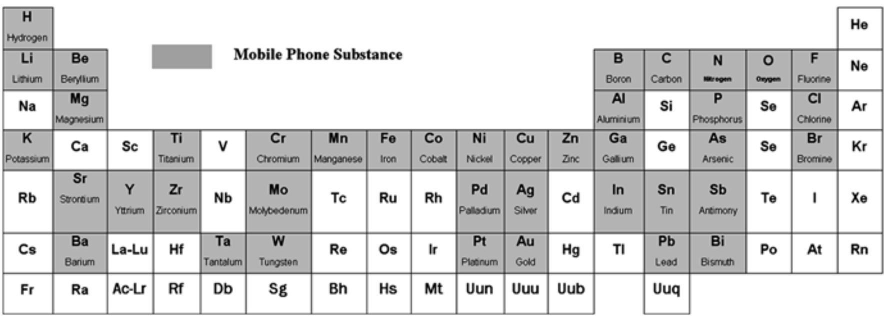


Fig. 11.5 Material content of mobile phones (Developed by author using data from Recycling – From E-waste to Resources, Sustainable Innovation and Technology Transfer Industrial Sector Studies (2009))

(palladium), and 9 g Cu (copper), while PC and laptops may consist of 1,000 mg Ag (silver), 220 mg Au (gold), 80 mg Pd (palladium), and 500 g Cu (copper) (Resources and Technology Transfer Industrial Sector Studies 2009).

Current e-waste inventory estimates from PC and laptop projected till 2020 indicate recovery potential of silver (Ag) from 6 to 11 tons, gold (Au) from 1.4 to 2.4 tons, palladium (Pd) from 0.5 to 0.89 tons, copper (Cu) from 3.14 to 5.6 tons, and cobalt (Co) from 0.4 to 0.73 tons (Fig. 11.6). Therefore, material and metals recovered from e-waste in India can not only provide strategic materials and ensure industrial growth but also save precious foreign exchange. It can also be a source of rare earth metals and strengthen "material security" of the country. Further, greenhouse gas (GHG) emissions due to precious metal recovery from e-waste through manual dismantling/smelting in India range from 2 to 35 % of the GHG emissions due to primary mining of these metals indicating environmental benefits of recycling e-waste (Eisinger et al. 2011). The major factors for tapping e-waste as a source are the recycling technology available to domestic e-waste recyclers and assured supply of e-waste to feed their recovery facilities. Technology evaluation of Indian e-waste dismantlers/recyclers indicates that only five e-waste recyclers have technology to recover precious metals. Further, downstream products from their operations are either going to the local market or exported to Europe, Japan, Hong Kong, and the USA. However, the monetary value received by them is based on four to five metals, viz., copper, silver, gold, and platinum/palladium only without any accounting for rare earth metals. This indicates that Indian e-waste recycler is neither getting full value of their material nor they have technology for rare earth metal recovery (Jain 2014). Further, they are facing competition from the informal sector.

Global strategies for sustainable management enabling policy and regulatory framework indicate that environmental protection, social fairness, and equity were the major drivers followed by resource recovery/material security, infrastructure development, reduction in financial burden of the government, and international

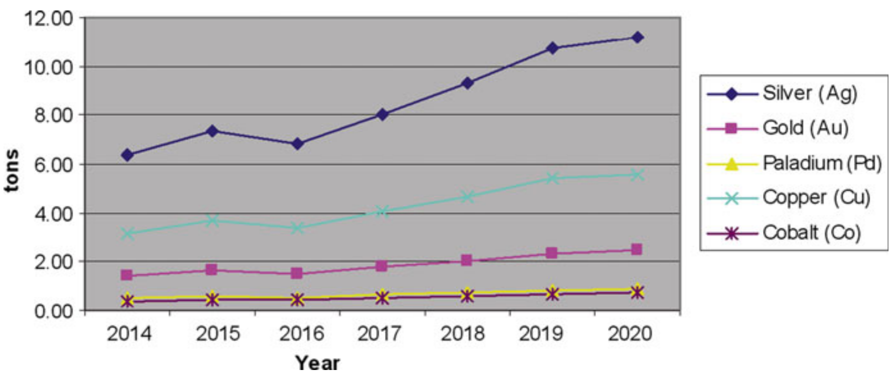


Fig. 11.6 Metal generation potential from e-waste (PC/laptop) (Developed by author using data from Central Pollution Control Board)

pressure. Evolution of global policy and regulatory framework related to e-waste indicates similar trends. In India, similar drivers enabled enactment of e-waste rules based on extended producer responsibility (EPR) in May 2011 by the Ministry of Environment and Forests (MoEF), Government of India, which become effective from May 1, 2012 (e-waste (Management and Handling) Rules 2011). These rules are applicable to every producer(s), collection center(s), dismantler(s), recycler(s), consumer(s), or bulk consumer(s) involved in the manufacture, sale, purchase, and processing of electrical and electronic equipment or components. Major responsibilities of the stakeholders related to e-waste management are summarized in Table 11.1 (Jain and Deshpande 2012).

The new regulation mandates producers to be completely responsible for the environmentally sound management of electrical and electronic equipment throughout its "life cycle" till its disposal at the end of life. This responsibility includes physical, financial, and legal compliance. All the stakeholders in the e-waste material flow chain shown in Fig. 11.3 are linked to each other through their functions under physical responsibility while independently responsible for legal compliance at the same time (Tables 11.1 and 11.2) (Implementation of E-waste Rules 2011). However, financial responsibility throughout the chain is the responsibility of the producer.

Globally, EPR compliance programs mobilize the resources from the producers to improve the environmental performance of the e-waste material flow chain. This resource mobilization triggers a shift of e-waste from the informal sector to formal sector leading to its diversion to registered dismantlers/recyclers (Jain and Deshpande 2012). Major gaps in the Indian regulation include absence of target to collect e-waste from the time of enforcement. Since the producer does not have any collection target, there is an uncertainty in the diversion of quantity of e-waste to the registered dismantler/recycler. Further, there are no mandatory provisions for producers in the rules to declare quantity of EEE placed in the market since 2012 (Jain and Deshpande 2012). The producer is expected to channelize the e-waste through the entire material flow chain and finance all the cost to implement it. However, there is no economic instrument to recover the cost of channelization, and hence resource mobilization from producers is either minimal or symbolic in nature. Producers are reluctant to pass on this cost to consumers under individual producer responsibility because it will lead to increase in price of their products leading to drop in market share. Therefore, e-waste rule's enforcement raises major issues: (1) start-up of an EPR-based system, (2) securing resources including finances to ensure a self-sustaining and smooth-functioning system, (3) reverse logistics network for the take back of the E-waste, (4) ensuring regulatory compliance, and (5) monitoring supply chain are not addressed (Jain and Deshpande 2012). Literature cites that in major metros, a "viability gap financing" (VGF) of 20–25 % of the total cost of the e-waste management project introduced either in the "take back" system or to a "service provider" offers the potential to "pull" the material in the supply chain within a radius of 100–150 km (Jain and Deshpande 2012). This can be tapped either from the producers "collectively" or from infrastructure development agencies.

Table 11.1 Responsibilities of stakeholders for collection, transportation, storage, and disposal of e-waste (Jain et al. 2012)

Responsibilities		Producer	Consumer	Bulk consumer	Collection center	Dismantler	Recycler/reprocessor
Collection	Manufacturing	√					
	End of life	√					
Take back	Individual	√					
	Collectively	√					
Transportation to	Producer		√	√			
	Collection Center	√	√	√			
	Dismantlers/recyclers	√	√	√	√	√	
	TSDF	√				√	√
Storage					√	√	√
Financing		√					
Registration		√			√	√	√
Filing of annual returns		√			√	√	√
Return of annual inventory handled		√		√	√	√	√

√ "Yes," *TSDF* means treatment, storage, and disposal facility

Table 11.2 E-waste (M&H) rules – 2011 including RoHS applicability (implementation of e-waste rule guideline 2012)

Sr. no.	Type of applicant	To maintain records	To maintain record in form 2	Filing annual return in form 3	Authorization form 1	Registration form 4	RoHS
1.	Consumer	X	X	X	X	X	X
2.	Bulk consumer	√	√	X	X	X	X
3.	Urban local bodies	√	X	X	X	X	X
4.	Collection center	√	√	√	√	X	X
5.	Producer – offer to sell	√	√	√	√	X	√
6.	Producer – importer	√	√	√	√	X	√
7.	Producer – manufacturing EEE	√	√	√	√	X	√
8.	Dismantler	√	√	√	√	√	X
9.	Recycler	√	√	√	√	√	X

X not applicable, √ applicable

11.4 Conclusions

SWOT analysis indicates that e-waste generation potential, EPR-based regulation, and e-waste dismantling/recycling infrastructure are the major strengths, which provide opportunities for augmenting material security, reducing environmental/toxic footprint, and promoting industrial development in India. However, weakness due to sluggish enforcement of regulations without any targets, economic instrument, and take back mechanism will increase the threat of higher leakage of material to the informal sector with increased environmental/toxic footprint and health impact and opportunity loss. The possible solutions to use these opportunities include identification of economic instrument to recover the cost of channelization of e-waste and fixation of annual collection targets to ensure definite quantity of e-waste flow into the material flow chain. In the interim during the transition period to take back regime, one of the options is to create a "special purpose vehicle" (SPV) for "take back" with participation of producers and dismantlers/recyclers with equity participation with VGF from the government under "public private partnership" (PPP) mechanism. Other options could be financing of the dismantler/recycler with VGF under PPP. Under both options, both "pull" and "push" strategy provide opportunity to convert SPV into collective producers' responsible organization (PRO) and VGF into "financial instrument" and fix up "e-waste collection targets." This can lead to successful demonstration of the e-waste management in metros as a subset of overall 3R (reduce, recover, and recycle) strategy for waste management which can be scaled up to waste management parks/circles addressing other waste streams and offering potential for the development of ecotowns and integration with smart cities.

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Chapter 12
Air Pollution: Short-Lived Climate-Forced Ozone in Urban Areas of Kolkata

Anjali Srivastava and Dipanjali Mujumdar

Abstract The rapid growth in the economy as well as urban population brings us challenges to the venture of maintaining the clean urban air. Urban air quality is a cause of public concern, largely as a result of increased instances of smog and health problems. New pollutants are being increasingly recognised and point to sources, which are of inevitable use in day-to-day modern life. Air pollution sources have grown and so the pollutants. Many of these sources are indices of development. As ubiquitous components in the atmosphere, non-methane volatile organic compounds have received immense attention due to not only their adverse health effects on humans but also because of their role as the precursor of lower tropospheric ozone which eventually leads to urban photochemical smog.

Modern studies on atmospheric photochemistry indicate that ozone mixing ratios at ambient air depend on complex, non-linear, feedback control processes involving NOx and VOC precursor mixing ratio. Hence, control computation is required, adopting mathematical models that include the best representation of the non-linear chemistry as the basis.

12.1 Introduction

Cyclical variations in the Earth's orbit have been a cause of changes in the distribution of surface heating and natural variability. Climate change today is dominated by 'anthropogenic' factors, principally emissions of greenhouse gases. Fifty-five to sixty percent of anthropogenic radiative forcing is caused by carbon dioxide. The

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remaining 40–45 % of radiative forcing is due to secondary reactions of pollutants in the atmosphere.

The secondary reactions of pollutants involve an array of pollutants such as methane, black carbon, tropospheric ozone and hydrofluorocarbons (HFCs). Collectively they are referred to as short-lived climate pollutants (SLCPs). These pollutants have short atmospheric lifetimes varying from days to a couple of decades. For slowing the rate of climate change over the next few decades and for protecting the vulnerable ecosystems and sensitive regions as well as sensitive human population, it is extremely important to reduce the SLCFs. These pollutants are more local/regional in nature than long-lived GHGs. Reducing SLCFs can lead to immediate climate benefits as the Earth's climate system responds quickly to reductions in these pollutants. Reducing SLCFs may be particularly beneficial for the protection of regions more sensitive to climate change like the Arctic and the Himalayan glaciers. The so-called climate tipping point may be deferred by slowing the rate of warming which will also be abetted by the reduction of SLFCs.

Non-methane volatile organic compounds (NMVOCs) and are precursors to ozone and are one of the SLCFs. NMVOCs, one group of precursors of ozone, lead to warming; where as on the other hand, NOx emissions lead to cooling. The overall effect of controls on ozone precursors varies on climate depending upon other meteorological factors. Tropospheric ozone (O_3) is of concern due to its adverse effects on both the environment and human health (Goldsmith and Nadel 1969; Krupa and Manning 1988). Breathing O_3 can trigger an array of health problems including coughing, throat irritation, congestion and even chest pain. It can worsen bronchitis, emphysema and asthma. Ground-level O_3 also can severely affect lung function and inflame the linings of the lungs (Roselle et al. 1991). Ozone does not essentially respond in a proportional manner to reductions in its precursor emissions (Finlayson-Pitts and Pitts 2000), and thus control of ground-level O_3 is difficult.

The present study focuses on the monitoring of ozone (hourly for 24 h) and its precursors non-methane VOCs (NMVOC) and carbonyls (24-hourly average), twice in every month in each of the 12 sites characterised by residential, industrial and traffic intersections and petrol pumps in the urban area of Kolkata along with VOCs, carbonyls and NOx. The probabilistic collocation method used by Tatang et al. (1997) was used to predict ozone concentrations for comparison with observed values.

12.2 Methodology

Ambient air was sampled at 12 sampling sites in the urban area of Kolkata using a low-volume sampler for the analysis of VOCs and carbonyls. The sampling locations can be characterised as residential, industrial and traffic intersections and petrol pump, three in each category (Fig. 12.1).

The detailed description of the study sites can be found in a previous publication (CPCB 2010). Samples were collected in three shifts for 24 h twice every month for

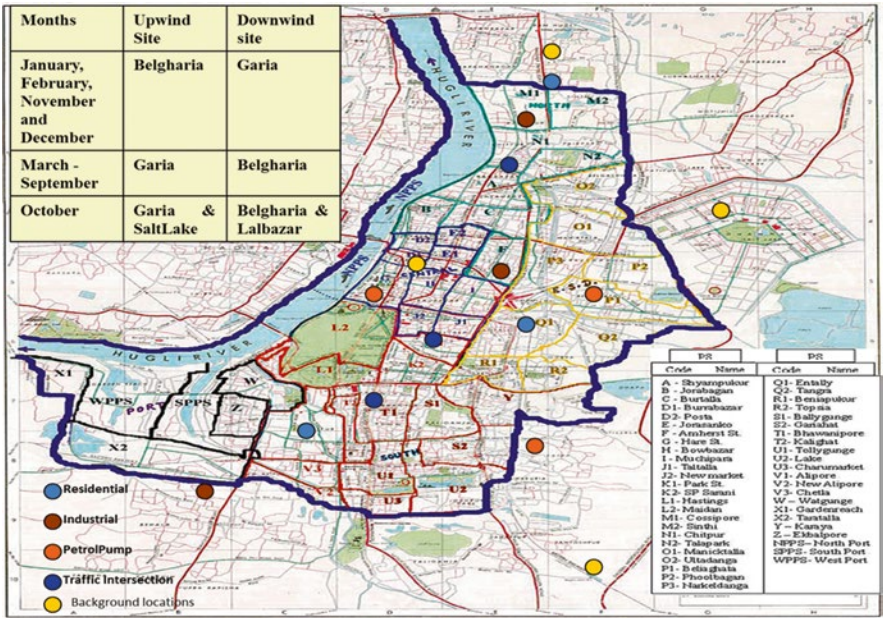


Fig. 12.1 Sampling locations

NOx; VOC and aldehyde hourly ozone concentrations have been monitored using ambient O_3 monitor (Model No. APOA370) of HORIBA along with the other target pollutants.

VOCs were analysed using compendium method TO-17 and carbonyls were analysed using compendium method TO-11A.

Levels of VOCs in ambient air have been determined by adsorbing air drawn at a uniform flow rate through specially fabricated sorbent tubes with partly filled Chromosorb 106 and Carbopack™ B 60/80 mesh used as sorbents, followed by thermal desorption and its further detection on Varian GC-MS in accordance with TO-17 compendium of methods for the determination of toxic organic compounds (USEPA 1999). Sorbent cartridges were fabricated using glass tubes with a length of 15 cm with an internal diameter of 4 mm and external diameter of 6 mm and having a tapered nozzle on one end. A battery-operated air sampler (Model Polltech-PEM-LVAS2) was used to sample air at the rate of 50 ml per minute through the fabricated adsorption cartridge. Uniform flow rate was monitored using a rotameter. The monitoring was carried out from 12 noon to 6:00 pm, 6:00 pm to 6:00 am and 6:00 am to 12:00 noon. Breakthrough value was estimated by connecting two tubes in series, and it was considered that breakthrough occurred when the backup tube had a concentration of more than 5 % of the total concentration. At the end of the sampling period, the sorbent tubes were removed, capped tightly, sealed in plastic zip bags and stored at 4 °C. Blank cartridges were also stored in identical conditions.

Varian GC-MS (Model Saturn 3) with injection mode of sample introduction with DB 624 capillary column of 30 m length, 0.32 mm internal diameter and 1.8 microfilm was used. Helium gas with a flow rate of 1 ml per minute was used as carrier gas with a split ratio of 1:25; GC oven was programmed for a hold at 35 °C for 4 min and ramped to 210 °C. Thermal desorption of sorbent tube was carried out by slowly heating the tube up to 180 °C for 10 min and 100 μl of the desorbed gas was Injected and analysed by gas chromatography (GC).

The estimation of oxygenated VOCs (aldehydes and ketones) was done following USEPA TO-11 method where the air sample was passed through a cartridge filled with silica impregnated with an acidified solution of 2,4-dinitrophenylhydrazine (2,4-DNPH), producing hydrazone which itself was quantified using high-performance liquid chromatography (HPLC). The cartridges were kept away from direct sunlight by wrapping them with an aluminium foil, and they were dried in a vacuum desiccator for 15–24 h before being closed with two caps and stored in a refrigerator until use. To prevent any consumption of hydrazones by reaction with the ozone contained outdoor which may lead to an underestimation of aldehydes concentrations, an ozone scrubber was used before the DNPH cartridge in order to trap ozone.

The cartridges after sampling were eluted with about 2 mL of acetonitrile. The obtained extracted derivative solutions were then analysed by HPLC coupled to UV detection (Dionex ICS-3000). The solution obtained after extraction was injected by a 20 μl sample loop into a reversed-phase C-18 column ((Supelcosil™, Supelco), 25.0 cm length, 4.6 mm i.d.) and detected at a wavelength of 360 nm using gradient mobile phase consisting of 10 % THF in water and acetonitrile. The compounds were quantified against a five-point external calibration curve prepared using TO11/IP6A Carbonyl-DNPH Mix procured from Supelco.

NOx has been measured as NO_2 by modified Jacobs-Hochheiser method (Na-arsenite). In the method, the NO_2 from ambient air is absorbed in a solution of sodium hydroxide and sodium arsenite. Sulphur dioxide is the major interfering compound. The interference of sulphur dioxide is eliminated by converting it to sulphuric acid by the addition of hydrogen peroxide. The absorbed nitrogen dioxide is then reacted with sulphanilamide in the presence of phosphoric acid at a pH of less than 2 and then coupled with N-(1-naphthyl)ethylenediamine dihydrochloride. The absorbance of the highly coloured azo-dye is measured on a spectrophotometer at a wavelength of 540 nm. The detection range of the NO_2 concentration is 9–750 μg/m^3. Calibration was carried out by plotting standard curve using high-purity sodium nitrite solution. Known concentration of sodium nitrite was determined intermittently to verify the validity of the calibration curve.

12.2.1 Quality Assurance and Quality Control

A linearity test has been carried out to determine the breakthrough volume by sampling a synthetic mixture of six components of VOC mix-15 for 20, 40 and 80 min at a rate of 100 ml/min. The linearity study indicated that breakthrough has not occurred at a sampling volume of 8,000 ml. Percentage accuracy for observation has been determined as a relative difference of measured concentration and spiked concentration for each component. Also mean response factor and percent relative standard deviation for all target compounds have been calculated. Method detection limit (MDL) has been established by making seven replicated measurements of 0.002 μg. The standard deviation for these replicated concentrations multiplied by Student's *t* value for 99 % confidence for seven values gives the MDL. The MDL varied from 0.00076 μg for 1,2-dichlorobenzene to 0.0045 μg for butyl benzene.

12.3 Results and Discussions

A maximum number of 132, 130, 86 and 85 NMVOCs have been identified at residential locations followed by traffic intersections, industrial and petrol pumps, respectively. The percentage of hazardous air pollutants (HAPs) identified was highest at petrol pump followed by industrial, residential and traffic intersections, respectively (Table 12.1). In the present discussion, NMVOCs that do not include carbonyls are referred to as non-carbonyl VOCs.

12.3.1 Industrial Areas

Amongst the industrial areas, highest concentrations of total non-carbonyl VOC are observed at Behala (456.1 μg/m^3) during winter season. The minimum concentration of 47.3 μg/m^3 was observed at Cossipore during summer. The total non-carbonyl VOC concentration at Behala was higher as compared to Baithakkhana Bazar and Cossipore. At Baithakkhana Bazar, the total non-carbonyl VOCs ranged from 48.0 to 210.9 μg/m^3, while at Cossipore, it ranged from 47.3 to 282.5 μg/m^3, and at Behala, the minimum concentration observed was 83.4 μg/m^3 and a maximum of 456.1 μg/m^3 (Table 12.2).

Amongst the industrial areas, highest concentrations of carbonyls were observed at Baithakkhana Bazar (1,131.7 μg/m^3) during summer. A minimum concentration of 135 μg/m^3 was observed at Behala during summer. The carbonyl concentration at Baithakkhana Bazar was higher as compared to Behala and Cossipore. At Baithakkhana Bazar, carbonyls ranged from 461.6 to 1,131.7 μg/m^3, while at Cossipore, it ranged from 217.8 to 1,111.5 μg/m^3, and at Behala, the minimum concentration observed was 72.0 μg/m^3 and a maximum of 1,091.1 μg/m^3 (Table 12.3).

Table 12.1 Category-wise distribution of VOCs and HAPs identified

Category	No. of VOCs identified	No. of HAPs identified	% of HAPs identified
Industrial	86	28	32.56
Petrol pump	85	30	35.29
Residential	132	35	26.52
Traffic intersection	130	31	23.85

Table 12.2 Seasonal variation of total non-carbonyl VOCs observed at industrial locations

Seasons	Sampling locations	1 12:00–6:00 pm	2 6:00 pm–6:00 am	3 6:00 am–12:00 noon
Summer	Baithakkhana Bazar	53.4	67.12	61.7
	Cossipore	55.7	72.3	47.3
	Behala	98.0	79.0	98.1
	Upwind	56	62	58
	Downwind	87	113	72
Monsoon	Baithakkhana Bazar	48.0	50.2	53.4
	Cossipore	64.6	77.3	66.5
	Behala	102.7	111.5	104.2
	Upwind	49	64	51
	Downwind	71	96	91
Post-monsoon	Baithakkhana Bazar	177.1	146.3	170.5
	Cossipore	158.8	209.3	194.3
	Behala	302.3	83.4	198.1
	Upwind	89	114	100.7
	Downwind	123	145	111
Winter	Baithakkhana Bazar	195.2	210.9	210.4
	Cossipore	236.1	282.5	234.4
	Behala	381.2	456.1	380.3
	Upwind	79	132	121
	Downwind	117	178	124

Table 12.3 Seasonal and diurnal variation of carbonyls observed at industrial locations

	Industrial	Baithakkhana Bazar	Cossipore	Behala	Upwind	Downwind
Summer	Shift 1	1131.7	723.4	426.9	315.9	564.8
	Shift 2	511.7	908.2	1091.1	357.4	1072.0
	Shift 3	1056.0	649.9	135.0	578.7	1537.0
Monsoon	Shift 1	529.0	676.3	928.1	379.5	900.6
	Shift 2	557.9	993.0	732.2	389.1	652.8
	Shift 3	627.6	545.5	475.7	121.5	385.5
Post-monsoon	Shift 1	727.4	599.1	555.3	623.0	382.1
	Shift 2	637.7	323.0	268.8	667.9	840.7
	Shift 3	712.5	373.1	398.3	374.7	777.9
Winter	Shift 1	1082.5	880.5	731.2	495.5	893.1
	Shift 2	461.6	217.8	345.2	483.9	1480.4
	Shift 3	645.2	1111.5	891.2	223.3	517.1

Table 12.4 Seasonal variation of non-carbonyl VOCs observed at petrol pumps

		1	2	3
Seasons	Sampling locations	12:00–6:00 pm	6:00 pm–6:00 am	6:00 am–12:00 noon
Summer	Beleghata	405.8	128.3	171.9
	Bose Pukur	141.0	459.4	136.3
	Theatre Road	221.0	319.8	276.1
	Upwind	56	62	58
	Downwind	87	113	72
Monsoon	Beleghata	212.0	187.6	307.6
	Bose Pukur	131.1	267.8	301.5
	Theatre Road	154.5	284.9	197.9
	Upwind	49	64	51
	Downwind	71	96	91
Post-monsoon	Beleghata	260.6	346.1	686.4
	Bose Pukur	297.2	561.9	294.1
	Theatre Road	500.2	689.0	499.0
	Upwind	89	114	100.7
	Downwind	123	145	111
Winter	Beleghata	753.9	1173.6	650.0
	Bose Pukur	395.3	518.2	306.2
	Theatre Road	621.0	741.7	633.5
	Upwind	79	132	121
	Downwind	117	178	124

12.3.2 Petrol Pumps

Table 12.4 gives the seasonal concentration of total non-carbonyl VOCs observed at Bose Pukur, Beleghata and Theatre Road petrol pumps. Maximum and minimum total non-carbonyl VOC concentrations have been observed at Beleghata petrol pump during winter and summer, respectively. At Bose Pukur petrol pump, the total non-carbonyl VOC concentrations ranged from 131.1 μg/m^3 during monsoon to 561.9 μg/m^3 during post-monsoon. At Beleghata petrol pump, a minimum concentration of 128.3 μg/m^3 during summer and a maximum concentration of 1,173.6 μg/m^3 during winter were observed. At Theatre Road petrol pump, a minimum concentration of 154.6 μg/m^3 during monsoon and a maximum concentration of 741.7 μg/m^3 during winter have been observed.

Amongst these three petrol pumps, the highest concentration of total carbonyls has been observed at Beleghata during monsoon (1,184.8 μg/m^3) and a minimum concentration at Bose Pukur petrol pump (130.7 μg/m^3) during post-monsoon. The concentration of total carbonyl was found higher at Beleghata as compared to the other two petrol pumps. The concentration of total carbonyls at Bose Pukur ranged from 130.7 to 1,015.4 μg/m^3. At Theatre Road, the minimum and maximum concentrations were 205.8 μg/m^3 and 688.8 μg/m^3, respectively (Table 12.5).

Table 12.5 Seasonal variation of carbonyls observed at petrol pumps

Petrol pump		Beleghata	Bose Pukur	Theatre Road	Upwind	Downwind
Summer	Shift 1	859.2	612.6	512.6	315.9	564.8
	Shift 2	394.1	834.5	417.0	357.4	1072.0
	Shift 3	302.0	616.0	380.4	578.7	1537.0
Monsoon	Shift 1	1184.8	856.8	578.9	379.5	900.6
	Shift 2	735.7	590.5	535.5	389.1	652.8
	Shift 3	597.6	477.7	205.8	121.5	385.5
Post-monsoon	Shift 1	609.1	236.0	381.6	623.0	382.1
	Shift 2	564.6	227.1	383.3	667.9	840.7
	Shift 3	522.1	130.7	291.1	374.7	777.9
Winter	Shift 1	1104.4	642.8	464.8	495.5	893.1
	Shift 2	959.3	1015.4	688.8	483.9	1480.4
	Shift 3	573.4	219.9	344.9	223.3	517.1

12.3.3 Residential Cum Commercial Areas

The total non-carbonyl VOC concentrations observed ranged from 43.0 μg/m^3 at Dunlop during monsoon to 546.1 μg/m^3 at Alipore during post-monsoon in residential cum commercial areas. At Alipore, the minimum concentration observed was 41.5 μg/m^3 during monsoon. Entally showed a minimum total non-carbonyl VOC concentration of 43.1 μg/m^3 during monsoon and a maximum concentration of 412.0 μg/m^3 during post-monsoon. The total non-carbonyl VOC concentration observed at Dunlop ranged from 43.0 μg/m^3 during monsoon to 84.8 μg/m^3 during winter. Seasonal and annual averages of total non-carbonyl VOCs at Alipore, Dunlop and Entally are presented in Table 12.6. In the case of carbonyls, the highest concentration was found at Entally (1,430.1 μg/m^3) during monsoon, while the lowest concentration was observed at Dunlop (177.4 μg/m^3) during post-monsoon. Entally showed a higher concentration of total carbonyls as compared to Alipore and Dunlop. At Entally and Dunlop, the concentration of total carbonyls varied from 189.3 to 1,430.1 μg/m^3 and 177.4 to 972.4 μg/m^3, respectively. The total carbonyl concentration range at Alipore was 246.6 to 781.4 μg/m^3 (Table 12.7).

12.3.4 Traffic Intersection

The total non-carbonyl VOC concentration at Rash Behari was observed to be in the range of 255.6 μg/m^3 during monsoon to 668.9 μg/m^3 during winter. At Shyam Bazar, which is located at the northern side of Kolkata, a minimum concentration of 177.6 μg/m^3 was observed during summer and a maximum concentration of 745.2 μg/m^3 was found during post-monsoon which was also the maximum observed concentration for all the traffic intersections (Table 12.8). At Park Street, a maximum concentration of 472.2 μg/m^3 was observed during summer and a minimum of 28.3 μg/m^3 during monsoon which was the lowest observed concentration for traffic intersections.

Table 12.6 Seasonal variation of total non-carbonyl VOCs observed at residential cum commercial locations

Seasons	Sampling locations	1 12:00–6:00 pm	2 6:00 pm–6:00 am	3 6:00 am–12:00 noon
Summer	Dunlop	56.4	61.3	60.0
	Entally	51.3	51.5	52.2
	Alipore	56.9	43.2	66.1
	Upwind	56	62	58
	Downwind	87	113	72
Monsoon	Dunlop	55.6	43.0	52.0
	Entally	74.7	43.1	75.7
	Alipore	44.3	49.7	41.5
	Upwind	49	64	51
	Downwind	71	96	91
Post-monsoon	Dunlop	77.7	51.9	45.0
	Entally	103.3	61.0	412.0
	Alipore	129.3	546.1	385.9
	Upwind	89	114	100.7
	Downwind	123	145	111
Winter	Dunlop	84.8	58.0	69.0
	Entally	85.6	55.6	45.5
	Alipore	107.0	140.0	98.0
	Upwind	79	132	121
	Downwind	117	178	124

Table 12.7 Seasonal variation of carbonyls observed at residential cum commercial locations

	Residential	Alipore	Dunlop	Entally	Upwind	Downwind
Summer	Shift 1	706.1	828.5	510.8	315.9	564.8
	Shift 2	453.1	384.1	496.6	357.4	1072.0
	Shift 3	554.8	483.4	794.2	578.7	1537.0
Monsoon	Shift 1	781.4	972.4	1430.1	379.5	900.6
	Shift 2	590.2	418.6	741.7	389.1	652.8
	Shift 3	451.2	594.6	382.3	121.5	385.5
Post-monsoon	Shift 1	483.7	481.8	669.0	623.0	382.1
	Shift 2	246.6	353.5	633.6	667.9	840.7
	Shift 3	429.6	177.4	189.3	374.7	777.9
Winter	Shift 1	374.6	614.9	671.5	495.5	893.1
	Shift 2	646.5	298.5	218.4	483.9	1480.4
	Shift 3	363.8	405.6	398.2	223.3	517.1

The highest concentration of carbonyls was found at Rash Behari during summer (1,985.4 μg/m^3), while the lowest concentration was observed at Shyam Bazar (325.1 μg/m^3) during post-monsoon. At Shyam Bazar and Park Street, the concentration ranges were found to be 325.1 to 1361.9 μg/m^3 and 413.8 to 1680.3 μg/m^3,

Table 12.8 Seasonal variation of total non-carbonyl VOCs observed at traffic intersections

Seasons	Sampling locations	1 12:00–6:00 pm	2 6:00 pm–6:00 am	3 6:00 am–12:00 noon
Monsoon	Park Street	297.3	28.2	262.6
	Rash Behari	329.7	317.2	255.6
	Shyam Bazar	344.5	545.6	395.0
	Upwind	49	64	51
	Downwind	71	96	91
Post-monsoon	Park Street	257.3	404.5	244.9
	Rash Behari	465.3	373.3	312.1
	Shyam Bazar	485.8	557.3	745.2
	Upwind	89	114	100.7
	Downwind	123	145	111
Summer	Park Street	367.9	472.2	345.8
	Rash Behari	573.9	490.0	663.4
	Shyam Bazar	607.7	177.6	433.4
	Upwind	56	62	58
	Downwind	87	113	72
Winter	Park Street	401.8	467.0	379.0
	Rash Behari	488.0	668.9	350.5
	Shyam Bazar	535.8	364.3	450.0
	Upwind	79	132	121
	Downwind	117	178	124

Table 12.9 Seasonal variation of carbonyls observed at traffic intersections

Traffic intersection		Park Street	Rash Behari	Shyam Bazar	Upwind	Downwind
Summer	Shift 1	839.9	1985.4	1361.9	315.9	564.8
	Shift 2	547.3	419.5	480.5	357.4	1072.0
	Shift 3	1024.2	879.3	1310.8	578.7	1537.0
Monsoon	Shift 1	1687.1	815.3	1004.2	379.5	900.6
	Shift 2	635.1	675.6	1178.0	389.1	652.8
	Shift 3	442.6	1277.6	872.8	121.5	385.5
Post-monsoon	Shift 1	767.9	354.1	475.7	623.0	382.1
	Shift 2	413.8	606.1	325.1	667.9	840.7
	Shift 3	545.1	702.4	775.8	374.7	777.9
Winter	Shift 1	1112.0	1730.5	743.3	495.5	893.1
	Shift 2	599.5	755.7	1246.9	483.9	1480.4
	Shift 3	1680.3	1154.2	694.2	223.3	517.1

respectively. The concentration of total carbonyls at Rash Behari varied from 354.1 to 1985.4 μg/m^3 (Table 12.9).

In the urban air of Kolkata, high values of aldehydes have been observed (Tables 12.2, 12.3, 12.4, 12.5, 12.6, 12.7, 12.8, and 12.9). This may be due to the

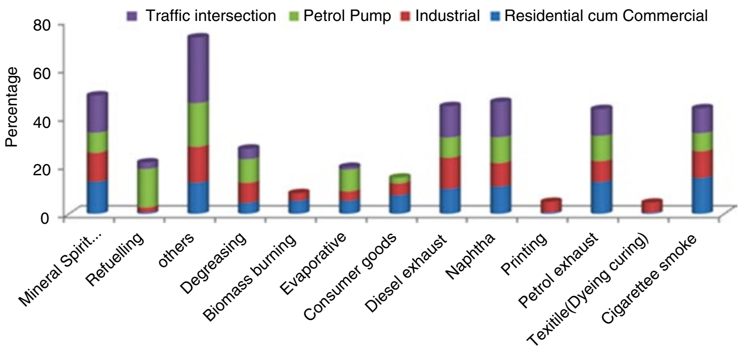


Fig. 12.2 Major sources of VOCs in ambient air

oxidation of VOCs. Source apportionment of VOCs using CMB 8 model shows that the major sources of VOCs in ambient air are petrol and diesel exhaust, combustion of naphtha and mineral spirit and cigarette smoke (Fig. 12.2).

Contributions of different sources at each category of location are shown in Fig. 12.3.

It is observed that the average level of NO_2 is quite low in all Kolkata air. The level is consistently lower than 80 μg/m^3 which is the permissible limit of NO_2 (24-h average) (National Ambient Air Quality Standards, CPCB 2009). Figures 12.4, 12.5, 12.6, and 12.7 depict the seasonal as well as diurnal distribution of NO_2 concentration in different categories of sites.

Percentile distribution of hourly concentration of ozone (Figs. 12.8, 12.9, 12.10, and 12.11) shows that from November to May, 95 percentile values crossed 100 μg/m^3 at residential areas. At industrial locations except Behala, 100 μg/m^3 was never exceeded. At Behala, this concentration exceeded 5 % times from July and December to March. At traffic intersections, only at Rash Behari, crossing the month of February, violation from the standard of 100 μg/m3 was observed 5 % times. At all petrol pumps, ozone concentrations exceeded 100 μg/m^3 5 % times in the month of July.

VOC/NO_2 ratios observed in Kolkata are primarily high, indicating NO_2-sensitive conditions. A high rate of VOC emissions (due to local activity like biomass burning, roadside cooking, etc.) increases the ratio of VOC to NO_2 and makes NO_2-sensitive conditions more likely.

Instantaneous photochemical ozone P(O_3) formation can be computed as the O_3 production rate is a function of NO_2 concentration. The chemical production rate of ozone is defined as

$$P(O_3) = \frac{d(Ox)}{dt} \tag{12.1}$$

where

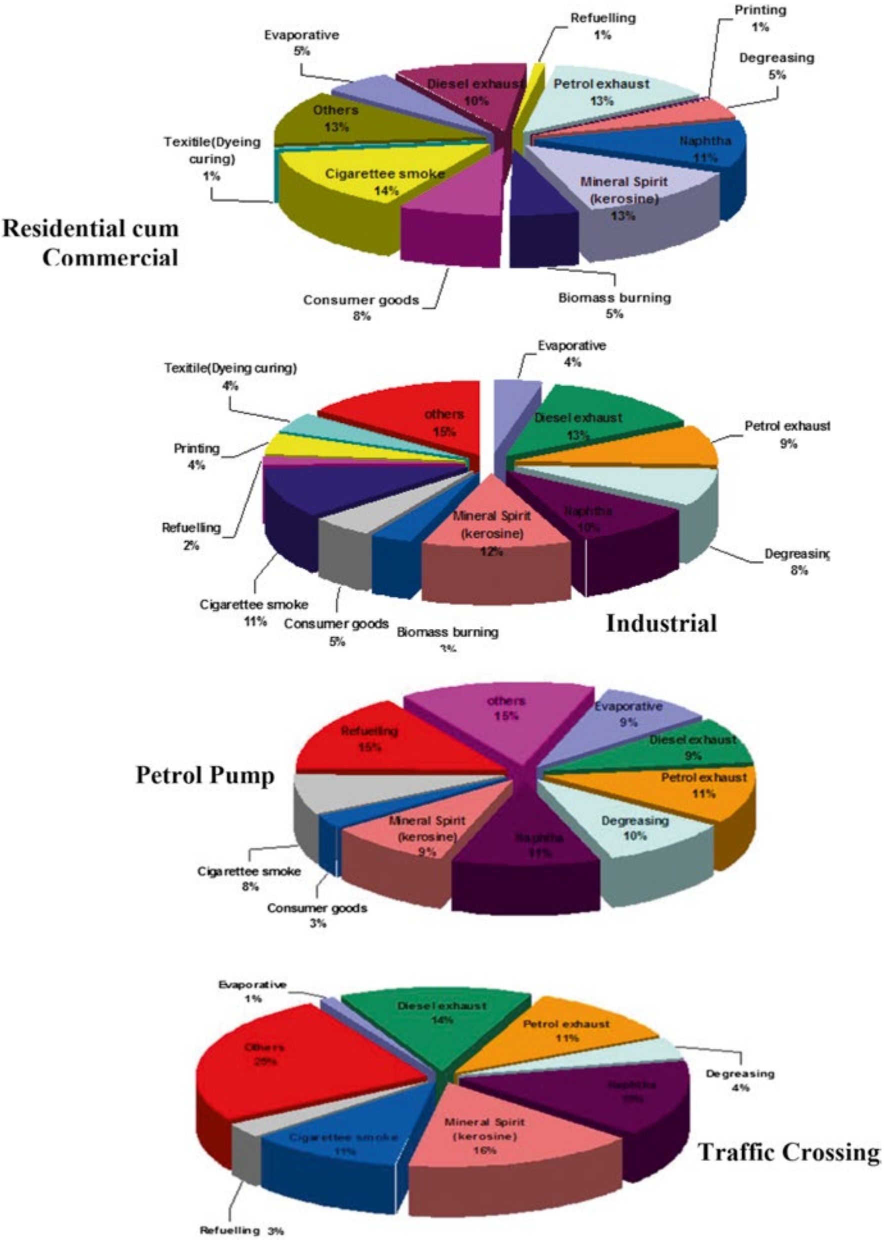


Fig. 12.3 Contribution of sources of VOCs at different categories of locations

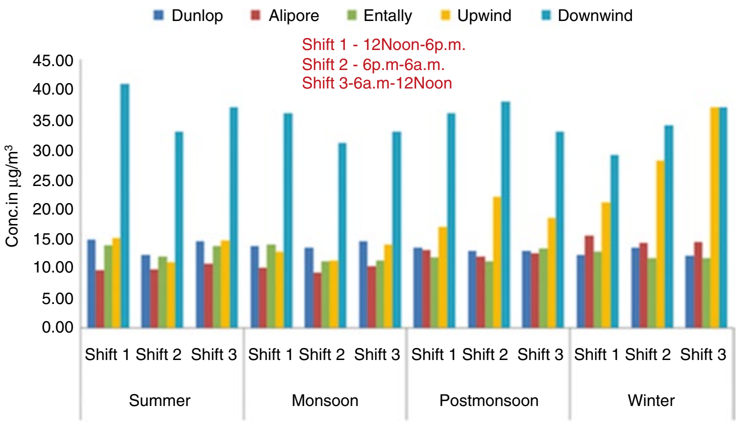


Fig. 12.4 Diurnal distribution of NO_2 in residential cum commercial location

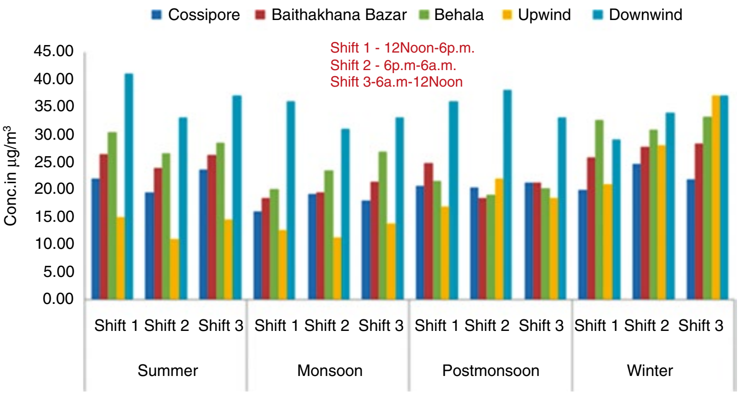


Fig. 12.5 Diurnal distribution of NO_2 in industrial location

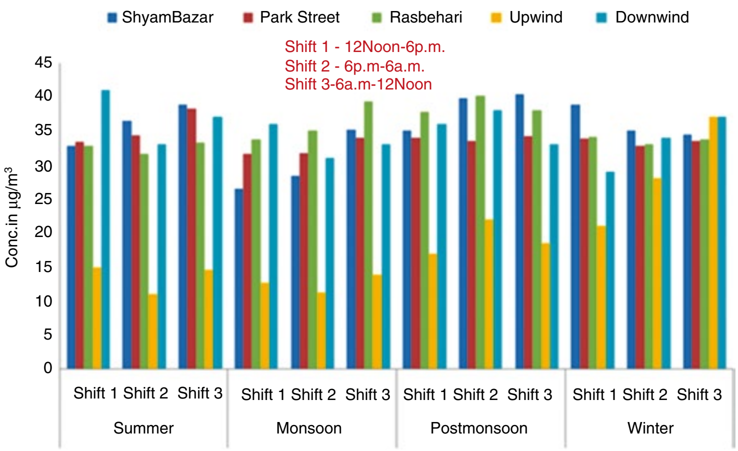


Fig. 12.6 Diurnal distribution of NO_2 in traffic intersection

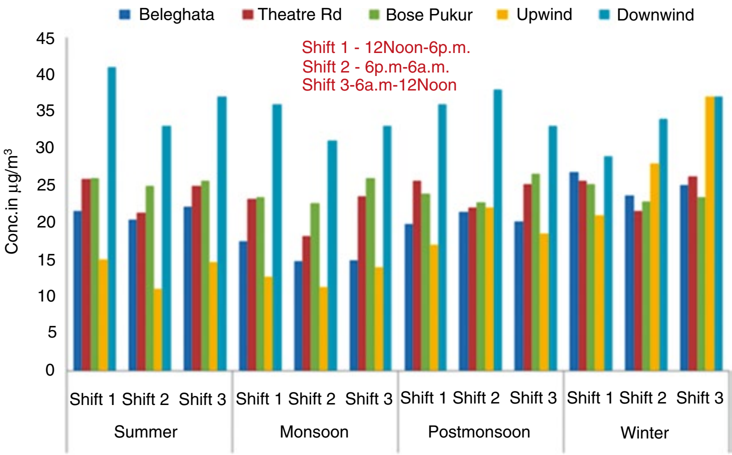


Fig. 12.7 Diurnal distribution of NO_2 in petrol pumps

$$Ox = O(1D) + O_3 + NO_2 \tag{12.2}$$

During daytime, NO_2 can be reasonably assumed to achieve a steady state so that $d(Ox)=d(O_3)/dt$. It is commonly believed that the O_3 production rate increases at low NO_2 until a maximum is reached and then decreases at high NO_2. Figure 12.12 shows a similar behaviour for urban air of Kolkata. Negative values of P (O_3) have been observed from 6:00 pm to 6:00 am during all seasons. This behaviour occurs because high NO_2 promotes removal of OH radicals by reaction with NO_2 and hence reduces photochemical O_3 formation. In addition to NO_2, P(O_3) is also dependent on VOC reactivity, sunlight and radical precursors.

The upper-limit kinetic and mechanistic reactivities are used to obtain an estimate of the incremental reactivity in the MIR scale. The incremental reactivities obtained by multiplying the kinetic and mechanistic reactivities derived is in units of moles of ozone formed per mole VOC emitted, but for regulatory applications, the appropriate units are grams of O_3 per gram VOC. This conversion is done by multiplying the ratio of the molecular weight of O_3 to the molecular weight of the VOC. Therefore,

$$\begin{matrix}\text{Upper Limit MIR} \\ (\text{gm } O_3 / \text{gm VOC})\end{matrix} = \begin{matrix}\text{Upper Limit} \\ \text{Kinetic Reactivity}\end{matrix} * \begin{matrix}\text{Upper Limit Mechanistic} \\ \text{Reactivity}(\text{mol } O_3 / \text{mol VOC})\end{matrix} * \frac{48(\text{gm } O_3 / \text{mol } O_3)}{\text{Mwt}^{voc}(\text{gm/mol})} \tag{12.3}$$

For regulatory or life cycle impact assessment applications where NO_2 impacts need to be evaluated using the same scale as VOC impacts, and where the MIR scale is used for evaluating VOC impacts, the NO_2 impacts used should be those derived for the NMIR scale. For the SAPRC-07 reactivity scale given by Carter (2007, 2010), the NMIR values of 25.37, 17.24 and 15.85 g O_3 per gram compound for NO, NO_2

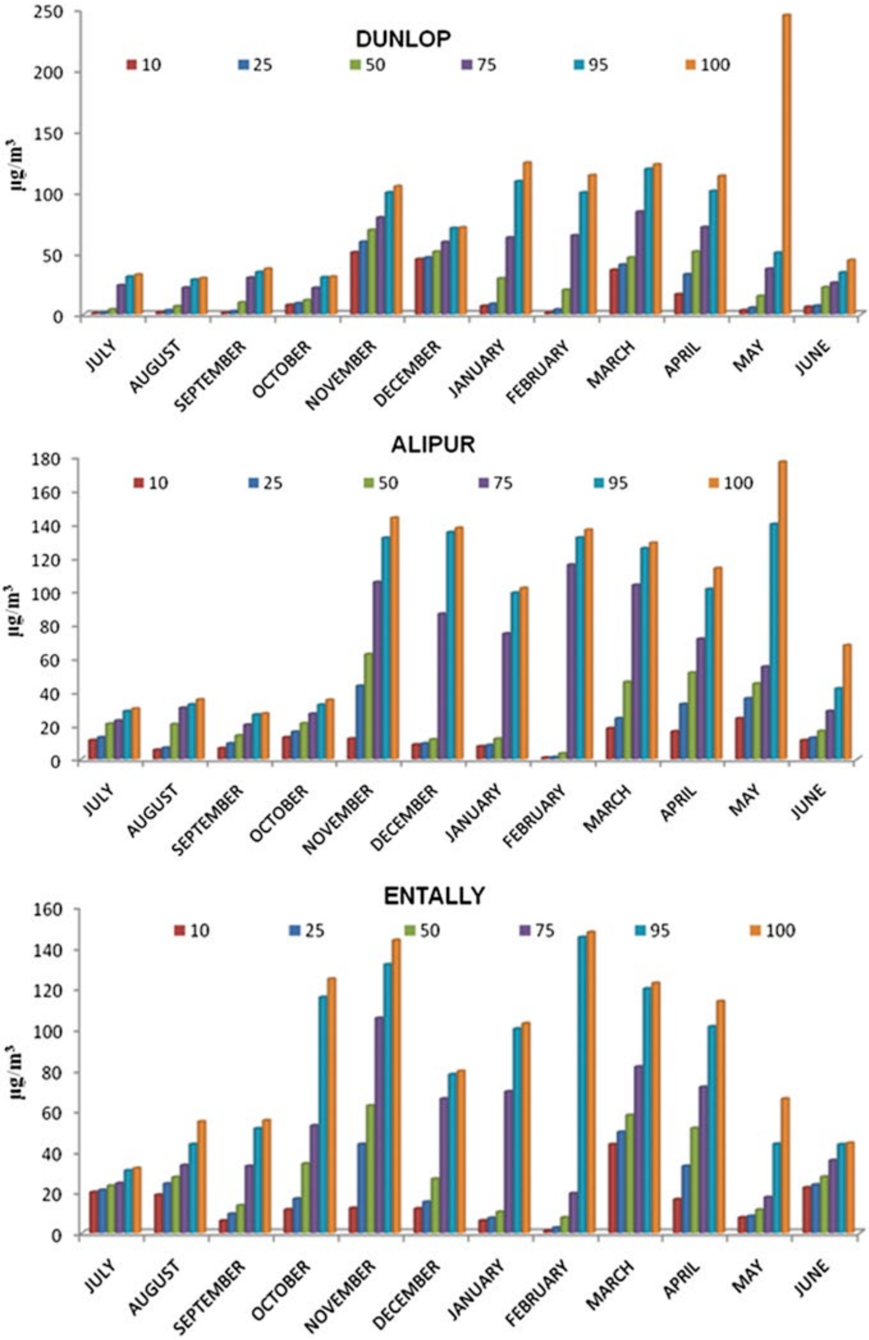


Fig. 12.8 Percentile distribution of hourly concentration of ozone (residential cum commercial locations)

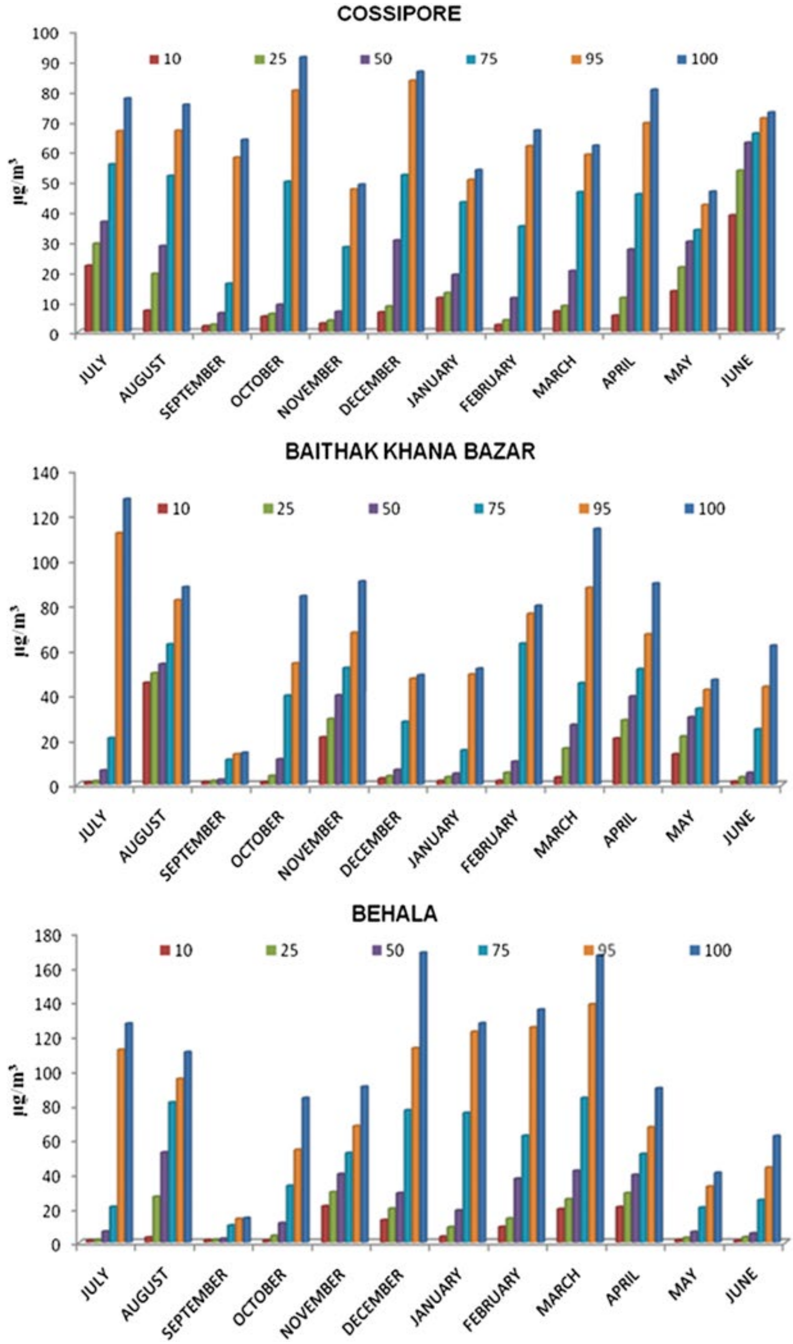


Fig. 12.9 Percentile distribution of hourly concentration of ozone (industrial locations)

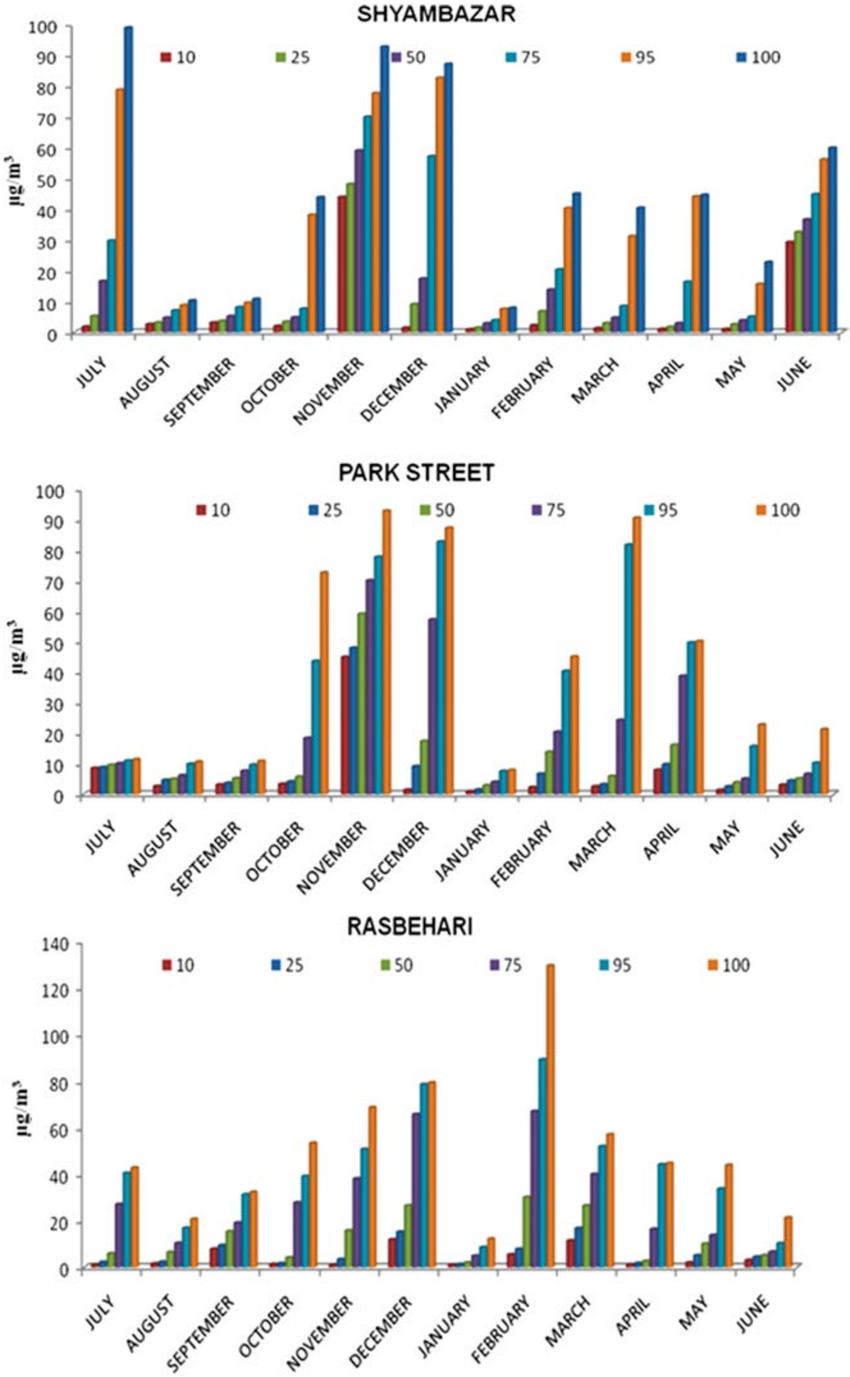


Fig. 12.10 Percentile distribution of hourly concentration of ozone (traffic crossings)

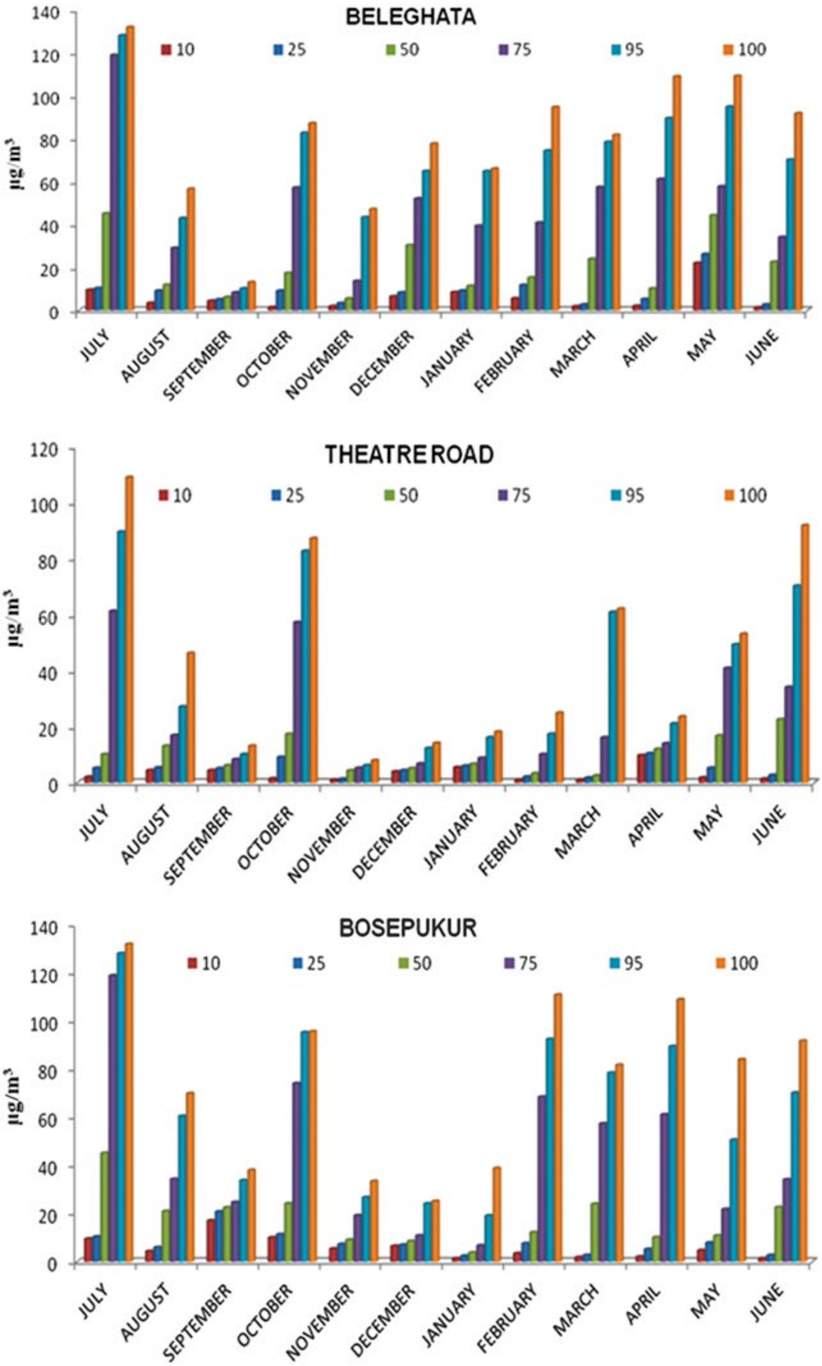


Fig. 12.11 Percentile distribution of hourly concentration of ozone (petrol pumps)

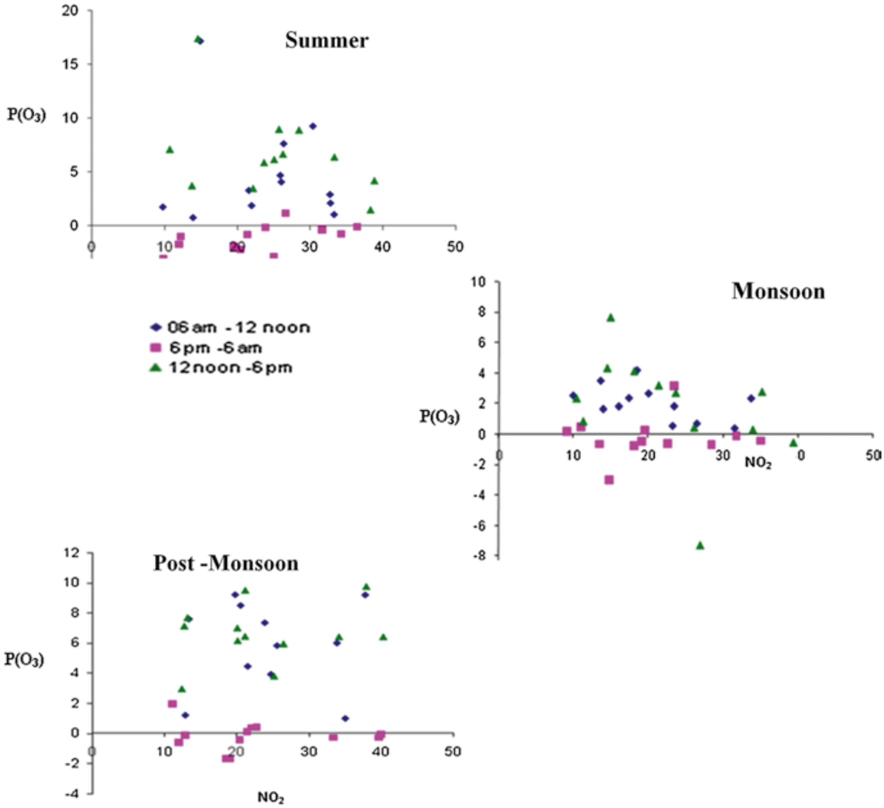


Fig. 12.12 Instantaneous ozone production in Kolkata with respect to NO_2 (seasonal variation)

and HONO, respectively, are to be added to the MIR values given for the VOCs. Table 12.10 shows the ozone formation by VOCs observed using MIR values given by SAPRC-07.

A strong correlation between ozone, NO_2 and total VOCs (i.e. carbonyl and non-carbonyl VOCs) is observed.

12.3.5 Probabilistic Collocation Method (PCM)

The probabilistic collocation method was used to predict ozone concentrations. The probabilistic collocation method used by Tatang et al. (1997) is one of the several mathematical techniques which can be used for parameterisation. Given a set of k input parameters xj used to drive a model, $\{x_1, x_2, \ldots, xk\}$, there are M output responses yj predicted by the model that are functions of the xj values:

Table 12.10 Instantaneous ozone formation by VOCs using MIR values

Compound	MIR	6:00 pm–6:00 am	12:00 noon–6:00 pm	6:00 am–12:00 noon
Toluene	5.2	5.51E-02	1.17E+03	5.55E-02
4-Isopropyltoluene	7	3.94E-02	6.92E+02	6.18E-02
1,3,5-Trimethylbenzene	13.9	3.35E-02	1.27E+02	4.32E-02
p-Xylene	5.69	1.09E-02	4.68E+01	1.06E-02
Ethylbenzene	2.93	9.38E-03	6.59E+01	8.98E-03
Styrene	1.95	5.28E-03	5.18E+01	1.05E-02
Naphthalene	3.24	3.67E-03	1.81E+01	3.23E-03
n-Propylbenzene	1.95	1.90E-03	2.86E+00	4.21E-03
Benzene	0.8	1.79E-03	3.18E+00	1.36E-03
Benzene, 1,3-dimethyl-	7	1.04E-03	3.08E-01	9.63E-04
Benzene, 1,2,4-trimethyl-	11.44	9.89E-04	2.46E-01	1.36E-03
Isopropylbenzene	2.43	5.59E-04	2.41E-01	6.33E-04
Benzene, propyl-	8	4.20E-04	2.60E-02	5.12E-04
Benzene, butyl-	8	3.21E-04	1.67E-02	4.06E-04
1-Propene, 1,3-dichloro-,	8	2.74E-04	3.23E+02	3.00E+00
Benzene, 1,2,3,4-tetramethyl	9.01	1.93E-04	5.05E-03	2.18E-04
Ethene, 1,1-dichloro-	1.69	4.24E-05	9.13E-04	3.30E-05
o-Xylene	7.44	2.01E-05	6.01E-05	3.50E-05
m-Xylene	9.52	1.35E-05	2.47E-05	2.07E-05
p-Isopropyltoluene	7	8.90E-06	1.36E-05	6.76E-06
Methylene chloride	0.04	5.30E-06	6.39E-04	4.27E-06
Ethane 1,1-dichloro	0.07	1.24E-06	2.74E-05	1.67E-06
Chloroform	0.02	7.28E-07	3.05E-05	5.85E-07
Ethane, 1,2-dibromo-	0.1	2.44E-07	1.38E-06	4.18E-07
Ethane, 1,1,1-trichloro-	0.005	3.62E-08	4.88E-07	5.40E-08

$$\{y_1, y_2, \ldots, y_M\} = f\left(\{x_1, x_2, \ldots, x_k\}\right) \tag{12.4}$$

where *yj* are the physical concentrations, mass fluxes and deposition fluxes of species that are approximated. Since there is a range of possible values which each input parameter can take, it is important to treat the input variables as being independent of each other with their statistics defined by their probability distribution function (PDF) over this range. All of the input variables are considered random; thus, the output variables also are considered random variables. This is explained in more detail in Cohen and Prinn (2009).

The smallest possible set of input variables capturing the effects of urban chemical and physical processing must be derived in order to form a reduced-form model which is as compact as possible. This set of inputs need to be flexible enough to be applicable to the many variations of the properties of urban areas. The variables need to span the differences in geography, location, time of the year, atmospheric temperature, cloudiness, amount and type of precipitation, vertical motion, time tendency of emissions, spatial tendency of emissions, the amount of each type of

Table 12.11 Descriptions of the input variable PDFs used

Input variable	Type of PDF#	Kolkata urban area
Day of the year (days)	Uniform	1
	(a,b)	365
Geographic latitude of urban area (°+90)	Beta	2.554
	(p,q,a,b)	2.131
		78.4
		125.4
Temporal weight	Uniform	0.00
	(a,b)	1.00
Spatial distance (Km)	Uniform	21.6
	(a,b)	93.2
Daily Average:	Beta	8.483
Surface temperature [° K]	(p,q,a,b)	2.810
		267.4
		309.4
Diurnal	Beta	1.741
Temperature [° K]	(p,q,a,b)	1.976
		5.318
		18.76
TVOC [ton/day]	Fixed (S)	0.2089
NOx [ton/day]	Fixed (S)	0.2511
Boundary values		
Ozone [ppb]	Lognormal	70.11
	(m,σ)	1.099
NOx [ppt]	Lognormal	19.22
	(m,σ)	1.595
TVOC [ppt]	Lognormal	472.98
	(m,σ)	2.534
Carbonyls [ppt]	Lognormal	502.65
	(m,σ)	3.015

See Eqs. 12.5, 12.6, 12.7, and 12.8 for PDF formulas and parameters

emitted species and the upwind concentrations of species of interest as a function of space and time.

These input variable PDFs are defined and described in Table 12.11 using the following formulas:

$$\text{Uniform}\left(a \le x \le b\right): \mathrm{f}\left(x\right) = 1/\left(b-a\right) \tag{12.5}$$

$$\text{Beta}\left(a \le x \le b; p,q > 0\right): \mathbf{f}\left(x\right) = \left[\left(x-a\right)p-1\left(b-x\right)q-1\right] / \left[\left(\int 01tp-1\left(1-t\right)q-\mathbf{1d}t\right)\left(b-a\right)p+q-1\right] \tag{12.6}$$

$$\text{Lognormal}\left(x, m, \sigma > 0\right): \mathbf{f}\left(x\right) = \exp\left(-\left(\ln\left(x/m\right)\right)2/\left(2\sigma 2\right)\right)/\left(x\sigma\sqrt{}\left(2\pi\right)\right) \quad (12.7)$$

$$\text{Fixed}: \mathrm{f}\left(x\right) = xS \quad (12.8)$$

where a, b, p, q, m, σ and S are the parameters, and x is the input value, which in the case of the fixed equation is the emissions of the appropriate parent species (either CO or BC). The first set of input variables in Table 12.11 are for the time, location, emission spatial distribution and temperatures as discussed later. The second set of input variables are fluxes for those species that are directly emitted in the urban area. The directly emitted species considered here are NOx (95 % emitted as NO and 5 % emitted as NO_2) and VOCs.

The other set of input variables in Table 12.11 are the mole fractions of trace species along the boundaries (the four sides and the top) of the urban area that impact the chemical and physical processing inside the urban area. The trace species considered in this analysis are NOx, O_3, TVOCs (represented by toluene, xylene and chloroform) and carbonyls. These concentration data were fitted by lognormal probability distribution functions, as given in Figs. 12.13, 12.14, 12.15, and 12.16.

The first two variables are the day of the year and the latitude of the urban region. These are both needed for computing the ultraviolet radiative flux. A uniform variable has been assigned, from 1 to 365, for the day of the year. A beta fit of the distribution of latitudes of urban area has been assumed, with an assumption that the whole urban area is of equal importance.

The daily average temperature and the daily diurnal temperature, at the surface of the urban area, are the other inputs. The atmospheric temperature in the urban area and its range are important variables for determining the rates of many chemical reactions, Henry's law partitioning, gas/aerosol phase partitioning, the state of water in the urban atmosphere and the state and amount of precipitation. For the purposes of determining their global distribution, historical temperature data (Jones et al. 1999) has been weighted by the beta PDF of latitude for the urban area and the

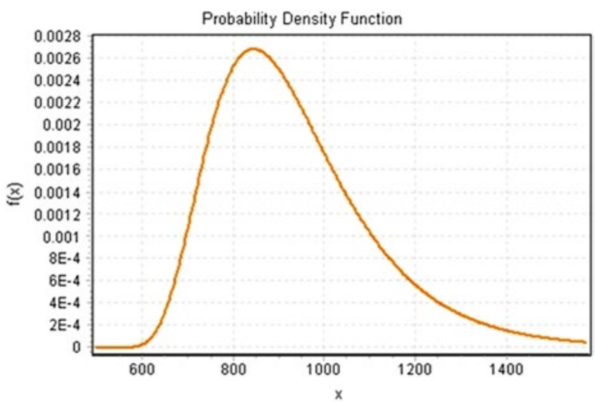


Fig. 12.13 Lognormal probability distribution function of carbonyls

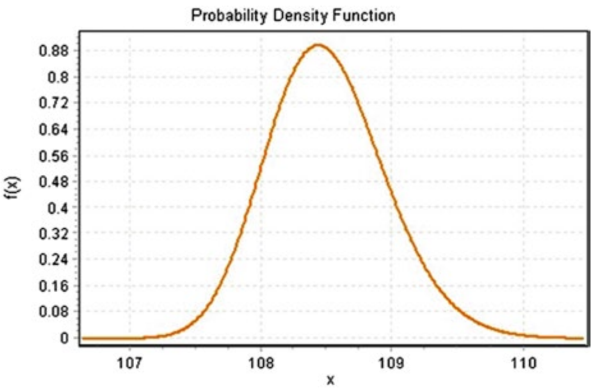


Fig. 12.14 Lognormal probability distribution function of NOx

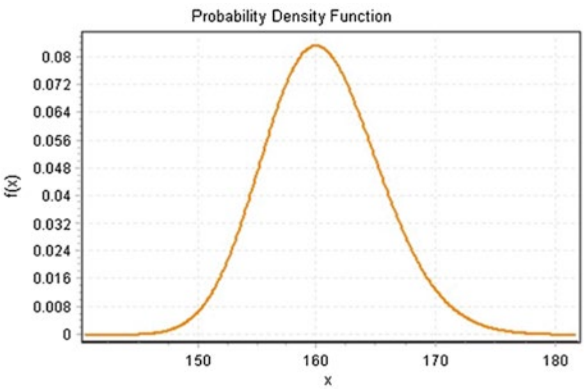


Fig. 12.15 Lognormal probability distribution function of ozone

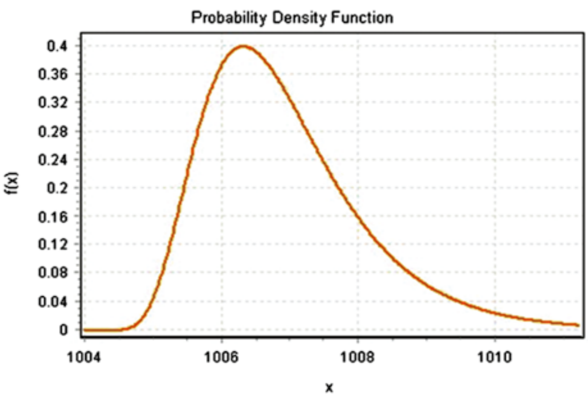


Fig. 12.16 Lognormal probability distribution function of total non-carbonyl VOC

resulting data fitted by a beta function. The average 16 temperatures of each vertical layer above the surface is computed assuming a linear decline with height with standard linear lapse rate of 6.5 K/km. The spatial and temporal deviations from these layer averages in the temperature of each grid box of the urban domain are taken from the meteorology chosen for that particular urban region.

The last physical input is rainfall (and the associated cloudiness), which impacts the radiative fluxes, the uptake of soluble gases and the removal rate of aerosols. After extensive testing, it has been found that treating these inputs as separate variables using the PCM approach does not yield reasonable results, due to the extremely non-linear impact these variables have on the system. Therefore, separate metamodels were formed for each of the four meteorological conditions. It is commonly found that emissions in urban areas have a time profile which is doubly peaked, with the peaks occurring around the times of the morning and evening rush hours.

The first variable thus represents the temporal distribution of emissions, which mimics transportation and habitation patterns of the people.

To account for this, an input variable (wt) is defined that is uniformly distributed from 0 to 1 and is the weight given to this double-peaked temporal emissions spectrum when it is linearly added to a time-invariant emissions profile. Therefore, for any given value of wt, the weights assigned to the double-peaked distribution is wt and the weight assigned to the time-invariant emissions distribution is 1-wt (Yang et al. 2005). A second input variable relates to the spatial distribution of emissions in the urban region. Such a distribution must consider that urban areas vary greatly in terms of their density of people, activity and thus emissions. In general, different emitted species come from different sources, which themselves may be distributed independently from one another in many cases. However, since most emissions are related to the population in the urban centres, the emissions of both VOC and NOx are considered to be spatially correlated. These spatial distributions are fitted by a two-dimensional Gaussian function whose standard diameter has a uniform distribution.

Another input is required to simulate whether VOC emissions consist of a larger fraction of light hydrocarbons.

To address the issue of the impacts of the circulation, water content and temperature on the processing in urban areas, three different realistic sets of meteorology have been used to drive the urban modeling system. The widely different cases are considered to represent different seasons and to numerically analyse the impact of adopting different types of realistic meteorology.

12.3.6 Concentrations, Mass Fluxes and Deposition

The results for the urban concentrations for ozone, formaldehyde, acetaldehyde, toluene and xylene species are given in Figs. 12.17, 12.18, 12.19, 12.20, and 12.21.

The regions of higher mole fractions must have a larger net chemical production (production minus loss) of the species. Conversely, regions with lower mole

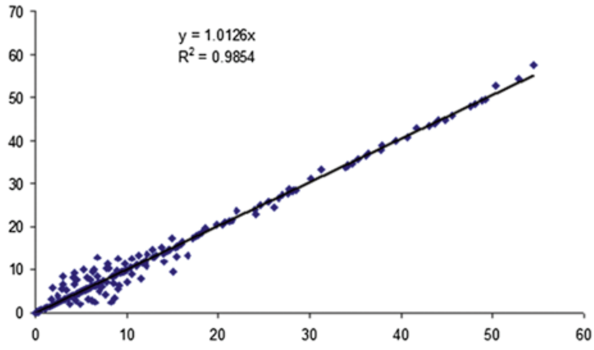


Fig. 12.17 Observed and predicted concentration of ozone

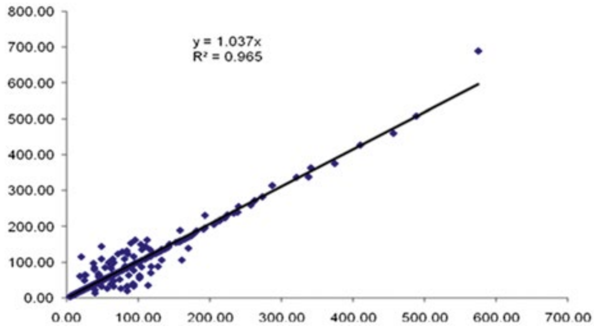
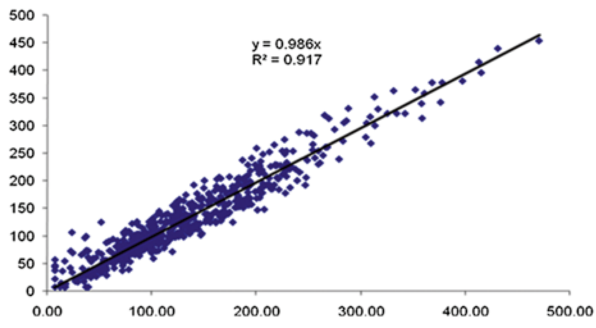


Fig. 12.18 Observed and predicted concentration of formaldehyde

Fig. 12.19 Observed and predicted concentration of acetaldehyde. X-axis, observed concentration, y-axis predicted concentration



fractions must have a more smaller or negative net chemical production of the species. Also, if the mole fraction remains constant across different regions, then this means that there is negligible net chemical production.

When looking at the metamodel results for the mass fluxes, emissions, chemical production or loss and the deposition, it is straightforward to determine whether the urban area is a net importer or exporter of the species of interest. For a species to have a mass flux which is not equal to its emissions, there must be a net amount of

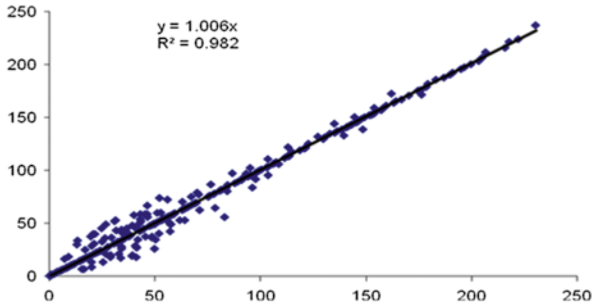


Fig. 12.20 Observed and predicted concentration of toluene

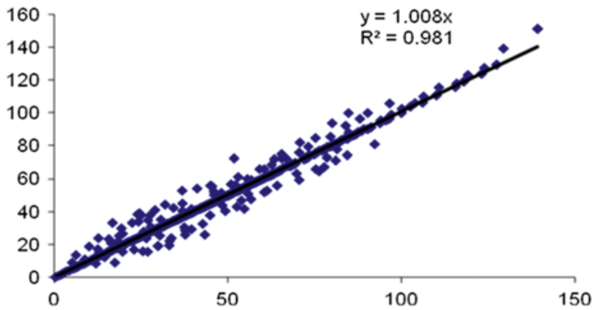


Fig. 12.21 Observed and predicted concentration of xylene. X-axis observed concentration, y-axis predicted concentration

chemical processing, deposition or convergence or divergence in the continuity equation. A convenient parameter is the ratio of the export flux to the emissions:

$$\text{Flux} / \text{Emiss} = (\text{Emiss} + \text{Chem} - \text{Dep}) / \text{Emiss} = 1 + \text{Chem} / \text{Emiss} - \text{Dep} / \text{Emiss} \quad (12.9)$$

Here the Flux is the net mass flux [g/day] through the boundaries of the urban region, Emiss is the emissions [g/day] into the urban area, Chem is the net chemical production [g/day] within the urban region and Dep is the deposition [g/day] to the surface of the urban region.

Using this, if the mass flux is positive and larger than the emissions, then the in situ chemical net production must be larger than the in situ depositional losses. Conversely, if a species has a mass flux which is positive but smaller than its emissions, its losses due to deposition must be greater than its net chemical production. Furthermore, for a species to have a mass flux which is negative (a net flux into the region), the in situ net chemical loss must be so large as to consume not only all of the emissions but also some of the species mass transported through the boundaries into the urban area.

If *Xi* is the value computed by the metamodel, *Xip* is the value computed by the CAMx model and n is the number of points analysed, we have

$$\text{Normalized RMS} = \surd\left(\Sigma i = 1, n\left(X_{ip} - X_i\right)2/n\right)/\surd\left(\Sigma j = 1, nX_i^2/n\right) \tag{12.10}$$

The RMS error gives a measure of the absolute magnitude of the error.

Normalised fractional RMS errors for species concentrations using CAMx model

Species	Summer	Monsoon	Winter
Ozone	1.38E-01	2.68E-01	1.46E-01
Formaldehyde	2.98E-01	3.75E-01	3.01E-01
Acetaldehyde	1.36E-01	3.69E-01	3.76E-01
Toluene	7.94E-01	0.89E-01	8.15E-01
Xylene	3.57E-01	9.67E-01	4.15E-01

12.4 Conclusions

VOCs in the urban airshed of Kolkata are contributed mainly due to fuel burning. It is observed that benzene levels are below the recent standard prescribed by CPCB. Vehicle-related sources typically contribute the largest to ambient VOCs. Naphtha and mineral oil combustion as major sources indicate rampant adulteration of fuel. High levels of chloroform may be due to the liberal use of bleaching powder in fish markets. Odabasi (2008) has shown that concentrations of chloroform (8–52 times) and carbon tetrachloride (1–1,170 times) significantly increase above baseline quantities in the household with the use of bleach-containing products.

Observed high levels of acrolein, formaldehyde and acetone may be due to cigarette smoke. This fact corroborates with the fact that the percentage of the smoking population is highest in Kolkata in India. High levels of observed formaldehyde and other carbonyls confirm cigarette smoke as a source besides the atmospheric chemistry.

Kolkata urban airshed can be considered to be NOx sensitive based on the VOC/NOx ratio.

	Percentage of population smoking (age 15–49)		
Location	Men	Women	Total
India	33.3	1.6	34.9
Kolkata	50.0	0.1	50.1
Chennai	30.5	0.1	30.6
Mumbai	22.1	0.1	22.2
Hyderabad	21.9	0.1	22.0

Source: National Family Health Survey (NFHS-3), 2005–2006, by the International Institute of Population Sciences, Deonar, Mumbai

It is currently established that ozone is a secondary pollutant formed by reactions of NOx and VOC, known as ozone precursors. So it is widely accepted that control strategies targeting ozone attainment must necessarily be based upon the control of its precursors. As the science of atmospheric photochemistry evolved, it became clear that complex, non-linear, feedback control processes relate NOx and VOC precursor mixing ratios to ozone mixing ratios. This fact led regulators to adopt mathematical models that include the best representation of the non-linear chemistry as the basis of needed control computations.

The amount of ozone attributable to each reaction species is estimated using MIR scales developed by Carter and SAPRC-07. Control strategies derived from the isopleths generated under the constraint of constant VOC/NOx ratio, for an upwind location, often do not reflect the conditions in downwind areas, where the VOC/NOx ratio is different. Mathematical model provides useful information and may be used to explain the main aspects of air pollution, but it requires detailed meteorological and kinetics of tropospheric chemical reaction data as inputs.

Note: Figures 12.2, 12.3, 12.4, 12.5, 12.6, 12.7, 12.8, 12.9, 12.10, 12.11, 12.12, 12.13, 12.14, 12.15, 12.16, 12.17, 12.18, 12.19, 12.20, and 12.21 have been developed by the authors from data generated at the institute.

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Chapter 13
Green Infrastructure: Issues and Recommendations

Achyutha Rao Aleti and Krishna Chaithanya Talacheeru

Abstract The provision of urban services, such as potable water supply and safe sewage disposal, is often energy intensive and contributes to overall carbon emissions. Though the prime objective is to improve public health and environmental quality, poorly conceptualized and implemented projects often require, among others, significant amounts of energy, thus negatively affecting the environment. Besides, the high energy-intensive systems become unsustainable and fail to provide the intended benefits. Pumping installations consume large amounts of energy, often determining the overall cost of service provision. Wastage of water in the system further adds to the energy usage and thus carbon emissions. A high proportion of non-revenue water is common in almost all towns across India and other developing countries.

The term "green infrastructure" is thus coined signifying the environmental friendliness. Given the large-scale development the urban sector in India is witnessing, enhancing environmental sustainability is essential. One of the main criteria that determine environmental sustainability is carbon emissions. Going beyond the routine techno-economic studies and integrating green concerns such as potential carbon emissions are essential. This chapter examines energy consumption vis-à-vis carbon emissions from urban water and sewerage infrastructure facilities in three case study towns with diverse characters.

13.1 Introduction

Infrastructure is generally defined as basic physical and organizational structures and facilities needed for the operation of community or an enterprise. This chapter focuses on physical infrastructure, such as water supply, sewerage, and storm water drainage, which supports the people in living and performing their activities; is important to human, social, and economic development; and plays a vital role in poverty reduction. Infrastructure also plays a vital role in improving the

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environment, and in many cases, it is also contributing to the degradation of environment by high resource consumption, generating problematic pollutants, and encroaching into ecologically sensitive areas.

The word “green” is thus prefaced to infrastructure denoting whether or not particular infrastructure facility is comparatively environmental friendly. “Green infrastructure” is an “approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. It incorporates both the natural environment and engineered systems to provide clean water, conserve ecosystem values and functions, and provide a wide array of benefits to people and wildlife. Reducing greenhouse gas emissions is one of the key challenges of our generation” (Environmental Protection Agency, USA).

In India, urban areas are home to 31.2 % of total 1.21 billion population (Census 2011); this figure is likely to go up to 50 % by 2030 (World Population Prospects 2008). The urban sector contribution to India’s economic growth is enormous; urban sector contribution to the gross domestic product (GDP) has increased from 29 % in 1950–1951 to 47 % in 1980–1981 and is currently pegged at 62–63 %. The 11th Five-Year Plan (11th FYP) acknowledges urbanization as a key indicator of economic development and should be seen as a positive factor for overall development. The 11th FYP Vision for Urban Infrastructure, Housing, Basic Services, and Poverty Alleviation indicates that “Indian cities to be the locus and engine of economic growth over the next two decades and realization of an ambitious goal of 9–10 % growth in GDP depends fundamentally on making Indian cities much more liveable, inclusive, bankable, and competitive” (Planning Commission, Govt. of India).

Urban infrastructure situation in many urban centers in India is abysmal. Increasing population has put tremendous pressure on already overloaded and inadequate infrastructure facilities. The Government of India embarked on urban infrastructure development, according to high priority, and launched various programs. Many other urban infrastructure programs/projects are in implementation in various states with the assistance of multilateral/bilateral agencies like Asian Development Bank, World Bank, and Japan International Cooperation Agency (JICA). Water supply, wastewater, and drainage infrastructure accorded priority in most of the projects.

It is important to understand green infrastructure concept in the urban sector, which is witnessing large-scale development. One of the main issues with urban basic infrastructure that determines environmental friendliness is the energy usage. It is therefore important to understand the role that energy consumption plays in determining the carbon footprint of infrastructure and to integrate the same in project planning, design, construction, and operation. Consideration of carbon footprint in early stages of project preparation shall go a long way in greening the urban infrastructure in India.

Providing households with safe drinking water and wastewater disposal is an energy-intensive process. Electricity costs are usually between 5 and 30 % of the total operating costs among water and wastewater utilities (WWUs). The share is

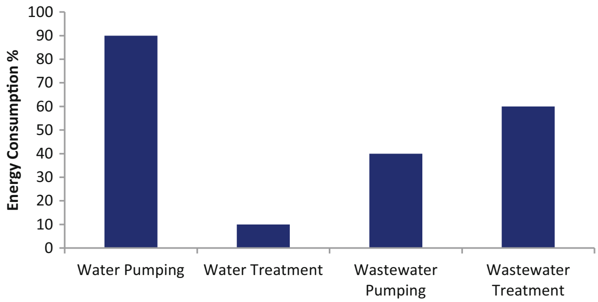

Fig. 13.1 Energy-intensive activities in water supply and sewerage

usually higher in developing countries and can go up to 40 % or more in some countries. Such energy costs often contribute to high and unsustainable operating costs that directly affect the financial health of water and wastewater utilities. Improving energy efficiency (EE) is at the core of measures to reduce operational cost at WWUs. Since energy represents the largest controllable operational expenditure of most WWUs, and many energy efficiency measures have a payback period of less than 5 years, investing in energy efficiency supports quicker and greater expansion of clean water access for the poor by making the system cheaper to operate (Energy Sector Management Assistance Program, World Bank). In this chapter, energy consumption by environmental infrastructure like wastewater treatment and water supply (based on different types of sources) and their contribution to CO_2 emissions are discussed and appropriate recommendations are mentioned.

13.1.1 Energy Consumption in Environmental Infrastructure

Generally, energy consumption in water supply system and sewerage mainly involves water pumping including extraction of raw water from source to treatment plants and pumping clear water to service reservoirs, and wastewater pumping includes sewage pumping from pumping stations to sewage treatment plants. Poorly planned and designed systems are high energy intensive (Vigneswaran and Sundaravadivel 2004). Energy-intensive activities in water supply and sewerage are shown in Fig. 13.1.

13.1.2 Carbon Emissions from Environmental Infrastructure

Carbon emissions from water industry are largely associated with grid electricity use. Key processes consuming electricity are (1) treating water to a potable standard, (2) pumping water around the supply network, (3) pumping wastewater around the sewer network, and (4) treating wastewater to discharge standards.

Carbon emissions associated in supplying drinking water to the public have been assessed based on the type of source like surface water, groundwater, and combination of both surface and groundwater. Pratapgarh, Jalore, and Sri Ganganagar towns in Rajasthan were chosen for the study purpose.

13.1.3 Description of Project Towns

13.1.3.1 Pratapgarh

Pratapgarh is the Tehsil headquarter of Pratapgarh district. The population of the town is 42,079 as per Census 2011. Town is situated at the border of Madhya Pradesh and famous for its opium production. The area of the town is almost undulating and hilly. The water table of the town is about 10–20 m. The climate of the area is dry. The minimum and maximum temperatures of the town are 2–42 °C. The average rainfall of the town is about 900 mm. The first water supply scheme was executed for Pratapgarh town in 1955 with source as three Nos open wells. Due to the reduction in the production from open wells/groundwater sources and increased demand, reorganization scheme was proposed in the year 1994. Surface source, Jakham Dam, was taken as the source of water to meet out the demand of town Pratapgarh. The capacity of Jakham Dam is 5,015 MCFT. At present surface, water is available in sufficient quantity for domestic purposes throughout the year. The quality of surface water in Jakham Dam requires prior treatment for human consumption. Currently, the Public Health Engineering Department is extracting water from Jakham Dam. 2.5 MLD of water is being abstracted from Jakham Dam. A filter plant of 3.6 MLD capacity is under operation to treat the raw water. Raw water is being pumped to clariflocculator along with pre-chlorination (2 ppm) and then to filter beds.

Pratapgarh town has 78 % of storage capacity over daily supply of water. As per the CPHEEO norms, 33 % of storage capacity against total supply of water should require. Pratapgarh has a total storage capacity of 1.94 ML comprising four elevated storage reservoirs (ESR), one ground level storage reservoir (GLSR) and one clear water reservoir (CWR). However, in some zones, the PHED directly pumps into the distribution system from CWR.

At present, the PHED divided ULB area into eight water supply zones. The total length of existing water distribution network in Pratapgarh town is around 36 km, which includes transmission mains, trunk mains, feeder mains, and distribution mains. After the second scheme, PHED extended distribution lines as per the requirement. The existing distribution system covers 72 % of road length. Sixty-five percent of pipe material used in the distribution network is of AC pipe material. Due to this, leakages are very common in the system resulting in energy wastage.

The existing water supply service connections covered 61 % of total property tax assessments in the town (Year 2011). All water connections are metered including commercial and industrial connections. However, 95 % of meters are nonfunctional due to poor maintenance. In total, there are 8,277 domestic and 561 non-domestic water connections and 174 public standposts (Year 2011).

There are 6 pumping stations in the town supplying water to the town. A total of 19 pump sets have been installed during different years. Out of 19 pump sets, three are 25 years old, 13 are 15 years old, and three are 10 years old. Existing pumps are in poor condition and leakages in valves result in high energy consumption. Most of the pumps need immediate replacement. Pumping stations and pumping machinery are installed and function with sufficient capacity to cater to the present-day demand. However, there is no proper account of their efficiency, and there are no measures seem taken to ensure that they are operated at an optimum level. Pumps/motors reporting efficiencies lesser than 50 % shall be replaced in phased manner.

13.1.3.2 Jalore

Jalore town is the district headquarters and has a population of 54,081 persons as per Census 2011. Jalore is situated in the southwestern part of Rajasthan State. The district shares boundary with Barmer district in the northwest, Pali district in the northeast, and Sirohi district in the southwest and shares border with Gujarat in the south. The temperature in Jalore would reach as high as 48 °C in the summer and as low as 2 °C during winter. In summer months, humidity remains relatively very low. The average annual rainfall of the Jalore is about 389 mm.

Groundwater is the major available source for catering to the drinking water needs to Jalore town. Hence, the municipality is depending on groundwater source.[1] At present, groundwater is available in sufficient quantity for domestic purposes at depth around 50–230 m throughout the year.

Currently, the PHED is extracting water from 25 tube wells and 2 open wells. 5.1 MLD of water is abstracted from these tube wells and open wells. The average yield of each tube well is 0.2 ML per day and each tube well is operated for 20 h in a day. The tube wells are fitted with submersible pumps with a head of 75 m.

There are 6 pumping stations in the town to supply water to the town. A total of 22 pump sets have been installed during different years. Out of 22 pump sets, three are 30 years old, five pumps are 22 years old, and the remaining are 10 years old. Existing pumps are in poor condition and leakages in valves. Due to this, high energy is being consumed. Most of the pumps need immediate replacement. Pumping stations and pumping machinery are installed and functioning with sufficient capacity to cater to the present-day demand. However, there is no proper account of their efficiency, and there are no measures seem taken to ensure that they

[1] Central Ground Water Board has released a report on Ground Water Scenario in Jalore District. (Ground Water Brochure of Jalore district, Rajasthan, June 2008). According to the CGWB, out of 07 blocks, the southern part with 3 blocks have very low groundwater sources (Raniwara, Bhinmal, and Soyala). The Hardness of groundwater and Chloride content dropped down in the central part of Jalore district, but the alkalinity has gone up in the blocks of Sarnau, Bhinmal, Dedwa, and Jalore Blocks.

are operated at an optimum level. Pumps/motors reporting efficiencies lesser than 50 % need replacement in a phased manner. Some of the existing pump sets are having efficiency around 35–40 %. Suction and delivery valves are also throttled at some locations.

Jalore is having 126 % of storage capacity over daily supply of water. As per the CPHEEO norms, 33 % of storage capacity against total supply of water is enough. Jalore has a total storage capacity of 6.44 ML comprising 9 elevated storage reservoirs (ESR) and 7 clear water reservoirs (CWR). At present, the PHED has divided the ULB area into 24 water supply zones. The total length of existing water distribution network in Jalore town is around 363 km, which includes transmission mains, trunk mains, feeder mains, and distribution mains. The existing distribution system covers 90 % of the town area. Eighty percent of pipe used in the distribution network is of AC pipe material. Due to this, leakages are very common in the system resulting in energy wastage.

PHED delivers water to the civic through service connections and public standposts. Thirty-nine percent of total assessed properties in the town have been provided with water supply connections. All water connections are metered including commercial and industrial connections. However, 66.7 % of meters are nonfunctional due to poor maintenance. In total, there are 3,345 domestic and 751 nondomestic water connections and 20 public standposts (2011).

13.1.3.3 Sri Ganganagar

Sri Ganganagar, the district headquarters, is situated toward the northernmost part of the State. The town is situated at the point where the Satluj Waters enter the Rajasthan State. It is the largest urban center in the canal irrigated area of northern west of Rajasthan. Sri Ganganagar Municipal Council has a population of 2.38 lakhs (Census 2011) which accounts for 44 % of the total urban population in the district. The climate of Sri Ganganagar is generally hot and arid with extreme conditions. In summers, the temperature reaches up to 50 °C, while in winters, the temperature dips just around 0 °C. The average maximum temperature in summer is 41.2 °C, while in winter, it is 6 °C. Sri Ganganagar receives an average annual rainfall of about 300 mm. The maximum rainfall is received during the months of June to September.

The first water supply scheme was executed for Sri Ganganagar Town in 1954 and commissioned in the year 1959 taking Gang Canal as the source of water. Both surface water and groundwater source are available for serving drinking water needs to Sri Ganganagar town. Currently, the PHED is extracting water from two surface water sources and 7 tube wells. 32 MLD of water from surface sources and around 6 MLD water from 7 tube wells are extracted. The average yield of each tube well is 0.85 ML per day, and each tube well is operated for an average of 18 h per day. The tube wells are fitted with submersible pump.

Two water treatment plants having a total capacity of 42 MLD are under operation to treat the raw water. Raw water is pumped to rapid gravity and slow sand filters after pre-chlorination (2 ppm). Post-chlorination (3 ppm) is carried out before transmitting to clear water reservoir and then pumped to Over Head Service Reservoir (OHSRs). There are 13 filter beds and recycling tank in WTP.

Sri Ganganagar has 53 % of storage capacity over daily supply of water. As per the CPHEEO norms, there should be 33 % of storage capacity against total supply. Ganganagar has 18 elevated storage reservoirs (ESR) and 13 clear water reservoirs (CWR).

At present, the PHED has divided ULB area into 18 water supply zones. The total length of the existing water distribution network in Sri Ganganagar town is around 709 km, which includes transmission mains, rising mains, feeder mains, and distribution mains. After the implementation of the second scheme, PHED extended distribution lines as per the requirement. The existing distribution system covers 80 % of road length. The material used for pipe diameter below 150 mm was PVC, AC, and CI &GI, and more than 150 mm AC and PVC material. Eighty-five percent of pipe used in the distribution network is of AC pipe material. Due to this, leakages are very common in the system resulting in energy wastage.

There are 15 pumping stations in the town to supply water. Existing pumps are in poor condition and leakages in valves. Due to this, high energy is being consumed. Most of the pumps need immediate replacement. Pumping stations and pumping machinery are installed and function with sufficient capacity to cater to the present-day demand. However, there is no proper account of their efficiency and there are no measures seem taken to ensure that they are operated at an optimum level. Pumps/motors reporting efficiencies lesser than 50 % need replacement in phased manner. Static head is higher at some locations. This also results in high energy consumption.

All water connections are metered including commercial and industrial connections. In total, there are 30,140 domestic and 5,266 non-domestic water connections (Year 2011). The PHED is serving potable water to 80 % of Ganganagar population.

13.2 Reasons for High Energy Consumption in the Towns

The following are the reasons for high energy consumption in the towns:

1. Transmission and distribution losses: Around 65–85 % of the water supply network in the three towns is of AC pipe material. Due to this, leakages are common in all the towns which results in low consumer end supply and energy losses.
2. High storage capacity: As per CPHEEO norms, 33 % storage capacity is sufficient enough against the total production. But in the three towns, storage capacity is more than 53 %. Highest storage capacity is in Jalore which is 126 % and followed by Pratapgarh of 78 %. Due to lack of comprehensive planning, high storage capacity has been provided in the town. High storage capacity results in intensive energy consumption to pump the clear water from treatment plant to

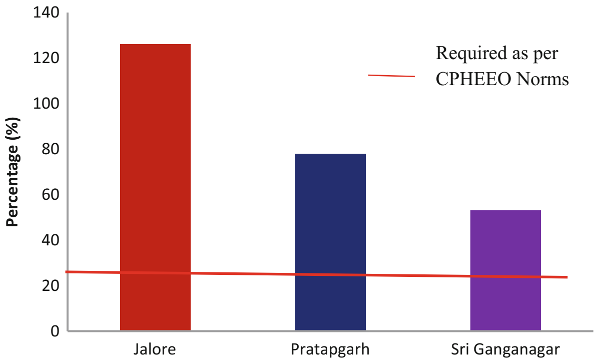

Fig. 13.2 Existing storage capacity in the towns

service reservoirs located at different parts of the town. Figure 13.2 shows the existing storage capacity in three towns.

3. Poor condition of pump sets: Most of the pump sets in the clear water pump house are of more than 20 years old. Leakages from the valves are common. Due to poor condition of pump sets, high energy is consumed to pump the water.
4. Less utilization of treatment capacity: Treatment plants in the towns are running with undercapacity of treatment. Only 75 % of treatment capacity is being utilized. This results in high energy consumption per MLD of treatment.
5. Lack of bulk flow meters: There are no bulk flow meters in the water supply system of the town. Due to this, there is no measurement of quantity being produced and being supplied at consumer end. This practice results in high non-revenue water which results in high operation and maintenance cost.

13.3 Analysis of CO_2 Emissions

The population of Pratapgarh, Jalore, and Sri Ganganagar towns are of different sizes and production of water varies from town to town. To do the comparative study of CO_2 emissions per capita in the towns, energy consumption has been calculated with respect to per capita in all the three towns, and for uniformity purpose, population size of 50,000 and rate of supply as 100 lpcd have been considered for different types of sources. Per capita energy consumption is calculated based on the energy consumption in the case study year. To estimate the CO_2 emissions, grid emission factor of northern grid 0.90 tCO_2e/Mwh has been considered. Details of town wise energy consumption with respect to source are given in Table 13.1

As per the analysis, energy consumption for a town with a population of 50,000 and rate of supply of 100 lpcd with source of water as surface water is around 141 kWh/year/capita, whereas energy consumption with source of water as groundwater is 34 kWh/year/capita and with both surface- and groundwater is 96 kWh/year/capita.

Table 13.1 Details of town wise energy consumption depending on type of source

S. no	Name of the town	Population (2011)	Type of source	Energy consumed in a year (kWh/year)	CO_2 emissions (kg CO_2 emissions/ per capita/year)
1	Pratapgarh	42,079	Surface water	41,64,916	151
2	Jalore	54,081	Groundwater	16,16,790	29
3	Sri Ganganagar	237,780	Surface and Groundwater	47,76,045	86

Source: Public Health Engineering Department, Rajasthan & Analysis

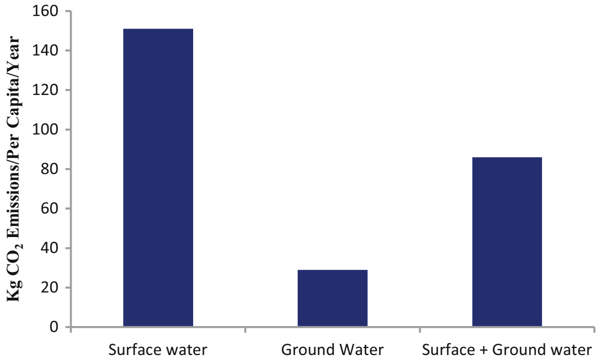

Fig. 13.3 CO_2 emissions with respect to type of source

Contrary to the popular belief, sourcing water from a surface source is not always energy economical. It is therefore important to take into consideration the lifecycle energy consumption as an attribute in determining the project feasibility and finalizing the alternative.

As per the analysis of the above three towns, energy consumption in surface water source is more due to treatment, and extensive pumping is involved, whereas in groundwater, energy consumption is comparatively less due to the absence of water treatment and less pumping. An amount of 151 kg CO_2 emissions per capita per year is being contributed through surface water source, and 29 kg CO_2 emissions per capita per year is being contributed through groundwater source. CO_2 emissions with respect to type of source are shown in Fig. 13.3.

In sewerage system, the major energy consumption is involved in wastewater treatment (Report on Sewage Treatment in Class I Towns: Recommendations and Guidelines, Ganga River Basin Environmental Management Plan). Depending on the type of technology, adoption for treatment energy consumption varies. Different wastewater treatment technologies like Waste Stabilization Ponds (WSP), Sequential Batch Reactor (SBR), Activated Sludge Process (ASP), and Moving Bed Biofilm Reactor (MBBR) technologies have been considered. Carbon emissions from Waste Stabilization Pond are very less (56 tons of CO_2 emissions/MLD/year), whereas MBBR is very high (2,205 tons of CO_2 emissions/MLD/year). Figure 13.4 shows CO_2 emissions for different types of technologies.

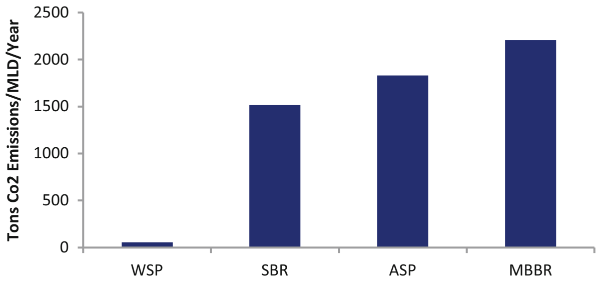

Fig. 13.4 CO_2 emissions based on sewage treatment technology

13.4 Low Impact Development: A Case Study

Located close to the national capital, Delhi, at about 30 km north, Sonepat is an important town in Haryana. It is the district headquarter of Sonepat district. The town is well connected by both roads and railways. National Highway 1 (NH 1) connecting Delhi and Wagah Border in Punjab and connecting many important cities passes near the town. In Sonepat, at present, there is no proper storm water drainage system. Due to flat topography, there is no proper natural drainage system developed in the town. Except a major drain constructed and maintained by Irrigation Department, and a 1.5 m dia RCC pipe drain along Gohana Road that serves some part of the town and disposes storm water in major drain, there are no storm water drains in the town. Flooding and water accumulation during monsoon are therefore very common in some localities.

It is proposed to construct major drains of total length 14 km in Sonepat. Four rain water harvesting structures are proposed in the project (Fig. 13.5). Surface runoff collected through storm water drains can be diverted into the rainwater harvesting wells (Mehta 2009).

13.5 Issues Related to Energy Consumption in Water Supply and Wastewater System

The collection, distribution, and treatment of drinking water and wastewater consume tremendous amounts of energy and release carbon dioxide. The following are the issues causing high energy consumption:

- Real losses (leaks, physical losses) and apparent losses (theft or metering inaccuracies)
- Increase in static head in pumping systems
- Having more storage capacity than actually required
- Depending on boosting system instead of gravity system
- Lack of comprehensive project planning approach in water supply system
- Inappropriate technology selection for treating wastewater

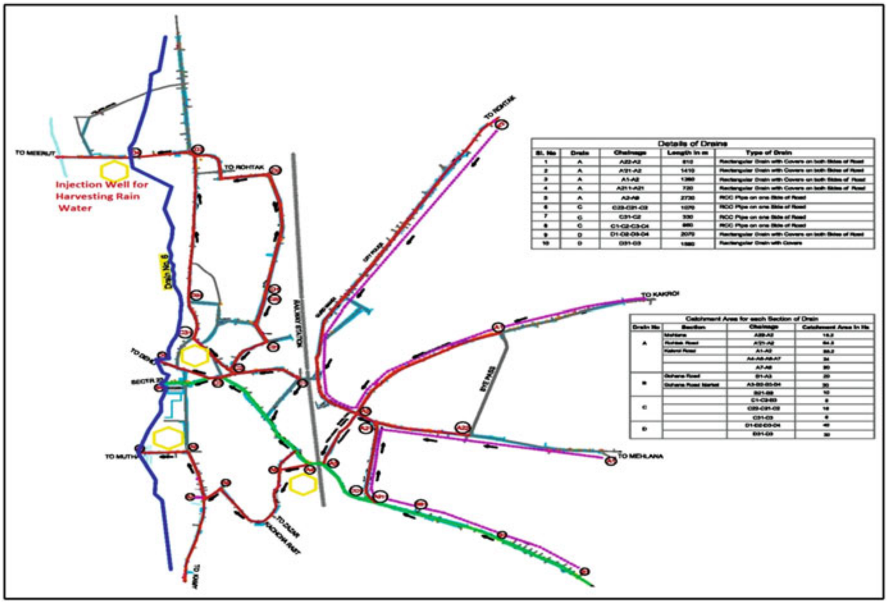

Fig. 13.5 Proposed storm water drain network with rainwater harvesting structures in Sonepat

13.6 Recommendations

The following are the recommendations to improve energy efficiency and reduce carbon dioxide emissions:

- Reducing static head on the pumping system directly reduces power consumption. It can be reduced by keeping water level high in sump/reservoir.
- Maintaining power factor to a minimum of 0.95.
- Run standby transformer in parallel with main transformer sharing the load.
- Using online pumping wherever feasible to reduce static head.
- Replacing old pipe lines/AC pipes in rising main/transmission/distribution network.
- Identification and regularization of illegal/unauthorized consumer water connections.
- Conducting leak detection exercise to identify and reduce leakage loss.
- Establishing bulk water meters at pumping stations and service reservoirs and providing good quality water meters to consumers.
- Regular cleaning of strainers and foot valves to avoid head loss.
- Pumps should not be operated with suction/delivery valve throttled.

- Sluice valves or butterfly valves on delivery/suction side, non-return valves, and foot valves should be of good quality and should be functional.
- Proper pump selection at the time of procurement that meets the duty parameters like head and discharge.
- Selection of proper size of suction/delivery pipes and valves plays a crucial role in efficient function of pumps.

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Chapter 14
Municipal Convergence for Inclusive Habitat

Kamla Kant Pandey

Abstract This chapter brings together the municipal ability to mobilise necessary resources to promote inclusive habitat with a particular reference to shelter, services and livelihood opportunities for the urban poor. It is noted that sustainable habitat has to specifically include suitable access to land tenure, affordable housing, water supply, sanitation, education, health and social security. At the same time, appropriate arrangements are to be made for adequate space and operational arrangements for skill development, job creation, public distribution system of oil, ration and other necessary items in the low-income areas, community centre and its multipurpose use, bus stop, designated hawking place, police post, school, etc.

It is in this context, two case studies are presented. This is indicated that the city governments of Bhopal and Hyderabad have mobilised necessary funds and involved other stakeholders from public and private sectors to converge resources over a period of time. However, there have been delays and obstacles to involve various stakeholders.

Finally, the chapter presents a twofold action agenda covering project-specific and city-scale actions on municipal finance in the form of a generic model for suitable adaptation to mobilise resources for inclusive habitat to facilitate the urban poor to have a reasonably acceptable lifestyle and quality of life.

14.1 Introduction

Successive studies have emphasised on the need to mobilise municipal finance in a participatory manner at a municipal level to promote inclusive habitat with a particular focus on the urban poor (NIUA 1983; RBI 2006; HPEC 2010). It is also noted that integration of the urban poor with municipal infrastructure/services and shelter is an integral part of inclusive habitat. In this context, this chapter examines the mobilisation of municipal finance for the urban poor in terms of shelter, services and livelihood opportunities in the overall context of municipal governance. There are three main areas of resource constraints at the municipal level which include (1) matching contribution for projects from centres/state and other partners, (2) upkeep

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of assets created by projects already implemented and (3) short-term/immediate requirements of funds at the municipal level. It is noted that municipal governments alone cannot do the needful due to resource constraints, and therefore, a larger sense of convergence has to be achieved to integrate resources from a cross section of stakeholders to address the requirements of inclusive habitat. These include the resources available within the city and outside.

There is a vast potential to converge central, provincial and local level options and incentive/initiatives to facilitate the urban poor. There are several intergovernmental schemes and programmes which have a direct bearing on the urban poor. At the same time, it is also noted that local actions and facilitation on these initiatives are fairly low. In this regard, resources need to be identified within the current system of urban governance and functional domain of urban local governments and other participating institutions at local level. These include a participatory process using resources from community, business, industry and trade to create and maintain assets for inclusive habitat.

Finally, it appears that the municipal finance in India needs to undergo a transition from conventional sources of resources to a convergence-based mobilisation of resources. It is observed that a range of stakeholders within the cities and outside, both in the public and private sectors, have vast potential to supplement municipal efforts on inclusive habitat. This involves a generic agenda at municipal level to carry out various initiatives to perform the role of mother institution and nodal agency at local level.

14.2 The Need for Municipal Convergence for Inclusive Habitat

India is undergoing a rapid pace of urbanisation. Census 2011 has placed that (1) urban India has added another 2,474 census towns (during 2001 and 2011); (2) net increase in the population in urban areas in the history of India has been (for the first time) more than the rural areas being 9.10 crores and 9.06 crores, respectively (Census of India General Population Totals 2011); (3) there is a reversal of decline in percentage increase in the size of the urban population occurring since 1980; and (4) urbanisation is directly linked with economic development (MoUD 2014). The states (provinces) with higher level of per capita income also have urbanisation level above the national average (Pandey 2012a; Economic Survey 2013, 2014). These trends show that India will become urban majority society sooner than expected (Pandey 2012a).

14.2.1 Normative Base of Habitat

It is, therefore, essential to ensure that urban growth in India is inclusive, and services and amenities are made available to a cross section of households. These are an integral part of sustainable habitat. On the other hand, the supply of land, shelter and core urban services in our cities and towns is fairly inadequate. Normative standard of urban basic services by and large indicates that:

1. Over 90 % of backlog in housing is constituted by low-income households. Nearly half of the urban population is residing in one-room accommodation.
2. The water supply has inadequacies in terms of quantity, quality, continuity and coverage. Due to O&M deficiencies, the supply of treated water gets affected by pollution caused during the transmission. Similarly, due to leakages (ranging up to 50 %), the total quantity remains almost half of the capacity utilised for supply. The 24×7 supply is a matter of exception, whereas the coverage of in-house connections to low-income housing areas is fairly poor (Pandey 2011).
3. Access to safe sanitation is also a matter of concern. Sewage system is extended to only 30–40 % of households, whereas a majority of households do not have safe system for disposal of human waste. Further, treatment of sewage is done for a small part of (10 %) sewage water among a few cities only. This has wide-ranging implications not only within the city but also down the line up to the places connected to the downstream of sewage water (CPWD 2014).
4. Solid waste management is no better; major concerns among urban centres include collection ratio (50–75 %), inadequate treatment (only 10–20 %) and availability fleet to transport the waste (downtime 3–5 vehicles). Further, the provision for waste collection which points at intra-city locations is highly inadequate (CPWD 2014; Pandey 2012a, b).
5. Municipal roads are highly congested combined with poor maintenance. In addition, services connected to roads covering street infrastructure such as bus terminus/stops, street lighting, parking places, roundabouts, foot over bridges, flyovers, relief roads, etc. are highly inadequate (GoI, Concepts Note on Smart Cities).
6. Impact of core municipal services such as water, sanitation, SWM, education and health are direct and clearly visible in terms of health and productivity, infant mortality rate, mother mortality rate, etc.
7. The implications of services and shelter are specifically recorded in terms of specific diseases such as malaria, measles, dehydration, intestinal worms, asthma and diarrhoea. Overall implication of inadequate sanitation is computed as 6.4 % GDP in India, out of which, nearly two thirds account for urban economy and poor (WSP, World Bank 2010).
8. It is in this context that the adequacy of urban housing and services has become a prerequisite for the development of sustainable and inclusive habitat.
9. The share of slums/squatters among Indian cities is by and large reported to be 30–60 % of the total population. We may recall that the city of Mumbai has a majority of population (60 %) living in slums (NBO/HUPA 2013).
10. Further, there is a typology of low-income areas constituting a vast majority of housing stock among individual urban centres (slums, squatters unauthorised/illegal land subdivision, urban villages, resettlement colonies, etc.) This typology includes shelter structure below the acceptable standards.
11. Building by-laws/regulations is not applied fully due to a host of reasons. A majority of housing stock therefore is considered below the acceptable standards or dilapidated structure.

14.3 Municipal Finance and Inclusive Habitat

Successive national policies and programmes have given special focus on municipal actions on shelter and services to more effectively include poor in the urban habitat (GoI 1992, NUHHP 2007 and JNNURM). As per a recent study on Basic Services to the Urban Poor (BSUP) programme of JNNURM (Jawaharlal Nehru National Urban Renewal Mission) by IIPA in the two cities (Bhopal and Hyderabad), it is noted that convergence of resources to augment municipal finance is an integral part of urban inclusion. It is also noted that there is a fiscal imbalance in the overall status of public finance in India affecting the ULBs adversely to perform their duties particularly with regard to the urban poor (Box 14.1).

Empirical evidence in the IIPA study suggests that total municipal governments have three types of resource crunch, namely, (1) adequate resources to create shelter, services and income generation with special reference to poor (even to meet their matching contribution), (2) resources to routine upkeep of assets created for low-income service/housing projects and (3) resources to meet immediate requirement of funds on a daily basis. On the other hand, municipal governments in India suffer from fiscal imbalance. This shows a fiscal stress which becomes one of the important barriers in the promotion of inclusive habitat.

In the absence of adequate funds, ULBs fail to *give* due attention to the necessary development of shelter, services and livelihood promotion for the urban poor. This leads to the development of informal city within a city whereby the size of a formal city remains relatively small.

Box 14.1: Fiscal Imbalance at Municipal Level

Municipal governments in India suffer from a fiscal imbalance caused by their inability to raise requisite funds to meet their mandated functions. This adversely affects the adequacy of shelter, services and livelihood opportunity for the urban poor. Recent estimates given in the XIII Finance Commission report (2010) suggest that barely half of the municipal expenditure is financed through own sources and the size of municipal expenditure as part of GDP has declined from 2003–2004 to 2007–2008 being 1.7 % to 1.5 %, respectively. Similarly, the share of municipal budget in the total budget of centre, states and local governments is around four per cent only as compared to 10–15 % shares among several other countries.

On the other hand, cities contribute nearly two thirds of the national income which is likely to increase to a level of 75 % + by the year 2030 (India's Urban Awakening McKinsey Global Institute 2010).

(continued)

Box 14.1 (continued)

A vast majority of taxes, fee, etc. are collected from urban centres. We may also recall that 86 % of the Indian GDP is generated by manufacturing/industry and services (Economic Survey, GoI 2014) which are predominantly located within and around urban centres (Pandey 2012a, b). Accordingly, a vast majority of the public finance is generated from services and industry. However, 2 % + share from a divisible pool of funds from the government of India is allocated to local bodies. Therefore, it appears that municipal governments do not have access to their due share in the public finance.

14.3.1 Need for Case Study

Sustainable habitat is part of the policy agenda of the government of India. NDA government has committed itself to have 'housing for all' and 'sanitation for all' which form an integral part of sustainable and inclusive habitat. In this regard, it is inevitable to identify actions that need to be taken to promote 'inclusive urban growth'. Therefore, a pointed and brief analysis of actions from a real-life case needs to be identified to draw a list of suitable actions for wider disseminations and adaptation.

The case study should provide specific information on applications of the seven-point charter which provided a conceptual basis for governmental policy and actions during the last decade (MoUD 2006). In this regard, BSUP (Basic Services to the Urban Poor) initiative as applied in Bhopal and Hyderabad is fairly good to be examined from the angle of inclusive habitat and municipal finance.

14.4 The Case Study Cities

The two cities, namely, Bhopal and Hyderabad, have historical background to take specific initiatives for inclusive habitat with a particular reference to slum improvement process in the country. Whereas Bhopal initiated early grant of legal title (Patta) to slum dwellers in the beginning of the 1980s, the Hyderabad has undergone a systematic process of inclusive habitat, being one of the initial efforts of its kind in the country on slum improvement under the Urban Community Development (UCD) programme carried out with the support of the Overseas Development Agency (ODA) of the United Kingdom in the mid-1980s now known as DFID (Department of International Development). The projects, therefore, in the two cities provide suitable environment to create a demonstration effect for wider understanding and replicability of slum improvement and low-income housing.

Table 14.1 Sizes of BSUP in respective cities

City	Estimated population in 2010 (lakhs)	Slum population (lakhs)	No. of beneficiary HHs	Size of beneficiary population	% of slum population to be covered under BSUP
Bhopal	19	6	18,452	92,260	15
Hyderabad	80	20	78,746	393,730	20

Source: Respective city government
1 Lakh = 100,000, *HHs* Households

14.4.1 BSUP Initiatives in the Two Cities

As part of the Basic Services to the Urban Poor (BSUP) programme under JNNURM (Jawaharlal Nehru National Renewal Mission), the two cities have taken appreciable steps. The scale of projects undertaken under BSUP as compared to slum population in the respective state is fairly significant on two specific grounds: (I) the past history of slum improvement and (II) replicability potential in the state and elsewhere. It is also noted that the two cities have also made a significant impact to improve the conditions of slums in their respective jurisdiction.

As may be seen from Table 14.1, nearly 20 % of the city population is likely to benefit in Hyderabad, whereas 15 % of the population of Bhopal will benefit from BSUP. These are one of the most effective strategies for low-income houses being provided under JNNURM in India. It is also important to mention that 50 % of the city population has benefitted from BSUP in each of the two cities.

14.4.2 Inclusive Habitat: Special Features

The two cities (Bhopal and Hyderabad) have taken up inclusion on the bases of the seven-point charter of the government of India which includes secure land tenure, affordable housing, water and sanitation, education, health and social security. These seven points tend to promote urban inclusion in a systematic manner. A brief summary of detailed initiatives on the seven-point charter in the two cities is given in Tables 14.2 and 14.3 that:

1. Secure tenure has been made available to the beneficiaries. Substantial additions have been made in the housing stock for the poor with suitable standards. There is a need to replicate this process.
2. As the rental housing option is not attempted, there is further scope to explore possibility of rental housing particularly in the context of just arrived/migrants.
3. It has been difficult to arrange loan to the beneficiaries of BSUP. There are basic hurdles on the account of KYC (know you client) qualifications of banks. Savings potential of HHs is not taken into account while deciding the product for affordability.
4. In this regard, municipal authorities have sought HUDCO loan on hire purchase method which comes to ULB for onward transfer to allottees who pay monthly

Table 14.2 Seven-point charter at BMC (Bhopal Municipal Corporation)

Item	Status	Scope
Land tenure	Secure tenure (mix of in situ and relocation)	Rental tenure not planned
		Option for just arrived not considered
Affordable housing	Loan through banks (using ISHUP)	Banks are not coming forward
		Savings potential not fully explored
		Authorities finally using hire purchase method on the bases of HUDCO loan
Water supply	In-house connection	Community supply system (tap) is needed; partnerships are not attempted in the supply/O&M
Sanitation	On-site provision	Segregation, disposal system with PPP is not tried
	O&M not effectively planned	
Education	Within reach/skill education also attempted	Preventive health care is not suitably planned
Health	Depend on existing system	Scope for convergence with existing schemes/ programmes
Social security	Community structure emerging	Multiple use of community/common space

Source: Pandey (2012a, b)

Table 14.3 Seven-point charter at GHMC (Greater Hyderabad Municipal Corporation)

Item	Status	Scope
Land tenure	Secure tenure (mix of in situ and relocations)	Rental tenure not planned
		Option for just arrived is to be addressed
Affordable housing	Loan through banks (using ISHUP)	Savings potential can be explored
Water supply	In-house connection	Community supply system for monitoring as planned is needed; partnerships can be attempted
Sanitation	On-site provision/O&M not effectively planned	Segregation, disposal system with PPP can be attempted
Health	PHC system and convergence	Preventive health care
Education	Within reach/skill education also attempted	Multiple use of space for education can be attempted
Social security	Community structure emerging	Scope for convergence with existing schemes and programmes
	Bus stand and buses are provided	

Source: Pandey (2012a, b)

instalments (as per past experience and general perception of borrowers, recovery could be a major issue on these arrangements).

5. Although water and sanitation are provided, a sustainable system for upkeep with the help of the community needs to be specifically planned.

Table 14.4 Additional BSUP cost implication on municipal finance

City	Additional cost over and above the sanctioned cost (` in crore)	Sanctioned cost (` in crore)	Municipal revenue actuals (2008–2009) (` in crore)	Additional cost as % of	
				Sanctioned cost	Municipal revenue (actuals)
Bhopal	179	181	194	98.89	92
Hyderabad[a]	486	1,487	1,392	28	28

Source: Respective ULB
[a]2009–2010

6. The need for preventive health activities in a comprehensive manner both for personal hygiene and community hygiene is not attended.
7. Solid waste management and drainage system are in place as per on-site/off-site plans. However, effective mechanism for O&M using the community resources is not yet operationalised.
8. Social security system does not exist.
9. Education is planned through municipal/state government schools located in the nearby areas. BMC has started vocational training at Madrasi colony. It has also linked training with employment in a hospital in the city. There is further scope to integrate the project sites with SJSRY (Swarna Jayanti Shahari Rozgar Yojana) to make suitable arrangements for vocational training and income generation thereon.
10. Interdepartmental convergence has been achieved to include supply of food items, oil etc., social security through police, education for children (nursery), multipurpose community hall, bus stop, etc.
11. Private sector has been involved for local transport and jobs for skilled persons in the hospitals.
12. Local community needs to be involved for upkeep of water supply (hand pumps) and solid waste management.

14.4.3 Cost Implication of BSUP Projects

The implication of BSUP projects on municipal finance needs to be examined in the light of the magnitude of cost overrun on municipal finance. Empirical evidences suggest from the two cities that cost escalation leads to additional financial burden on respective city governments. Being the nodal agency, the city governments have to continue the project to avoid further cost escalation. However, the additional costs have the potential to become a significant financial burden on municipal finance.

Additional cost works out to be 92 % of the municipal's own sources in 2008–2009 in Bhopal, whereas Hyderabad needed 28 % share of the municipal finance to meet additional costs. However, GHMC had revenue account surplus (RAS), and therefore, the impact of additional cost was further low on the overall liquidity of municipal finance in Hyderabad (Table 14.4).

The data also indicates that it is fairly difficult for BMC to spare money from own sources which are scarce and short of requirements. In this case, diversion of funds takes place to complete the task on a priority basis. At the same time, the activity concerned gets affected, and the cost for the respective activity goes up further adding to another burden to municipal finance in the concerned city.

14.5 Municipal Agenda for Convergence

As the resources are limited, municipal bodies need to mobilise requisite fund for sustainable habitat from a range of stakeholders. As noted in the two case study towns and elsewhere in India, the three different types of focus areas need to have necessary convergence to mobilise necessary resources such as:

(a) ULB share to fund inclusive habitat
(b) Upkeep of project (BSUP) assets
(c) Immediate short fall of funds (caused by delayed disbursement of central and state BSUP transfers and beneficiary contribution)

These three key issues need a systematic strategy at municipal level to supplement existing sources and create potential sources of funds.

14.5.1 ULB Share to Fund Inclusive Habitat

Due to historical reasons, the revenue account surplus (RAS) is not normally available with ULBs to arrange ULB share for inclusive habitat covering shelter, services and livelihood opportunities. Although municipal budgets show a minimum amount of surplus as a mandatory requirement (being equivalent to the number of months' salary expenditure) as per respective municipal actions, actuals (in the financial statements) do not reflect adequate surplus. Therefore, an alternate source has to be identified to have necessary liquidity in the municipal finance to mobile funds to arrange ULB share.

Possible options in this regard as given in Table 14.5 could be (a) optimum use of existing own sources (taxes, charges and asset management), (b) urban land (sale of land, commercial use of municipal land, commercial use of project land) and (c) loan finance (to meet requirements of municipal share).

14.5.1.1 Own Resources

Optimum use of existing/own sources has vast potential to stimulate municipal finance as part of existing sources. In this regard, the potential of property tax (PT) being the mainstay of municipal finance should be fully utilised through the application of GIS to cover all eligible properties and improve collection through ABC

Table 14.5 Areas for municipal convergence for inclusive habitat

Sl. no.	Areas of resource requirement	Existing resources	Alternate resources
(I)	ULB share for projects on inclusion of poor for sustainable habitat	Optimum utilisation of existing sources to have revenue account surplus (RAS)	Innovative use/sale of land
			Monetisation of land
			Loan finance (ISHUP/ Priority Sector Lending)
			Hire purchase method of loans
			P-budget
(II)	Upkeep of municipal/community assets	User charges	Land value gains property (alternate sources)
		Connection charges	Efficiency and equity through PPP/convergence of resources
		Subsidy from general kitty of municipal finance (taxes, charges, assets including land)	P-budget
(III)	Immediate shortfall of funds (lack of short-term solvency)	Optimum utilisation of existing sources to have revenue account surplus (RAS) or a larger kitty for P-budget	Loan from banks/ beneficiaries using ISHUP/ Priority Sector Lending
			Overdraft facility
			P-budget

Source: IIPA study (Pandey 2012b)

(always best control) analysis, incentives (insurance cover, collection camps, rebels), penalties (attachment of bank account), etc. A study by NIPFP (2008) quoted by XIII Finance Commission of India (Government of India 2010) shows that property tax (PT) alone that can give another 220,000–320,000 million provided innovations are applied to plug leakage in terms of coverage and collections.

It is also observed that community resources have enormous potential to stimulate a quantum jump in the available resources provided that local elasticity is brought within the ambit of municipal system (IIPA 2010). There are studies (IIPA 2010) which show that the community resources, i.e. the resources available within the city itself, are highly underutilised particularly within the jurisdiction of respective ULBs. In this regard, property tax board to be constituted as part of XIII Finance Commission report, innovative budgeting with benchmarking and P-budget, will go a long way to mobilise resources for BSUP and related activities.

In addition, P-budget can be a systematic exercise to incorporate many of these products as part of income and expenditure items under the respective budget. P-budget is now mandatory to prepare as per government of India's circular dated November 4, 2010. P-budget includes a dedicated non-lapsable earmarking of funds for inclusive habitat (GoI, Guidelines 2010).

Similar initiatives should be taken to minimise non-revenue water. Further, asset management strategy (listing, classification and valuation) will also provide an opportunity to have optimum revenue from the municipal assets.

14.5.1.2 Urban Land

Yet, another source is urban land supply which can augment municipal finance significantly. There are a range of products such as vertical supply combined with commercial use and TDR (Box 14.2) and leasing of land (partly) for commercial purpose. These can be applied at the project site as well as elsewhere in the city. These products are already being used at ULB level by city governments on Rajasthan, Maharashtra and Gujarat.

Box 14.2: Using Land Supply for Liquidity in Municipal Finance
Urban land is a scarce resource. However, municipal governments have access to the innovative use of land in the form of (1) vertical supply and (2) commercial use of land to generate additional liquidity in the municipal finance. This applies to low-income housing as well.

The city governments in Rajasthan, Maharashtra and Gujarat are including the commercial use of public land to cross-subsidise costs on low-income housing. Rajasthan is successfully using the land on-site (for commercial use) and off-site to apply TDR (transfer of development rights) for the additional liquidity at the municipal level. This is based on the optimum and effective use of vertical supply of land to raise revenue for low-income housing.

Maharashtra and Gujarat are also using similar initiatives in Pune, Mumbai, Surat, Ahmedabad and several other cities to accelerate vertical supply of land.

14.5.1.3 Loan Finance

Loan finance is another tool to arrange beneficiary contribution to make payments available to municipal governments on behalf of low-income beneficiaries. Hire purchase method of loan is particularly important for low-income housing. It also serves as a de facto rental housing method. We are coming back to this earlier system of hire purchase method as initialled by Bhopal Municipal Corporation to seek a sum of HUDCO loan for the allotment of 14,500 DUs under BSUP.

14.5.2 Upkeep of Municipal/Community Assets

Upkeep of municipal/community assets is an important exercise. This needs to be done through the appropriate use of user charges and connection charges. Further, consolidated funds of ULB should be used to have necessary funds for O&M of municipal assets in low-income areas, which are currently not available at municipal level. Therefore, potential areas to carry out upkeep of BSUP assets could include innovative revenue/resource availability from (a) increased coverage and collection of property taxes for the municipal kitty, (b) application of PPP, (c) inter-departmental agency convergence and (d) introduction of P-budget in a participatory manner to have higher allocations.

14.5.2.1 Property Tax

Normally, low-income housing is not covered under property tax net taking advantage of rental value exemption. However, current market rent of such properties is stated to be well beyond the exemption limit. This requires a political will to impose PT subject to innovative application of funds to create willingness and compliance for regular and timely payments. This may include assignment of PT to local association/community structure which will encourage tax compliance and ownership of assets among local communities.

14.5.2.2 PPP for Upkeep of Assets

Multipurpose, community centres, solid waste management, roads, transport, etc. can be provided and maintained through partnership arrangements. Some of these could be self financing, financing through advertisement potential or part payment by ULB (Pandey 2014). However, ULB can use its own standards for provision and upkeep of assets under reference (Table 14.6). Important point for PPP and pricing and cost recovery of community/project assets may be noted as below:

Table 14.6 Alternate funding for BSUP assets

BSUP assets	PPP activity	Pricing and cost recovery
Solid waste management	Segregation, transportation and disposal	Tipping fee by ULB
		Revenue generation by partners
Upkeep roads/streets	Cleaning and repair	Advertisement potential as part of package like FYC of Hyderabad
Street lighting	Provision of lights and upkeep	Fee paid by ULB as per prescribed rates (has to be a part of longer PPP for city)
Transport	Public transport buses	Legal permission by ULB
	Permission to other modes	User charges by service provider
Water supply	Maintenance and repair by community structure	Community contracting
	Private tankers	Payment to tankers by ULB
Community centre	Upkeep	Vocational skill training as per Madrasi colony Bhopal covering:
	Work plan for use of space	IT
	Multipurpose use	Nursing
		Pre-nursery, primary education

Source: Pandey (2012a, b)

1. Solid waste management should include segregation at source, transportation and disposal which can use charges and tipping fee as per activity.
2. Advertisement potential of roads can be used for upkeep of roads/street/street lights as per FYC (fund your city programme of Hyderabad) and PPP for sweeping (at Hyderabad, Rajkot, etc.).
3. Public transport buses can be used along with private sector vehicles to provide local transport as applied at GHMC.
4. Water supply O&M for community tap can be assigned to local community as planned at GHMC, and tankers may also be used to supply through local community structure.
5. Community centres could be put to multipurpose use through the application of user charges or budget funds for the respective activity; it may include IT, nursing, pre-nursing and primary education (Madrasi Colony of Bhopal).

14.5.2.3 Interdepartmental/Inter-stakeholder Convergence of Resources

Another area of supply of services covers convergence of resources. There are several government departments and other stakeholders who can come up with their support for specific activities. This requires specific initiative at municipal level as given in Table 14.7. It may be noted that:

- Security concerns can be met through a police post on project site/space.
- PHC can be provided on a project site.
- Ration shop can be arranged through provision of space.
- Super bazaar can also be provided by allocating space to government departments/agencies.
- Education can be extended with liaison with other departments or other stakeholders such as corporate social responsibility, charity funds, etc.

14.5.2.4 Introduction of P-Budget in a Participatory Manner

P-budget is equally important to bring the items under the financial planning of ULBs. It should be prepared carefully giving due cognisance to community structure at the local level, provision for municipal contribution and potential of revenue,

Table 14.7 Interdepartmental/stakeholder convergence of resources

	Convergence	
BSUP assets/activity	ULB contribution	Partners' contribution
Police	Space (on-site)	Staff and equipments
Primary Health Centre (PHC)	Space (on-site)	Staff and equipments/medicine
Ration shop	Space (on-site)	Staff and material
Super bazaar	Space (on-site)	Staff and material
Education	Space (on-site)	Staff and upkeep

Source: Respective Projects

e.g. rent for space (wherever feasible), etc. Although GoI guidelines stipulate that at least 10 % of the funds released are recovered and ploughed into the revolving fund to be created to carry out O&M of municipal assets, the fund has not been created by respective cities. It will further strengthen P-budget. Efforts should be made to engage ULBs to do so. There is a need to prepare P-budget in a participatory-, consultative- and performance-based manner which will include:

1. Consult local community/community structures through elected representatives, officials, NGOs, etc., prepare bottom-up assessment to have a realistic budget and develop resources form nonconventional sources such as constituency/local area funds and corporate social responsibility (CSR) contribution from business, industry and trade. It should also include potential from constituency fund from MPs and MLAs (Pandey 2014).
2. Further, the municipal staff needs training and exposure on best practices and modalities to prepare P-budget. In this regard, three-tier training is needed.
3. Material development covering manuals, checklists and guidelines is equally important. It should be done on bottom-up feedback on priorities, consultation and commitment. It is equally important to develop material in local language.
4. A budget cycle should be followed covering (a) the preparation of the final statement for last year and sending the Performa to different municipal departments during April to June, (b) preparation of RE (revised estimate) and consolidation of Performa (July–September), (c) preparation of draft (October–December) and (d) wider consultation and participatory funding (January–February) and resolution on final budget in the council (February and March).

These steps will go a long way to improve P-budget and make it a realistic exercise by removing the current barriers of line item incremental budgetary.

14.5.3 Immediate Shortfall of Funds

Short-term finance plays a critical role to implement programme as per schedule. ULBs already suffer from resource crunch. In this regard, necessary efforts could be made to arrange short-term finance on three aspects (Table 14.8):

- Overdraft facility against the sanctioned cost and stage of implementation
- Short-term loan as construction finance
- Timely identification of beneficiaries to seek their contribution to avoid immediate shortfall on this account

As indicated in Table 14.8, the delayed disbursement of funds could be tackled through (1) overdraft facility to ULB (against the overall sanctioned cost and respective stage of implementation) and (2) short-term loans that can be taken as construction finance. Further, the beneficiary contribution (including the escalated cost) is not received on time. This needs to be resolved through timely identification of

Table 14.8 Scope to meet immediate shortfall of funds

Item	Existing	Potential
Delayed transfers from centre/state	Optimum utilisation of existing sources	Overdraft facility against the sanctioned cost and stage of implementation
Delayed beneficiary contribution	Timely identification of beneficiaries and help to seek loan finance	Short-term loan as construction finance

Source: Discussion with ULBs

beneficiaries and enables them to seek loan from the banks so that the amount can be transferred to ULB well in advance.

14.6 Action Points for Municipal Convergence

Action points for municipal convergence as elaborated earlier and as indicated in the IIPA study on municipal finance for inclusive habitat are twofold: (1) project-specific actions for municipal finance and (2) city-scale actions for municipal finance as follows.

14.6.1 Project-Specific Actions for Municipal Finance

1. Establish a project cell within ULB to have expertise on project management and community mobilisation to guide, handhold and support stakeholders during the project implementation.
2. Identify dedicated flow of funds in the project document itself to meet project commitments within the ambit of municipal finance of a respective city.
3. Seek short-term construction finance (if necessary) to timely spare requisite funds for investments in the project on the account municipal commitment.
4. Incorporate monetisation of land within the project itself to have intra-project subsidy through vertical supply of land, commercial use and PPP (including the transfer of development rights) to generate requisite funds.
5. Ensure timely grant of land title and availability of land in case of relocation combined with a transparent and smooth selection of beneficiaries. Also, facilitate beneficiaries to have no frills account under Jan Dhan Yojana of NDA government and UID to quality KYC (know your client) requirements of financial institutions. It paves the way for easy and quick access to loan finance to beneficiary and subsequent receipt of their contribution. In this regard, the scope of mobile banking (through cell phone) is also emerging for future actions. The Central Bank of India has already attempted this instrument for the urban poor in Mumbai.

6. Initiate a drive to impart financial education through community mobilisation cell using help from financial institutions on savings, deposits, credit, remittances, insurance, etc.
7. Immediately create a separate project account (not the ledger account) in the books of municipal finance only. It will help the stability in the funds and avoid inter-account transfers.
8. Identify potential for overdraft facility (if necessary) to meet immediate shortfall of funds from suitable sources. In this regard, carry out accounting reforms to demonstrate credit worthiness of ULB.
9. Build formal community structure at the project site and provide suitable exposure on low-income neighbourhood commitments through necessary handholding, study visits and orientation courses with the help of community development cell of ULB.
10. Involve community structure in the project implementation, processing of loan for beneficiaries and its recovery, upkeep of project assets covering water, sanitation, solid waste management and monitoring of PPP applied as per scope of the respective services. It may include community contribution in the form of cash, kind, management and supervision responsibility. All these resources together have a de facto cash value for municipal finance.
11. Involve convergence of inter-agency/departmental resources including CSR (corporation social responsibility) and constituency funds from MPs (members of parliament), MLA (member of legislative assembly), councillors, etc. for provision and delivery of services and amenities wherever feasible such as water, sanitation, solid waste management, education, health, security/policing public distribution system, etc.
12. Introduce multiple use of community centre/space for livelihood, skill training, marketing, etc. using private corporate sector, inter-agency/departmental support, etc. for overall convergence and synergy of resources.
13. Apply project management skills to minimise time and cost overrun in the implementation of the project.
14. Build capacity of project staff to take up tasks as per I to XIII above through classroom training, awareness workshops, study/exposure visits, etc.

14.6.2 City-Scale Actions for Municipal Finance

15. Prepare P-budget in the letter and spirit of GoI guidelines, and converge funds from revenue and capital budget to upgrade basic services and housing as per seven-point charter. Although GoI guidelines stipulate that at least 10 % of the funds released are recovered and ploughed into the revolving fund to be created to carry out O&M of BSUP assets, the fund has not been created by respective cities. Efforts should be made to engage ULBs to do so.
16. Identify dedicated flow of funds from municipal kitty to mobilise (a) ULB share as per project, (b) funds for upkeep of assets and (c) immediate shortfall on the account of delayed transfer of state/central/beneficiary commitment.

17. Make efforts to have revenue account surplus (RAS) in the overall municipal finance to spare finances for necessary commitments. It will certainly increase the size of municipal finance and P-budget to make more funds available to the urban poor. This will include three specific actions, namely, (a) optimum mobilisation of existing sources, (b) use of additional sources and (c) innovations in the financial management system (FMS) of ULB to effectively expedite mobilisation of municipal revenue.
18. Existing sources of funds covering property tax and user charges should be liberated from the erosion of their revenue base through efficient GIS-based/ information system, innovative collection mechanism by using ABC (always best control) analyses, building attractive incentives (insurance cover on timely payment as in Mumbai), use of tribunal to sort out disputed cases (as per XIII Finance Commission), benchmarking of services as per XIII Finance Commission guidelines for a road map of improvement (to have better compliance for revenue collection) and suitable penalties on defaulters covering attachment of movable properties including bank account in case of major defaulters.
19. Further, advertisement potential should also be fully utilised through innovative methods such as fund your city (FYC) of Hyderabad and BOT of Delhi to provide necessary services.
20. Additional sources could be identified by ULBs to seek necessary approval from respective states to generate more revenues to leverage funds for BSUP and similar commitments. It should include (1) application of fiscal instruments to tap land value gains such as impact fee (Hyderabad), betterment levy (Gujarat), exactions (the United States and Latin American Countries), etc., (2) monetisation of land through vertical supply and commercial use on PPP bases and using TDR (as done by Rajasthan, Maharashtra and Gujarat) and (3) mobilising community resources as partial contribution towards provision and upkeep of municipal assets (Janambhumi – Andhra Pradesh, Namakkunane – Tamil Nadu, 50–50 Madhya Pradesh). It may be able to generate RAS which will in turn provide higher liquidity for P-budget.
21. There is also a need to take up city-scale capacity building of municipal staff, elected functionaries and civil society and community structures of the urban poor to give overview of inclusive habitat and its benefits to the city economy and national economic development and sensitise the need for additional resources and potential of city community thereon. It should cover awareness campaign using media, posters, meetings, RWA's, workshops, classroom training, study visits, etc.

Finally, it appears that the municipal finance in India needs to undergo a shift from conventional sources of resources to a convergence-based mobilisation of resources. A range of stakeholders within the cities and outside, both in the public and private sector, have vast potential to supplement municipal efforts on inclusive habitat. This is also essential in the larger interest of social and economic policy agenda of our welfare state.

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