Urban Environmental Evolution: The Case of Mumbai

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Preface

At different stages of economic growth cities faces different kinds of environmental problems. For instance, cities with less development face lack of sanitation facilities resulting in unhygienic conditions and spread of infectious diseases. With increasing economic growth such problems slowly disappear, giving rise to different problems like industrial pollution and air pollution. As the growth rate furthers environmental problems transform into rich life style problems like higher energy use and increased waste generation and the related problems. Many developed cities in Asia have undergone these stages and cities are facing different kind of environmental problems according to their respective economic growth levels.

However, with the increasing awareness for environment and the related problem, it should be possible to leapfrog certain environmental problems in the course of the economic developing by learning from the cities, which have already experienced those problems. City planners should be made aware of such trends of environmental dynamics and be helped with the measures to leapfrog some of the environmental problems that they may face in the due course of their development. This report examined such concept called environmental evolution and applied it to Mumbai, the commercial capital of India. It presents the dynamics of environmental changes in Mumbai and the driving forces causing these changes. This presents the city and environmental planners with required information to minimize certain environmental problems they might face in the process of economic development.

This study was carried out as a commissioned work for the Urban Environmental Management Project (UE), Institute for Global Environmental Strategies (IGES), Japan.
Abstract

This Paper presents the environmental evolution of Mumbai city. The concept of environmental evolution as developed and adapted by Bai and Imura is applied to study the present environmental status of Mumbai. In order to study its dynamics the entire process of environmental evolution is divided into four types viz. poverty related environmental issues, industrialization and urbanization related environmental issues, rapid economic growth related environmental issues and wealthy lifestyle related environmental issues. Suitable indicators are identified for all the above issues. Dynamics of those indicators over the economic development is studied. Temporal representation of respective indicator for each type of the environmental problem presented the distribution of these types of environmental problems on a longitudinal scale. In the analysis it is found that, Mumbai, at present, falls under “rapid economic development related issue” stage. Poverty related environmental issues show very little significance with industrialization and urban related environmental issues coexisting with rapid economic development related environmental issues. This provides interesting inputs to the Mumbai policy makers in designing the environmental action plan to avoid various environmental costs that other cities have already gone through.

Key Words: Environmental evolution, urban environment, environmental indicators, Mumbai
Introduction

Mumba Devi, the mother goddess of the aboriginal Kolis probably lent her name to this region. Four Centuries in the distant past, this little island was the seat of Silhara Dynasty of the Deccan, then it came under Muslim occupation. Later, the Portuguese wrestled it from its ruler, the Sultan of Gujarat in 1534. Bombay was given to the Britishers by the Portuguese as a part of dowry of the Portuguese princess Catherine of Braganza on her marriage to the British heir apparent. In 1665, the island finally came into the possession of the British. From the earliest record estimate of Bombay’s population taken in 1661, it is believed that about 10,000 persons resided on the island. By 1764 the population was crossing 100,000 over flowing Fort to the hills and gardens in the vicinity.

Annexation of the Deccan, consequent to the Treaty of Bassein in 1818 formally sealed the end of Maratha rule. A year later, with the capture by the British of the last of the rover valleys, Bombay extinguished piracy from its waters. The charter act of 1813 introduced a system of free trade and the removal of old privileges gave an immense boost to the commerce of Bombay. Bombay’s wealth was primarily based upon two items of export, raw cotton to Britain and opium to China. The major items of import were sugar, metal and silk. The resultant spawning of independent mercantile firms in Bombay led in 1836 to the foundation of chamber of commerce, which soon played a key role in the formation of public opinion and direction of affairs. From the beginning of population recording to the present day the population has grown more than 10 times.

The economic strength for the first urban center had its roots outside Mumbai. On April 12, 1861, when the southern states fired on fort Sumter in South Carolina, Civil war broke out in America. In retaliation the superior navy of the north effected an almost complete blockade of the southern ports thus bringing a famine in the cotton markets of Liverpool. The price of raw cotton soared to six or eight times its rate prior to the outbreak. Bombay, which was then the emporium of all cotton of India eagerly, stepped in to fill the void, created. The total gain to Bombay in the five years was as being approximately, eighty one million sterling over and above what she had in former years considered a fair price for cotton. This was the dawn for the commercial capital of India. In the history of Bombay, there hasn’t been much note of environmental concerns. Being an island, Bombay has high assimilation potential, which made this city less environmentally concerned.

Post Independence Development in Mumbai

Since, independence, Bombay has been the center for development and financial activities of India. Bombay is popularly known as the commercial capital of India with most of the Indian financial institutions like the
Bombay stock exchange and national stock exchange, Indian merchant chambers and central bank head quarters (RBI) etc. based in this island city. For ages this metropolis is called *Urbs Prima of Indus*. Due to this character, Bombay has grown multifaceted and the population has grown up several times. Manufacturing sector has been the major force in Bombay creating potential for employment resulting in migration. This has created increased demand for sharing the limited public resources and infrastructure available in the island. The population bulge brought out the new suburbs spanning over east and west. Most of the development and expansion has been in northward direction with the central business district remained in the island. Expansion of Bombay was due to the bulging of the Island. As the place became scarce the real estate value shoot up driving the public to the suburbs. As a result, expansion of Greater Bombay in 1971 was almost entirely due to its suburbs growth. In 1981 the city’s population of 3.3 millions was far outpaced by the suburb population of 5 million. Bombay city, in the post independence period has been facing severe resource constraints. This growth has further exacerbated the city’s problems by overstraining its services in catering to the hordes of commuters, all heading each morning for south Bombay where the port, business offices, and administrative offices are located.

Due to its long narrow shape, Bombay Island has no option but to grow in northerly direction. Then it was thought that it is essential to create another city center to ease the increasing pressure on Bombay and its resources and services. During the third five-year plan of Government of India, the concept of regional planning was introduced and the Bombay Metropolitan Region was demarcated. Subsequently, New Bombay was developed with all basic characters of a business center.

High growth rate, high migration and urbanization put tremendous stress on the resources and increased growth, economic activity and per capita income further overstresses the resources and “common goods”. This phenomenon created a wider scope for increased environmental concerns, which are multifaceted and also cross sectoral. For various social and administrative reasons, Bombay was renamed as Mumbai during late nineties.

**Facts about Mumbai**

- Mumbai has a population of 11.9 million as per the 2001 Population Census. The city accounts for about 1.2% of the total population in India and for about 12% of the state of Maharashtra. Literacy rate in Mumbai is on higher side at 82.4% against the national average of 65.38%. Female literacy is higher in Mumbai at 82.7% compared to the state average of 67.5 per cent and similar trends are observed with male literacy.
• Mumbai is known for its employment generation potential. For ages, this urban center is known for its industrial activity. However, in the post independence period, with the changing scenario of international market and India emerging as one of the major service providers in many sectors, the employment situation has changed in Mumbai. Of the total 3.43 lakhs main workers employed in the city, more than two-thirds i.e. 68.1% are employed in the service providing industries. Job opportunities in the organized manufacturing sector have been declining since the last few years.

• Per capita income levels in Mumbai are higher than the average state per capita income, which is again higher than the national average. The main reason for this distinction is the industrial activity. 33% of the state's income is from Mumbai's registered manufacturing units and 28% from the unregistered manufacturing units. Transport, trade and banking are vital services accounting for 33.5%, 32.19% and 42% respectively of the state's income generated in these segments. The services sector on the whole accounts for 64% of the income generated in Mumbai. The city has 75% of foreign collaborations with foreign equity against 60% in the state of Maharashtra. Maharashtra has been the attraction for foreign investors and Mumbai accounts for almost 30% of FDI in the State.

• Mumbai, with its intense finance activity has given scope for the western culture to penetrate into the system leading to the development of various environmental problems. The main driving force for all such developments is the level of financial and economic activity and the resulting increase in purchase power. Mumbai houses both National Stock Exchange and Bombay Stock Exchange and dominates the turnover and total market capitalization of the Indian stock markets. The share of these two exchanges is about 92% with respect to the total turnover. They represent virtually the total market capitalization of India's corporate sector.

• Mumbai is one among the better education provider cities in the country with approximately 42 students per teacher and 35 students per teacher at the primary level and secondary/higher secondary school levels respectively. The total number of primary schools in Mumbai are 2110 of which 1188 are municipal schools, 342 are private (aided) and 580 are private (non-aided). The total number of students enrolled in primary schools in Mumbai is around 1.07 lakhs (0.1 million).

• Mumbai presents one of the best mass rapid transit systems in India with its three-corridor metro rail system and the supporting BEST public bus network. The Central Railways and Western Railways operators run 1165 and 980 local train services per day, respectively. Both Central and Western Railways carry 1139 and 1136 million passengers per year, respectively. The BEST road transport carries approximately 4.3 million passengers per day (as per the 1998-99 data). In spite of these efforts Mumbai local trains remain a nightmare for the regular commuters.

• Mumbai, due to its commercial activity, has been the most connected city in India, both domestically and internationally. Mumbai alone handles about 25% of the domestic and 38% of the International air passenger traffic in the country. Mumbai handles 26% of the domestic air traffic cargo and an average of 40% of the international air cargo traffic in the country.

On entering the new millennium Mumbai walks the razor's edge. By 2010, Mumbai is expected to be housing around 27 million inhabitants, becoming the world's second most populous city after Tokyo. The manufacturing sector is no longer the city's main employer. Increasingly, services are filling the vacuum but in a haphazard way. Competition from other cities, many in South Asia, some in India itself are attracting investment in the services sectors such as financial services, software, media, printing and publishing, etc. For Mumbai to retain its status of Urbs Prima of Indus it needs to organize its resources optimally and adapt sustainable path of development. This is a major challenge for most of the "millennium cities" around the world.
Sustainable Environmental Management and the Need for Environmental Evolution

All the above described features of Mumbai gave a wider scope for development compared to the other cities in the country. Post-independence era of Mumbai witnessed numerous developments both economically and environmentally. In the post-independence history of Mumbai only 1951 census recorded urbanization less than 100% (around 99%). Since then Mumbai has been declared as a complete urban center. Due to abundant employment opportunities migration has been so predominant and till 1971 migrants constituted the major population growth in Mumbai. This has created a wider set of environmental problems viz. lack of sanitation facilities, lack of drinking water, increased incidence of cholera etc. Rapid industrialization took place with most of the industrial clusters located in the vicinity of Chembur, which turned it into a "gas chamber" with exceedingly high concentrations of air pollution (Parikh et al., 1995). Increased economic activity resulted in steep rise in transport demands and the vehicular stock. Increased stock of automobiles most of them being used for decades together created numerous environmental problems. Ambient air concentrations of SPM, NOx and hydrocarbons have crossed the allowable limits creating health problems to the Mumbai public (WHO-UNEP, 1992). Increased incidence of tuberculosis is an indicator for the impacts of pollution on Mumbai population. Urban transport sector is known for contributing greenhouse gas (GHG) to the atmosphere. With further economic development and influence of western cultures, new environmental problems have started cropping up and municipal solid waste and hospital solid waste management are the examples of such development. Increased per capita energy consumption and particularly in an unsustainable way creates much more stress on the environment.

With economic development the set of environmental problems keeps changing. It is apparent from the above description that the concerns of environmental management follow a trend: poverty related issue – rapid industrialization issues – rapid economic growth related issues – wealthy lifestyle related issues. As these issues are cross-sector in nature conventional environmental management dealing with a particular type of problem would not result in sustainable patterns. In this approach the indirect impacts developing out of environmental issue would remain unattended. Therefore, it is essential to adopt a macro approach with an evolutionary perspective. A combination of exogenous and endogenous forces drives the environmental change and to study and understand the dynamics and mechanism of these processes it is essential to understand the evolution of these issues.
Environmental Evolution – Concept and Development

The most significant features of urban issues in many developing country cities is their dynamics. Statistics show that existing cities are growing rapidly in size, and many new cities are emerging. The economic contribution that cities make to their nation’s economy is already significant and still expanding, and the living standard of urban dwellers is improving rapidly. Parallel with these dramatic changes, urban environment is also changing, in terms of significance of certain issues. In cities like Mumbai, the urbanization process is coupled with industrialization and followed by rapid economic growth. As explained by Bai (Bai, 2001), in this process, words like “change” or “growth” can describe the situation far more adequately than “equilibrium” which makes the dynamic viewpoint an inevitable feature in dealing with the urban environment and its management.

The municipalities, which in most countries are the responsible bodies for environmental management lack long-term understanding and planning of environment. They deal with the environment “as it comes to them”. With such an approach, decisions often tend to be short-sighted and lack broadness in scope. Due to this, the great opportunities presented by the risks remain untapped. Because many of the cities are undergoing rapid change now, the environmentally benign future of these cities can still be shaped, at least partly. If these cities can learn from the successful experiences as well as failures of other cities, they might avoid having to pay some of the unnecessary environmental costs their fellow cities have paid. For this purpose, it is essential to have a systematic understanding of how urban environments change and what drives the change.

So far, the dynamic feature of the urban environment is treated as a risk rather than opportunity. It is often shadowed by the overwhelming complexity of the issue. Viewing this as an opportunity needs an improved conceptual and theoretical understanding about what kind of changes are taking place in urban environment, and how the process is driven. In various studies, Bai and Imura (Bai and Imura, 2000; Bai 2001; Bai, 2002) have explained the evolutionary viewpoint of the urban environmental change with empirical evidences from East Asian cities, where the most rapid social, economic and environmental changes have taken place over the last several decades.

The importance of introducing the temporal dimension and an ecological viewpoint in urban environmental studies was pointed out by Douglas (1988) in his study of Manchester City, in which he linked urban growth, physical change and human impact succession. In addition to the temporal dimension, Bai and Imura (2000) further emphasized the importance of viewing urban environmental change as an evolutionary process and outlined the following four elements.
a) Cities can be viewed as complex systems that are subject to constant changes, which can be viewed as a
dynamic evolutionary process.

b) Urban environmental profiles of cities are diverse, but there are certain commonalities in the evolutionary
trajectories among different cities.

c) On the other hand, the environmental evolution of cities exhibits a strong non-linearity in their trajectories,
instead of following a fixed, common pattern.

d) The non-linearity is a result of different mechanism in the evolutionary processes. Each trajectory is shaped
by a unique combination of endogenous and exogenous forces, reflecting both the outer pressures and the
responses within the system.

With the help of the above four points Bai and Imura presented the complexity of the issue within
system, diversity among different cities, dynamic feature, non-linearity or uncertainty in the scenario of urban
environment and the mechanism of urban environmental change.

Resolving the Complexity

Often environmental problems are cross-sectoral and complex. Categorization of these issues into several types
help to reduce the complexity of the issue. This categorization could be done based on various parameters like
type impacts, driving forces etc. Based on the type of impacts, Satterthwaite (1997) divided urban
environmental issues into the following five categories: environmental hazards within the human environment,
high use of those renewable resources that are only renewable within finite limits, high use of non-renewable
resources, high levels of non-biodegradable waste generation and over use of the renewable sink capacity. Based
on the driving forces, the World Resources Institute (WRI, 1997) has divided urban environmental problems
into two groups: one associated with poverty and the other associated with economic growth or wealth. Due to
the globalization of economies and functional specialization of cities, production and consumption activities are
often separated, and therefore become different driving forces for urban environmental problems.

In further such efforts, taking into consideration these different driving forces and the spatial scale of
the impacts of these problems, Bai and Imura (2000) categorized urban environmental problems into three
types: poverty-related issues, rapid-growth and production related issues, and consumption or wealthy lifestyle-
related issues. Poverty-related issues often have limited local impacts, production related issues might have local
to regional impacts, and the spatial scale of consumption related issues could be global. Evidence suggests that
each group of issues has special behavior over economic development. Poverty associated issues generally
decline in severity with economic development. Industrial pollution related issues typically have an inverse-u shape. And consumption associated issues increase with economic development (World Bank, 1992).

**Types of Urban Environmental Issues**

It has been a convention to segregate the environmental related problems into different segments for easy and efficient management of environment. Environmental problems are segmented into water pollution, air pollution, noise pollution, solid waste problem etc. Due to its easiness in handling and executing counter measure, most of the municipalities adopt this segmented pattern of environmental management. However, many environmental problems are not only cross sectoral but also have external impacts which are not captured in the conventional approach of urban environmental management. This ceases the opportunity of synergic action between sectors involved in handling the environmental problems. For instance, focus on air pollution in Mumbai could overlook its contribution to the GHG emission problem. However, by focussing on transportation and related energy issue one can capture both the problems. Better way to go about this cross-sectoral environmental problem is to identify the driving force or categorize them based on the type of impacts. This approach provides an opportunity to capture the externalities of the environmental problems as well. This could encompass most of the direct and indirect indicators of environmentally concern.

Based on the literature and criteria used by other researchers (Bili and Imura, 2000; Satterthwaite, 1997; WRI, 1997), environmental problems in Mumbai are categorized into four groups viz. poverty related issues, rapid industrialization and urbanization related issues, rapid economic growth related issues and wealthy life style related issues. Table I presents typical issues under each category and the major impacts associated and scale of impact.

<table>
<thead>
<tr>
<th>Type I: Poverty related issues</th>
<th>Typical issues</th>
<th>Causes</th>
<th>Major impact</th>
<th>Spatial extent of impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low access to safe drinking water; contamination of water bodies</td>
<td>Inadequate infrastructure; rapid population growth; income disparity</td>
<td>Increased incidence of infant mortality; sanitation related health impacts such as diarrhea, cholera</td>
<td>Local</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type II: Industrialization and urbanization related issues</th>
<th>Typical issues</th>
<th>Causes</th>
<th>Major impact</th>
<th>Spatial extent of impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pollution, Water contamination; industrial solid waste; poor urban sanitation</td>
<td>Rapid industrialization, low rates of emission treatment, lack of efficient management</td>
<td>Industrial pollution disasters like the one in Bhopal, India; disturbance to the ecosystem; health problems like tuberculosis due to air pollution</td>
<td>Local, regional</td>
<td></td>
</tr>
</tbody>
</table>
Behavioral Patterns of Typical Issue

As mentioned by Mrs. Indira Gandhi, the former prime minister of India, *Poverty is the main cause of environmental degradation*. This is particularly true for the poverty related issues. Essentially the poverty related issues of environmental management are prevalent when the economy is low. Lack of safe drinking water and sanitation resulting in health problems is a classical example of poverty related environmental issues. Malnutrition results in increasing infant mortality rates. As the economy rises, income levels grow and it results in controlling these issues. This falling trend of poverty related issues continue until the level reaches a significant low. This could be due to the fact that the growing income provides additional resources and capacity to improve public services.

Macro-economic approach explains the environmental management and its behaviour. When the economy is not strong, production related activity receives the top priority leaving a wider scope for environment deterioration and resource depletion. After achieving a certain level of economic improvement the environment gets better. This pattern is often referred as the Environmental Kuznet Curve (EKC) (Hilton, 1998; World Bank, 1992). Though it is not universally proved for all pollutants, EKC concept explains the behaviour of most of the pollutants against the economic development. The pattern of this inverted U curve varies depending on the environmental regulations, structural changes in the economy, technological improvement, energy efficiency and trade (Grossman and Kruger, 1995).

Category of consumption related issues - rapid economic related issues and wealthy lifestyle related issues, doesn’t improve with the economy. They keep rising with the economy with a possible time lag between them. This trend is observed in cases like per capita municipal solid waste generation, per capita carbon dioxide emissions, per capita energy demand, and other indicators (World bank, 1992). Reasons for this pattern could be - most of these problems are of not much significance for local governing bodies. As they are global in nature they could be easily externalized. Unlike the local pollution problems these issues fail to catch the public notice,
as they are not directly harmful. Thus, there exist very little incentive for the municipal authorities to handle these issues of global importance while they have much more bothering issues to handle in local domain. The future trends of these issues are uncertain. The curves beyond a certain levels of income could stabilize or even decline. But this trend could not be observed even from today’s richest states (Bai and Imura, 2000). In spite of various government initiatives to change the consumption patterns, there is no evidence of any downward turn in these curves (OECD, 1998).

For a poor economy like India, it is possible that the first two types of issues are prominent. However, in the case of Mumbai, it is possible to notice both types III and IV as the per capita income levels are much higher compared to the national average.

Selection of Indicators and Analysis of Trends

For the analysis of the above listed issues, their behavior with time and space, set of indicators are identified for each stage. These indicators are used to compare the characteristics of the current urban environmental situation.

The indicators are listed below in Table 2.

Table 2: Indicators grouped by type of environmental problem

<table>
<thead>
<tr>
<th>Type</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Poverty-related issues</strong></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>Population; population growth rate</td>
</tr>
<tr>
<td>Income level</td>
<td>GDP per capita; income per capita</td>
</tr>
<tr>
<td>Health and welfare</td>
<td>Per capita calories intake; infant mortality; incidence of death from infectious diseases; per capita medical expenses; illiteracy ratio</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Access to drinking water; access to sanitation</td>
</tr>
<tr>
<td>Pollution</td>
<td>Pathogenic contamination of water; incidence of cholera/diarrhea</td>
</tr>
<tr>
<td><strong>Rapid industrialization and urbanization related issues</strong></td>
<td></td>
</tr>
<tr>
<td>Industrial composition</td>
<td>Share of each industry; industrial product growth rate</td>
</tr>
<tr>
<td>Environmental pollution and health impacts</td>
<td>SPM concentration; SOx concentration; water contamination</td>
</tr>
<tr>
<td>Resource use by industry</td>
<td>Incidence of pollution related diseases; water use by the industry; energy use by the industry; material used by the industry</td>
</tr>
<tr>
<td>Employment patterns and urbanization patters</td>
<td>Employment generation industries; level of urbanization; migration</td>
</tr>
<tr>
<td><strong>Rapid economic growth related issues</strong></td>
<td></td>
</tr>
<tr>
<td>Economic growth rate</td>
<td>GDP growth rate; industrial product growth rate; dynamics of purchase power</td>
</tr>
<tr>
<td>Economic crimes</td>
<td>Crime history; police strength; economic crimes</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Dynamics of vehicular stock</td>
<td>Vehicular stock; road length</td>
</tr>
<tr>
<td>Financial statistics</td>
<td>Foreign exchange earned</td>
</tr>
<tr>
<td>Pollution treatment</td>
<td>Pollution control measures; pollution treatment plants</td>
</tr>
<tr>
<td>Resource consumption</td>
<td>Per capita energy consumption</td>
</tr>
</tbody>
</table>

**Wealthy life style related issues**

<table>
<thead>
<tr>
<th>Resource consumption</th>
<th>Per capita water consumption; per capita food consumption; ecological footprints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life style index</td>
<td>Automobile-population ratio</td>
</tr>
<tr>
<td>Pollution</td>
<td>Per capita municipal waste; NOx concentration; chemical contamination of environment</td>
</tr>
</tbody>
</table>

**Note:** Not all indicators are considered for time series analysis, as it is difficult to get city levels data for Mumbai. Episodic explanation was adapted for those indicators, for which time series data is not available.

The first set of indicators represents the poverty related environmental issues. It includes the following indicators - Population dynamics with detailed indicators such as total population and population growth rates; income levels with detailed indicators such as per capita income; nutrition, health and welfare issues with indicators such as infant mortality rate, death from infectious diseases, illiteracy ratio, per capita medical expenses; infrastructure and environmental pollution, with indicators such as access to drinking water and sanitation and incidence of diseases like cholera/diarrhea.

In most of the cases where data is available the indicators are analyzed with data for the post independence period. Figure 1 and 2 presents the trends of population and population growth rates of Mumbai from 1951-2001. The population growth rate has reduced considerably over time and stabilized for the last two decades. Mumbai Population is expected to reach 27 million by the end of 2010. This high population growth is resulting out of high rates of migration into the city. With the ever increasing population and the typical geographical features of Mumbai having a narrow wedge of land with the CBD on this southern tip, the city is growing in northward direction creating numerous numbers of slums. There are more than 600 slums in Mumbai and they registered for about 50% of Mumbai population (ESM, 2002). Providing public services to these unregistered slums is a major challenge for the municipal corporation of greater Mumbai (MCGM). This creates numerous health problems even in today’s developed economy of Mumbai.
With the increasing population, the slum formation has started in 60’s and that eased the number of persons living in each household. This change can be clearly observed in Figure 3. With increasing slums this parameter improved but it resulted in people travelling longer distances for their profession, which puts an additional load on the transport services of the city. The worrying fact is that the travel distances are growing fast and this essentially causes severe traffic congestion at road intersections leading to increase in pollution levels. Increase in income levels also adds to the traffic as people could afford staying at far off place for better accommodation and commute everyday to their work places. Per capita income levels in Mumbai in comparison to the state per capita are given in Figure 4.
Figure 3. Average number of persons living in each household

Figure 4. Per capita income in Mumbai

Maharashtra State has higher per capita income levels compared to other states in India and as it can be observed from the figure, Mumbai has a per capita income almost double that of the state average. There has been a gradual rise in Income for Mumbai since 1951.

The rise in income levels of Mumbai is reflected in the registered deaths presented in Figure 5. There is a considerable decrease in the registered malaria and diarrhea deaths. Malaria and diarrhea are the indicative diseases for poverty related health impairments. At present these two diseases are not among the dominant diseases in Mumbai. Health services are provided by municipality, government and the private sector. Lack of comparable data in respect to these three agencies prevents temporal comparisons. Mumbai’s superiority over

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1 Data on city per capita income (for Mumbai) is available only from 1993
the State (Maharashtra) and India could be noted from the fact that there were 1.53 hospital beds per thousand of Mumbai's population and 0.88 and 0.66 per thousand respectively for the State and India's population in 1971. The availability increased to 3.56 and 3.67 for Mumbai in 1981 and 1986 respectively. The corresponding ratios for 1981 and 1988 were 1.17 and 1.82 for the State and 0.83 and 0.91 for India (Deshpande and Deshpande, 1991).

![Graph showing registered deaths in Mumbai due to various diseases](image)

**Figure 5. Registered deaths in Mumbai due to various diseases**

![Graph showing infant mortality in Mumbai](image)

**Figure 6. Infant mortality in Mumbai**

Infant mortality rate (IMR) is the result of malnutrition and is a good measure for the poverty in any city. Figure 6 presents the IMR for Mumbai over a period of 60 years. There is multi-fold decrease in IMR.

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3 Per capita GDP is not calculated at city level and thus no time series data is available
which is an indication of improved health in Mumbai. Poverty related issues are on declining trend in Mumbai. This is more substantiated by the following facts about Mumbai water supply and sanitation status.

Mumbai is one of those few cities in India where a very high percentage of safe water supply and sanitation is achieved. Estimates of accessibility to drinking water are not available prior to 1981. According to the census of 1981, about 92% of the households had access to drinking water (tap water). Eight years later, 96% of the households surveyed by the BMRDA reported access to safe drinking water (Deshpande and Deshpande, 1991). In 1971 average household received 144 gallons of water per day. The daily supply increased by 4 gallons in 1981 and it has become 174 by the year 1989. Data on the sanitation record over time is not available. But it was reported that 99% of the Island City, 28% of the suburbs and 15% of the extended suburbs are sewer ed in 1971. However, the latest information is not readily available.

Mumbai is the most literate metropolis in the country with 86.82% against the national average of 65.38%. 87.8% of Mumbai male and 75.7% females are literate. This indicates that Mumbai has crossed the level of illiteracy though it is not yet 100% literate. Therefore, most of the indicators under poverty related issues are well above the limits, which indicates that Mumbai has almost cleared the prime of the poverty related environmental issues.

The second set is the measure of rapid industrialization and urbanization. It includes the pattern of industrial growth in Mumbai – number of units and employment generation history, GDP contribution of industrial sector; Urbanization and employment patterns with indicators such as employment patterns, unemployment levels, urbanization ratio, migration levels; resource use and pollution with indicators such as electricity consumption by industries, SPM levels, SOx patterns, water contamination.

Figure 7 presents the number of industrial units in Mumbai during post independence period. Total factories have grown from 4064 in 1961 to a massive 6986 in 1999. However the number of factories has come down in the year 1999/2000. The reasons could be two of the following: Mumbai’s economy going more towards the services sector like software in place of the manufacturing sector. The other reason could closure of a cluster of factories in Mumbai due to various environmental regulations. Mumbai has been the industry dominated city for ages and the peaking of industrial rise was achieved during 70-80’s. Number of workers employed by factories declined during the late 90’s. This trend is presented in Figure 8.
Industries provided a major share of employment in the city. Traditionally Mumbai is an industrialized city with major share of employment coming from industrial sector. In total number of factories in the state of Maharashtra Mumbai housed 49% in 1961. Where as this share has declined to 24% in the year 1999. This is an indication for the changing industrial sector in Mumbai. The same thing is reflected in the share of industrial workers placed in Mumbai's factories. Figure 9 present these trends.
As the industrial sector is manpower intensive Mumbai has been proving tremendous employment potential. Therefore the unemployment levels are less in Mumbai compared to Maharashtra State. However, given the changing scenario of industrial sector, the unemployment levels have started climbing up. This is a mixed pattern of slowed down industrialization and increased urbanization. Figure 10 presents the trend of unemployment in Mumbai in the last three decades. This curve presents the transition between shift over of the industrial sector from production to the services sector. The curve could slope down as the change gets stabilized over time.

GDP contribution from the industrial sector has been significant and it reached the peak during 70-80's. Late eighties and nineties there is a slack in the industrial contribution to GDP.
Mumbai is a surface water based city. Traditionally, a set of lakes provides drinking water to the city of Mumbai. Due to its geographical location, Mumbai is blessed with heavy monsoon and the swollen lakes provide sufficient water to the Mumbai population. Thus drinking water source is different from the effluent discharge streams. Due to this reason the water contamination is not a very serious problem in Mumbai. Unlike the cases of ground water source, surface waters are not prone to the contamination from the industrial effluents unless a back flow occurs due to lowered levels of ground water. However, Mumbai has faced severe air pollution during this phase of rapid industrialization and urbanization (Parikh et al., 1995). Suspended particulate matter (SPM) and SOx levels have gone up considerably. Figure 11 and 12 presents the ambient SPM and SOx concentration in Mumbai. Both the indicators peaked during 70-80's period exactly when the industrialization was at peak. SPM continued its upward trend. Both these indicators have contributions from industry as well as transport sector. Transport sector is not so predominant in 80's and hence the rise in pollution could be attributed to the industrial pollution. This trend of SPM and SOx has resulted in increased incidence of respiratory problems to the residents living in the vicinity of the industrial clusters.

Table 11. Average ambient SPM (annual) concentrations in Mumbai

![Graph showing ambient SPM concentrations](image)

From Figure 5 it can be observed that the chronic ailments like tuberculosis incidence rose during 80's. In an economic analysis of air pollution it was proved that the air pollution in Chembur, an industrial zone of Mumbai resulted in increased mortality and morbidity in Mumbai (Parikh et al., 1995). Increased incidence of brachial problems was the clear indication of increased air pollution in that industrial zone nick named "gas chamber" due to its pollution. Due to the increased incidence of pollution, the government of Maharashtra during 80-90's has shut down clusters of textile mills.
Table 12. Average ambient SOx concentrations (annual) in Mumbai

Figure 13. Pattern of urbanization in Mumbai

Mumbai has been declared as a 100% urban center. However, the patterns of share of population shared by the island and suburbs present an interesting scenario. Share of population between island and suburbs reversed with time. After 40 years time suburbs of Mumbai are hosting a similar population share of Mumbai as that of island in 60’s. This essentially indicates that the city is growing into suburbs leaving all the administrative and business centers in the island city. This has resulted in increased travel and the resulting pollution. Figure 13 presents the urbanization trends in terms of the share of suburbs in the greater Mumbai population. Till 1971 the island population was dominating. The suburb population has outpaced island population by far in 1981 census. This is interesting to observe that this change has occurred during the peak industrialization. Figure 14 presents the post independence migration pattern in Mumbai.
The third set (type III) of indicators is a measure of environmental issues in the rapid economic growth stage. India has undergone economic reforms in 1993 and the pattern of many indicators had a change thereafter. This phenomenon is clearly observed in Figure 15. Since 1993 a steep upward trend is noticed in the foreign exchange earned.

Increased economic activity and the resulting increase in the income levels (as shown in Figure 4) enhanced the affordability of Mumbai public, which is reflected in the vehicular stock in Mumbai. Figure 16 presents the pattern of vehicular stock in the Mumbai City over the last 50 years. Many of the urban transport indicators indicate that Mumbai traffic is on rise. There is considerable increase in personalized transport mode
though Mumbai continues to rely mostly on public transport unlike any other metro city in India. Energy demand from transport sector is estimated to grow 3folds by 2020 (IGIDR, 2001). This has resulted in tremendous increase in air pollution and also various green house gas emissions. The per capita CO₂ emission has gone up leaving serious concerns for the global environmental strategists.

Figure 16. Dynamics of vehicular stock in Mumbai

Nineties have seen many environmental regulations to control local emission from transport vehicles. Introduction of CNG and stringent standards for the new petrol and diesel vehicles controlled the emission of local pollution substantially. However, Global emissions are on rise. Vehicular emissions add to the ambient NOx concentrations. Figure 17 presents average ambient NOx concentrations in Mumbai. As this can be observed from the figure, there is a rise in NOx concentration after 1990, which is due to rise in number of vehicle registered. Subsequent emission regulations have resulted in reduction of NOx emissions.

Figure 17. Average ambient NOx concentration in Mumbai
Electricity consumption in Mumbai has increased substantially. Industry and commercial sectors have equal share in the electricity consumption. Figure 18 presents the number of unit of electricity sold in Mumbai over a period of time. There is a steep rise from late eighties. This rise in consumption could be attributed to economic growth and increased per capita incomes as well as increased economic activity.

![Figure 18. Electricity consumption in Mumbai](image)

During the period of economic jump, property prices rose in Mumbai. Figure 19 presents property prices of the main land area and major western suburb - Borivali. In particular the prices have gone up substantially during the post reforms period (Figure 19). It is interesting to see the rate of change in value is still higher in the Island City compared to the suburb. This rise in real estate value adds further to the generation of pollution with the increased travel of people from suburbs to the city center for their jobs.

![Figure 19. Property prices in Mumbai both at Island City and the suburb](image)

3 per capita energy consumption data is not available for Mumbai and hence this is taken as a proxy for per capita energy consumption.
in petrol and gas reserves are the indicator of this category of issues. Figure 20 shows the changes in per capita solid waste generation in Mumbai over last few decades. The percentage of growth in solid waste has increased considerably which is an indicator of increased consumption patterns and rich life style that Mumbai public enjoys. With the influence of western “throw away” culture and rise in packed food market, municipal solid waste management has become a major concern of the municipal authorities. Lack of proper institutional arrangement to force recycling and reuse and also lack of economic tool in controlling waste generation made things worse. Municipal solid waste (MSW) management is one of those very serious problems that Mumbai is facing at the moment. This not only creates local and regional concerns but also global concern as open dumping of solid waste emits methane and CO₂ to the atmosphere causing global warming. Burning of waste generate many obnoxious gases which are extremely harmful to humans. As there is no proper landfill in Mumbai, all the garbage is heaped in open dump creating numerous problems mostly, which are external in nature and difficult to capture in formal valuation of the system. There is no incineration unit in Mumbai for compost coming out of aerobic compost

![Figure 20. Per capita municipal solid waste generation in Mumbai](image)

*Data is not available prior to 1990. Future values are projected by us in some work to be published*
The fourth set of indicators (type IV) measure the environmental issues resulting out of wealthy lifestyle. This category of indicators is prominent in rich cities. Their significance is very little in Indian context. However, given the different economic status that Mumbai enjoys among the Indian cities, there are traces of these indicators showing significance in the case of Mumbai. Municipal solid waste generation, electricity consumption, changes in petrol and gas reserves are the indicator of this category of issues. Figure 20 shows the changes in per capita solid waste generation in Mumbai over last few decades. The percentage of growth in solid waste has increased considerably which is an indicator of increased consumption patterns and rich life style that Mumbai public enjoys. With the influence of western “throw away” culture and rise in packed food market, municipal solid waste management has become a major concern of the municipal authorities. Lack of proper institutional arrangement to force recycling and reuse and also lack of economic tool in controlling waste generation made things worse. Municipal solid waste (MSW) management is one of those very serious problems that Mumbai is facing at the moment. This not only creates local and regional concerns but also global concern as open dumping of solid waste emits methane and CO₂ to the atmosphere causing global warming. Burning of waste generate many obnoxious gases which are extremely harmful to humans. As there is no proper landfill in Mumbai, all the garbage is heaped in open dump creating numerous problems mostly, which are external in nature and difficult to capture in formal valuation of the system. There is no incineration unit in Mumbai for MSW. Thus there is no threat of dioxins at the moment. However, compost coming out of aerobic composting of MSW was found causing “metal poisoning” in the agriculture.

Figure 20. Per capita municipal solid waste generation in Mumbai⁴

⁴ Data is not available prior to 1990. Future values are projected by us in some work to be published.
Mumbai houses India's biggest oil and gas reserves. It caters the energy needs of Mumbai. With the increased energy needs and also consumption, a decline in the gas reserve is notice, which is presented in Figure 21. However, this fact cannot be ignored that this decline in gas reserve share the energy needs of the other cities that they cater.

![Graph showing gas reserves in Mumbai](image)

Figure 21. Gas reserves in Mumbai

Therefore, the stage IV type issues are also could be identified and analyzed in Mumbai. Though it is not possible to predict the future trends/behavior, it helps in assessing the "environmental status" of the city.

**Trends curve for Mumbai**

Mumbai is regarded as having one of the best off public sector services among Indian cities. In spite of that fact, poverty levels are still high and over crowding is causing lapses in the system. However, the significance of poverty related environmental issue is not very high. Most of the indicators under this category revealed steep declining trends. Figure 22 presents the illustration of different types of environmental problems spanned over economic growth in Mumbai. To facilitate the cross comparison, a representative indicator from each category of environmental issues viz. poverty related issues, industrialization and urbanization related issues, rapid economic growth related issues and wealthy lifestyle related issues is selected and normalized with respect to the corresponding maximum value. Figure 22 presents the behavior of each indicator against time. This presents the empirical evidence for the stage model proposed and presented by Bai and Imura (Bai and Imura, 2000; Bai, 2001; Bai, 2002). The entire graph can be divided into four different zones viz. poverty zone, industrialization and urbanization zone, rapid economic growth zone and wealthy lifestyle zone. Where the first zone is clearly demarcated, II, III and IV zones are closely clustered. This indicates that three zones are coexisting. However, it is possible to identify which one is predominant and in phasing out stage.
Future trends of electricity consumption (stage III) and waste generation (stage IV) cannot be predicted. Given the projected values of MSW it is possible to see that indicator growing with time. A similar trend can be expected with electricity also. As it can be seen from Figure 22, Mumbai at present stands at Stage III facing more of rapid economic growth stage related environmental issues. Poverty related issues are not of major concern any more where as there is a spill over from stage II, industrialization and urbanization related issues. Stage III issues and Stage IV issues coexist in Mumbai with both of them following rising trends. There is a time lag between stage III and stage IV.

Policy Implications

The next stage (stage V) could be "Eco-city stage" which is not seen in the Figure 22. For the case of Mumbai, there exist a possibility to channel through the upward curves of stage III and stage IV to reach stage V, the eco-city stage. Municipal authorities can make policies for cleaner production and energy conservation accordingly to achieve environmentally sustainable development in Mumbai. Policies for improved waste management is the need of the hour and so the measures to reduce the energy consumption. Measures to improve public transport would reduce the contribution of GHG to the atmosphere from the mobile sources.

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