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BENCHMARKING URBAN SUSTAINABILITY - A COMPOSITE INDEX FOR MUMBAI AND BANGALORE

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Indira Gandhi Institute of Development Research, Mumbai
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Abstract

The study investigates whether the present pattern of urban development in India in the creation of mega cities is sustainable and what it can learn from the global megacities. This has been done by comparing the two Indian cities Mumbai and Bangalore with selected mega cities of the worlds representing different stages of development (Shanghai, London, and Singapore) using an indicator-based approach under a sustainability framework. The prioritised indicators under the three dimensions of sustainability - economic, social and environmental - are included for the comparison. The approach is used for developing dimension-wise sustainability indices as well as composite urban sustainability indices (USIs) for all the chosen cities. In the next step, these index values are compared with the hypothetical benchmark urban sustainability index values and sustainability gaps are identified. These gaps essentially represent the targets for achieving sustainable urbanization. The results indicate that compared to benchmark index values, both Mumbai and Bangalore have large gaps to bridge with respect to economic sustainability where as they relatively better placed with respect to social and environmental sustainability. Among the five cities, Singapore emerges at the top with a high USI value and Bangalore and Mumbai occupy the last two positions respectively. We believe that the indicator-based approach represent a primary tool to provide guidance for policy makers and to potentially assist in decision-making and monitoring local strategies/plans. The outcome of the study will contribute to the design of policies, tools, and approaches essential for planning to attain the goal of sustainable development and the social cohesion of metropolitan regions.

Keywords: Benchmarking, Gap analysis, Indicator, Sustainability, Urban

JEL Code: Q4,L94,L95,L98

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1. INTRODUCTION

Cities are at the forefront of global socio-economic change and rapid urbanisation is a socio-economic phenomenon of the 20th century. Half of the world's population now lives in urban areas and the other half increasingly depends upon cities for economic, social, cultural and political sustenance. Urbanisation is occurring at an accelerating pace in developing countries, accompanied by the creation of some very large urban aggregations and megacities. Urbanisation[1] is now commonly regarded as one of the most important social processes and has enormous impact on the environment at local, regional and global scales. It is now widely acknowledged that the impact of urbanisation will continue to bring about major global and local changes in economic, environmental and social arenas (Anon, 2000).

Urbanisation results in major irreversible changes in production and consumption styles impacting the carrying capacity of the earth significantly. A city devours acres of land and materials for infrastructure like highways, water supply and power. It intensifies traffic problems on commuting roads from a city's central location to suburban areas. Hence, it is important to study the rapid urban change that is likely to take place in developing countries

[1] A shift from a predominantly rural to a urban society. Urbanization is not synonymous with urban sprawl. It is a process of sustainable densification with respect to urban environment and eventually upgrades a city into a metropolis.

that are least equipped with the means to invest in basic urban infrastructure—water, sanitation, housing—and are unable to provide vital economic opportunities for urban residents. It is surprising to note that urbanisation process is being viewed through a 'sustainability' lens[2] only lately.

In the context of rapid urbanization in developing countries, it is essential to apply the concept of sustainability in policy and planning decisions. However, the criteria for sustainability differ between developed and developing countries. These differences prohibit us from transferring the models of sustainability from advanced societies to those which lag behind. In such a scenario, we have to develop different indicators to assess urban sustainability. These indicators play an important role in turning data into relevant information for policy makers and help in decision-making. They also help in simplifying complex information. Indicators are now well established and are widely used in different fields and at various levels, viz., global, regional, national, local level (Anon, 2000). Examples of indicators include such measurements as GDP (Gross Domestic Product) as a way of assessing economic development in a country, the infant mortality rate (IMR) as an indicator of the health status of a community, or the rise in carbon emissions as a way of estimating the environmental conditions of a region. The main criteria for the selection of indicators are: (i) easily understood by stakeholders; (ii) measurable using the available data at city and national levels; and (iii) related to policy goals and capable of being changed. To be useful, indicators should be user-driven and depend on factors and the purpose for which they are used.

Our main aim in this study is to investigate if the present pattern of urban development in India in the creation of mega cities is sustainable. This is proposed to be done by performing an indicator-based evaluation of Mumbai and Bangalore against some benchmark sustainable cities (London, Singapore and Shanghai). Thus, the objectives of the study are: (i) developing sustainable urban indicator variables spanning all the relevant sectors of a typical megacity, (ii) developing a benchmark sustainable indicator-base for a benchmark megacity, (iii) by adopting a similar methodology and similar indicators develop a database for Mumbai and Bangalore in India, (iv) comparing and evaluating the indicator

[2] Sustainable urban development means achieving a balance between the development of the urban areas and protection of the environment with an eye to equity in employment, shelter, basic services, social infrastructure and transportation.

data with the benchmark indicator database using "gap analysis" approach, (v) comparing Mumbai and Bangalore cities with selected mega cities of the world on sustainability benchmark, and (vi) suggesting appropriate policy measures and implementation strategies to bridge the identified gaps to attain the goal of sustainable urban system. In this context, the economic, social, environmental and the governance sub-systems of an urban system are proposed to be studied.

2. METHODOLOGY

2.1 Literature Review

Ever since sustainable urban development[3] became the catchword in most international discussions, several approaches to its assessment have sprung up. To assess urban sustainability, indicators are crucial for target setting, performance reviews and facilitating communication among policy makers, experts and public. A wide range of indicators is therefore in use across the diversity of different cities and regions, which vary according to particular needs and goals (Verbruggen and Kuik, 1991; Brandon and Lombardi, 2005). However, practical challenges have led to mixed results in applying sustainability indicators in different environments and sometimes with little gain in sustainability performance (Alshuwaikhat and Nkwenti, 2002; Seabrooke, Yeung, and Ma, 2004; Selman, 1999). It has been argued that a significant reason for failure to attain the desired performance is the inadequate selection of indicators guiding and monitoring the sustainable urbanization process (Briassoulis, 2001; Seabrooke *et al.*, 2004). It has also been argued that the lack of consensus on urban sustainability indicators between different practices has been causing confusion when selecting and relating them with the objectives defined or policies implemented (Planque and Lazzeri, 2006; Nathan and Reddy, 2011; Hardoy *et al*., 2001; McGranahan *et al*., 2005 and Grimm *et al*., 2008) have documented the battle for sustainability highlighting the importance of cities in pursuit of broader sustainability goals. Despite the fact that there is a rapidly growing literature on ‘‘good’’ urban practices, very little is known about how they are practiced and their role in policy-making processes (Bulkeley, 2006). Attempts have been made to study the extent to which cities are becoming

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[3] Sustainable urban development is that which develops and grows in harmony with, and can reinforce the productive potential of, their life-support environments, ranging from local and regional to global ecosystems (Huang *et al*., 1995).

sustainable or unsustainable through the use of indicators and the challenges that are encountered in the process (Bell and Morse, 1999; Briassoulis, 2001; Wong *et al.*, 2006; Roy, 2009; and Tanguay and Rojaoson, 2010).

A comprehensive list of urban sustainability indicators is composed by using various sets of indicators promoted by international and regional organizations, such as the European Commission on Science, Research and Development (2000), the UN Habitat (2004), the United Nations (2007), the World Bank (2008). The purpose is to have a comprehensive list as a comparative base. However, what is important is that the process of selection should not be to gather the data for all indicators, but rather select those that are likely to produce the most accurate information about the status of practice (Shen *et al.*, 2011).

2.2 Scope

For the present study, the sustainability issues concerning urban systems have been divided into broad groups of indicators, viz., economic, social, environmental institutional/governance systems. The prioritization of categories of urban sustainability indicators has been made with the support of literature and logical assessment (Zainuddin 2005; Theo and Frank 2007; Peter 2009; UNHABITAT 2009; Silverio and Jesús 2010; Stewart 2010, Matthew and Giles 2010; GCIF 2011, Lynch *et al*, 2011, Shen 2011, Marzukhi et al, 2011, Natalie 2011). This process facilitated short-listing of 25 categories of sustainability indicators under four dimensions of sustainability.

- *Economic Sustainability*—Capture the current as well as the dynamic economic strength of an urban system.
- *Social Sustainability*—Map the extent of equitable distribution of the benefits of economic development to the people.
- *Environmental Sustainability*—Assess the conformation of economic development to environmental standards.
- *Institutional/Governance Sustainability*—Measure the extent and effectiveness of institutions in creating opportunities like employment, financial resources, community services, government support, etc.

2.3 Framework

In real-life situations, indicator values have different measurement units (income in local currencies, electricity in KWh, etc.). For developing composite indicators, it is essential to transform the values of all these indicators into some standard form. Thus, for each of the indicator included in the analysis, a relative indicator is estimated using the actual and the sustainability threshold values. For each indicator, a minimum and maximum threshold value will be determined. The relative indicator is developed using a scaling technique where the minimum value is set to 0 and the maximum to 1. The equation used for this is

$$\text{Relative indicator (or Dimension index)} = \frac{\text{Actual value} - \text{Minimum threshold value}}{\text{Maximum threshold value} - \text{Minimum threshold value}} \quad \text{-- (1)}$$

The next step is to derive the composite indicator dimensions from appropriate indicators belonging to that particular dimension. There are two ways to develop the composite indicator dimensions. One is to use the weights of the indicators in relation to a given dimension and combine the indicators to form a composite indicator dimension. The other is where the indicator weights are not available, the composite dimension index is computed as the root mean square of the relative indicator variables belonging to that particular dimension. The equation used is as follows:

$$d_j = \left(\frac{\sum_{i=1}^{I} V_{ij}^2}{I}\right)^{0.5} \quad \text{--------------------------------} \quad (2)$$

where, d_j = Dimension of type "j"

V_{ij} = Variables "i" belonging to dimension "j", i = 1, 2, …., I

I = Number of variables in a dimension

Further, a composite urban sustainability index, the USI, has been developed from these dimensions that are assumed to contribute to the issue of urban sustainability. If the dimension weights are not available, the following equation could be used

$$USI = \left(\frac{\sum_{j=1}^{J} d_j^2}{J}\right)^{0.5}$$

where, USI = Urban sustainability index

d_j = Dimension "j", j = 1, 2, …., J

J = Number of dimensions

2.4 Benchmarking Urban Sustainability—A Gap analysis approach

As stated earlier, the indicators of sustainability for each of the dimensions that is being determined for Mumbai and Bangalore cities will be compared with the benchmark indicators of a hypothetical sustainable mega city developed using maximum and minimum threshold values of sustainability indicators. The values will be derived from the best and the worst values obtained for a given indicator by any city in the world. In the first step, the standardized indicator dimensions for both the study cities (Mumbai and Bangalore) and the sustainable city will be mapped on a radar diagram (a hypothetical depiction of such mapping). The distance between the two points of a given dimension for the two cities gives the prevailing gap. The dimension gaps for the study city suggest how far they are from achieving the level of a benchmark sustainable city, and also provide insights into the dimensions seriously lacking. Thus, the quantified gaps in dimensions as well as individual indicators can provide greater insights into the reasons for the existence of such sustainability gaps, targets that need to be fixed to bridge them and strategies that need to be adopted for achieving these targets.

For the present study, the indicator data were gathered mainly from secondary sources of information such as journal papers, reference books, government reports, project reports, websites of concerned government departments and ministries, websites related multilateral agencies and variety of databases from the internet (Worldatlas 2012, UNHABITAT 2012, Bangalore Census 2011, BBMP 2011, BRSIPP 2011, Chaudhuri 2011, John 2011, Siemens 2011, TERI 2011a, WHO, 2011, Anonymous 2010, Mahendra *et al.,* 2010, Singh 2010, World Bank 2009, Gopakumar 2008, Sitharam 2008, and Sekher *et al., 2008*). We could gather data for 48 indicators under economic dimension (original list had 56 indicators), 45 indicators under social dimension (original 52 indicators), 36 indicators under environmental dimension (original 42 indicators) and six indicators under institutional/governance dimension (original 13 indicators). Thus, we could gather data for both Mumbai and Bangalore cities for a total of 135 sustainability indicators.

3. RESULTS: A COMPARATIVE ANALYSIS OF MUMBAI AND BANGALORE

3.1 Demographic profile

The demographic base of Mumbai and Bangalore is structurally different and distinct in terms of overall size and features. Mumbai is historically an urban region, an industrial power house and a port city. On the other hand, Bangalore’s growth dates back to 1980s after information technology became prominent and fuelled in part by a strong in-flow of migrants, particularly educated youth. Mumbai constitutes only 0.16 per cent of the area of the state of Maharashtra, but is home to 16.4 per cent of its population. This results in a very high population density (28,330/km^2) which is 90 times higher than that of the state as a whole. Mumbai is the administrative and commercial center of Maharashtra with many national and international enterprises having their headquarters here. It is also a seat of manufacturing industries, above all electro-technical and chemical industries and manufacturing of fabricated metal products. Comparatively, Bangalore has a larger land area (741 km^2) and uses much of its land for housing, industry and parks. The Bangalore Urban Agglomeration has grown faster than Mumbai between the years 1981 and 2011. During the last decade, Mumbai's population grew by 10.4 per cent whereas that of Bangalore grew by 65.2 per cent. A key feature of population growth in Bangalore is that most of the growth is taking place in the surrounding areas. However, the population density of Mumbai is higher than that of Bangalore thus necessitating different kind of long-term planning and significant investments for improved service delivery. The land-use data indicate that the residential area of Mumbai constitutes 38 per cent followed by an equal percentage by green cover under forest land and agriculture. In Bangalore, the residential areas comprise around 43 per cent. The green cover per person in Bangalore (2.55) is slightly higher than that in Mumbai (2.01) (Table 1).

3 2 Assessing indicators for Mumbai and Bangalore

Here we try to assess how mega cities in India perform against sustainability yardstick. In other words, the objective is to compare Indian megacities with a sustainability benchmark established using prioritized and classified list of indicators. The data obtained for all the dimensions (Economic, environment, social and institutional) are presented in Tables 2–5.

Economic sustainability: This constitutes a subset of five indicators formulated to evaluate the economic performance of the city in terms of income, growth, consumption, infrastructure and transportation. Of the individual indicators, income and growth showed good performance for both Mumbai and Bangalore, while on infrastructure front, the performance is poor. Water is the basic resource for human life. The quality and use of water impact the health of the city dwellers, soil and nature quality. The per capita water use for Mumbai (208 l) is nearly double that of Bangalore (129 l). Similar is the case with energy use. Mobility patterns and policies play a significant role in deciding the quality of urban environment. A high dependency of personal transport negatively affects parameters such as air quality, noise, and liveability. On the other hand, the density of public transport network plays a very important role in the sustainable mobility of a city. For Bangalore, the accessibility of public transportation infrastructure is 46 per cent and hence the automobile ownership (no/family) is very high (1.7). In case of Mumbai the figures are 88 per cent and 0.36, respectively suggesting good performance. These indicators relate to the effective use of public transport which reflects on energy efficiency and resulting emissions (Table 2).

Social Sustainability: Achieving social sustainability requires three components that include: individual basic needs such as food, shelter, education, and health, and community needs such as safety and meeting/recreation facilities. These components support four guiding principles, viz., equity, social inclusion, security, and adaptability. Educational opportunities are a major focus of social sustainability. Education provides employment and the workplaces provide a place for social contact and interaction which is essential to improve the feeling of social wellbeing of citizens. Even though school enrolment ratio is high (over 95 per cent) both in Mumbai and Bangalore, the percentage of students completing secondary education is only about 83 per cent indicating a dropout of about 12 per cent. Provision of social infrastructure like location and number of schools, medical facilities, etc., impacts social sustainability of the city. In both the cities, for every 10,000 population, the number of beds in hospitals is around 20 and the number of physicians around 5 resulting in high infant mortality rate (> 30). Mumbai and Bangalore differ from each other in relation to piped water connection, LPG connections and sanitation. In all the three parameters, Bangalore scores higher over Mumbai (Table 3).

Environmental sustainability: Urbanisation results in higher income-generating opportunities resulting in higher resource use. Infrastructure and public services (including environmental protection) do not match this growth that results in a decline in urban environmental quality. Since cities are densely populated, air pollution is a critical issue due to the impacts that pollutant concentrations have on the health of their inhabitants. With regard to global and local air pollution, all the values for Mumbai are double of that of Bangalore. Fine particulate matter (PM10) concentrations are 90 in Bangalore and 132 in Mumbai which are significantly higher than the 2010 limit value of 40 $\mu g/m^3$. Bangalore shows lower CO_2 per capita emission (0.5/cap). Waste is one of the key evaluation parameters of environmental sustainability since it plays a significant role in living and environmental protection. It also impacts significantly other parameters such as saving of non-renewable raw materials, protection of soil and water production sources. Mumbai managed to contain the household production of waste under 209 kg/cap/year while in Bangalore it is 266.5 kg/cap/year. In Bangalore, there is a well-functioning waste management system which recycles 80 per cent of waaste. A part of the remaining waste is incinerated with energy recovery and the balance goes to landfills. In Mumbai, the household recycling rate is under 32.4 per cent and only a very small portion of the waste goes to landfill (Table 4).

Institutional sustainability: The institutional sustainability focuses on interactions between the government and the public and emphasises the role of these institutions in their development through actions. In other words, an institutional analysis attempts to explain a phenomenon (in the present case, performance of the government) by focusing on the rules and regulations and the interactions that govern them. In Mumbai the number of councillors per thousand population is 0.012 and it is 0.023 for Bangalore. It has been observed over the years, that during elections, voter participation is significantly low in urban areas compared to their rural counter-parts. This has been the case even in these cities. However, the brighter side is the greater female participation (Table 5)

3.3 Comparing Indicators of Urban Sustainability

As stated earlier, the objective is to develop a composite sustainability index for both Mumbai and Bangalore cities , which is achieved by consolidating individual indicators under each category to form the composite indicators. However, as observed from the tables there are different indicators with different values and units of measurement and their ranges are large. In such a case, a normalization procedure is employed to convert all the indicator values into a single form using the same unit of measurement. However, for normalizing the indicator values, we need the maximum and minimum possible values of the same indicators. In the present case, data for each of the indicators are gathered taking the maximum value from the city with the best value for that indicator in the world. Similarly, we need to choose a city with the worst value for that particular indicator. In other words, we need to have cities (same city can be repeated) with the best and worst values for every indicator. This results in threshold values (maximum and minimum) for every indicator. For the present study, the data are obtained from the literature with best and worst values for every indicator (Table 6) (NUMBEO 2012, World Atlas 2012, UNHABITAT 2012, John 2011, Rode and Kandt 2011, Siemens 2011, WHO, 2011, Edward 2010, UNHABITAT 2010, PWC 2009, World Bank 2009, UNHABITAT 2009, UNHABITAT 2008). Because of unavailability of data on institutional and governance dimension, regretfully, the category has been dropped from the analysis.

To make sustainability indicators easier to calculate and more comprehensive, this study standardizes indicator values so that each standardized value falls between 0 and 1, which facilitates the weighting of sustainability indicators in the future The estimated normalized indicator values for both Mumbai and Bangalore cities are given in Table 7.

3.4 Composite Indicator Values of different Categories and Dimensions of Sustainability

Now we derive the composite indicator values for different categories of sustainability from appropriate indicators belonging to that particular category. Further, these category-wise indicator values are used for developing composite indicator values for various dimensions of sustainability (see equation 2). The next logical step in indicator analysis for benchmarking urban sustainability is to develop a composite USI. This provides a single number (within the range of 0 and 1) for comparing the level of sustainability reached by a city or an urban system. The USI is developed using the composite indicator values of the three dimensions that are assumed to contribute to the issue of urban sustainability. The modified equation that is used for developing USI is as follows:

$$USI = \left(\frac{\sum_{j=1}^{J} d_j^2}{J}\right)^{0.5}$$

where, USI = Urban sustainability index

d_j = Dimension "j", j = 1, 2, …., J

J = Number of dimensions

The category- and dimension-wise composite sustainability indicator values and the USI, estimated using the above equation, are presented in Table 7. We observe from the table that Bangalore city performs better than Mumbai in most categories of sustainability indicators. In other words, Bangalore is more sustainable compared to Mumbai over most category-wise composite sustainability indicators. Under economic dimension, Bangalore is more sustainable compared to Mumbai with respect to all the categories, the differences being more significant with respect to indicator categories like consumption. In Social dimension, Bangalore's conformity to sustainability is higher than that of Mumbai with regard in all categories expect health. Under environmental dimension, the status remains the same except for categories like water pollution and energy consumption. Over these two categories, Mumbai outperforms Bangalore. The good performance of Bangalore in category-wise sustainability indicators naturally gets translated into good performance even in the case of dimension-wise sustainability. Bangalore is thus more sustainable compared to Mumbai with respect to all the three dimensions; economic, social and environmental. With respect to economic sustainability, Bangalore has an indicator value of 0.567 compared to Mumbai's 0.459. Similarly, in the case of social sustainability, Bangalore has a value of 0.724 compared to Mumbai's 0.630. Finally, in environmental sustainability, Bangalore scores 0.722 and Mumbai 0.671. The estimated USI for Bangalore is 0.675 compared to 0.594 of Mumbai (Table 8). It may be appropriate to reiterate here that these indicator values fall between 0 and 1 indicating the least and the highest sustainability.

It is important to remember again that these are relative index values and not absolute ones. Conceptually, the maximum USI of 1.0 is obtained by using the best or highest values for each of the indicator variables under different categories and dimensions. Thus, a city with USI of 1.0 is a hypothetical one with the highest achievement on sustainability radar. Similarly, the hypothetical city with 0 USI has the least achievement. Thus, all the cities in the world on a sustainability scale will fall in between these two limits. Similarly, the USIs of Bangalore and Mumbai need to be viewed from this context.

4.URBAN SUSTAINABILITY—COMPARISION WITH BENCHMARK CITIES

4.1 Profile of select cities

Here, we compare Mumbai and Bangalore with realistic benchmarks—one each from Europe (London) and China (Shanghai), and a city-country (Singapore). The cities are profiled in Table 9. Mumbai, Singapore and Shanghai have approximately similar gross domestic product (GDP) and per capita income too. London and Singapore are richer of all the cities under consideration. Such similarities are seen even with respect to other indicators too. For example, GDP growth rates are approximately the same for Bangalore, Mumbai and Singapore; and population is growing at the same rate in Mumbai, London and Shanghai. Bangalore and London at the lower end, and Mumbai and Singapore at medium level have similar levels of energy consumption in relation to GDP. Both Mumbai and Bangalore have approximately the same levels of per capita electricity consumption. Shanghai consumes the highest amount of energy in relation to GDP whereas in Singapore the per capita electricity consumption is the highest. These inferences suggest that there are similarities as well as differences among the chosen cities with respect to economic, demographic and resource use indicators. We feel that comparing and benchmarking Mumbai and Bangalore with this set of cities would be more appropriate rather than using a single city.

4.2 Quantifying and normalising indicators of Urban Sustainability

For the process of comparing the cities we gather the required data for quantifying all the prioritized indicators (NUMBEO 2012, Samuel *et al.*, 2012, World atlas 2012, UNHABITAT 2012, Bangalore Census 2011, BBMP 2011, BRSIPP 2011, Chaudhuri 2011, John 2011, Rode and Kandt 2011, Siemens 2011, TERI 2011a, WHO, 2011, Anonymous 2010, Edward 2010, Mahendra *et al*., 2010, Singh 2010, UNHABITAT 2010, GOK 2009, PWC 2009, World Bank 2009, Chanakya *et al.*, 2008, Gopakumar 2008, Sitharam 2008, Sekher *et al.*, 2008). Even after significant efforts, we could not gather the data for all the indicator variables. The requirement is to get data for a given indicator for all the cities. Where we could not get the data even for a single city, then that indicator was not used making our task even further difficult. Finally, we could gather data for only 22 indicators under economic dimension (original list had 56 indicators), 22 indicators under social dimension (original 52 indicators), and 16 indicators under environmental dimension (original 42 indicators). Thus, we have gathered data for all the five cities as well as for two threshold limits for a total of 60 sustainability indicators. In this process, we have ensured meeting of minimum requirement in terms of a number of indicators for every category of sustainability. The data obtained for all the indicators are presented in Tables 10– 12. The estimated normalized indicator values for all the five cities are given in Table 13.

4.3 Composite indicator values for different categories and dimensions of sustainability

The category-wise estimated composite sustainability index values for the three dimensions of sustainability are presented in Table 14. These estimates have been derived for all the five cities. If we use category-wise index values as performance measure of sustainability, cities have performed better with respect to different categories. For example, under the dimension of economic sustainability, London has the best index value of 0.601 for income, Singapore for growth/development (0.778) and Shanghai for consumption (0.641). Under economic dimension, Bangalore does well with respect to growth/development with a value of 0.656, which is higher than that of Mumbai and London. The index value of 0.454 obtained for consumption by Bangalore is higher than that scored by Mumbai and London, and is very close to Singapore's.

Under the dimension of social sustainability, Shanghai has the best index values for demographics and health whereas Singapore obtains high value for equity, safety and access to basic needs. London tops in education and access to basic needs, which it shares with Singapore. Bangalore obtains relatively high value for education, equity and access to basic needs; however, among the five cities it is in third position with respect to equity and in fourth position with respect to other two categories.

Bangalore scores 1.0 for global climate change under environmental dimension whereas Mumbai tops with 0.844 for energy consumption. Singapore is best under environmental sustainability dimension by obtaining high values for air, soil, and water pollution, and urban green spaces. This indicates that Singapore is the most environment-friendly city among the five chosen for analysis. In relation to other cities, Bangalore does well with respect to global climate change (top), energy consumption (second after Mumbai), urban green spaces (second after Singapore) and water consumption (second after London). However, it is in the last position in water pollution. Overall, Bangalore's performance with respect to environmental sustainability appears to be better compared to social and economic sustainability dimensions.

Category-wise index values are used to construct dimension-wise sustainability indices. Table 15 presents the estimated index values for three dimensions of sustainability for all the five cities along with a composite USI for overall comparison. This provides a single number (within the range of 0–1) for comparing the level of sustainability reached by a city or an urban system. The USI developed of three dimensions—economic, social and environmental—is assumed to contribute to the issue of urban sustainability.

We may observe from the table that Shanghai has the best value of 0.60 for economic sustainability and Singapore for both social (0.926) and environmental (0.784) sustainability. In comparison, Bangalore with values of 0.519, 0.715 and 0.720, respectively, for economic, social and environmental sustainability dimensions is better only in relation to Mumbai. Both Bangalore and Mumbai fare better than Shanghai in environmental sustainability. All these suggest that Mumbai and Bangalore need to do lot more to climb the ladder of sustainability. The USI value of Mumbai is 0.590 is the lowest among the five cities and Bangalore is ranked fourth with Singapore topping the list with 0.773.

4.4 Benchmarking Urban Sustainability— Comparing five cities

Figure 1 shows the benchmarking of Bangalore and Mumbai for economic sustainability against three cities with different sustainability index values. It may be observed from the figure that all the five cities are quite a distance away from the highest economic sustainability index value of 1. Out of the five categories under economic sustainability dimension, only with respect to Growth/Development indicator, the values have crossed 0.6 and are approaching 0.8. This relatively good performance is mainly because of the favourable indicators related to low consumer price index and low unemployment rate. In the case of remaining indicators, the values fall below 0.6 with Bangalore and Mumbai scoring around 0.4. The primary reason for such a low value is of a lower per capita water and electricity consumption, lower share of renewable energy, lower access to education and financial infrastructure, lower access to motorized transport and relatively higher congestion levels. The reasons are approximately similar to all the five cities with differing degrees of influence. These differences in the influence are exhibited through variations in the values of indices.

The next dimension considered is social sustainability (Figure 2). Unlike in the previous case, the indicators are either close to or above 0.8. This is true for almost all the cities with the exception of Mumbai. With respect to safety, except for Singapore (1.0), all the other cities have fared very poorly, with Bangalore and Mumbai scoring less than 0.2. In relation to indicators like education, equity and access to basic needs all the cities perform well. The reasons for this good performance are relatively high values scored for indicators related to longevity, population growth, literacy, and maternal mortality rates, access to potable water, access to basic needs, etc. Overall, all the five cities have shown better social performance compared to economic performance.

Figure 3 compares the composite environmental sustainability index values in different categories among all the five cities as well as with benchmark. Compared to economic and social sustainability index values, both the Indian cities have performed better with respect to environmental sustainability dimension. Especially, the index values for climate change, energy consumption and soil pollution are relatively high. Shanghai, does poorly with respect to most of the indicator categories under environmental sustainability dimension resulting in poor overall performance. All the cities have scored lowly on urban green spaces. Bangalore does well with respect to five of the seven categories under environmental sustainability. The city scores poorly in relation to water pollution and urban green spaces.

The composite index values of economic, social and environmental sustainability dimensions are compared for all the five cities (Figure 4). The figure shows the least achievement by all the five cities with respect to economic sustainability with the composite index value of each city not exceeding 0.6. With respect to environmental sustainability, the cities have achieved composite index values closer to 0.8 (less than or equal to 0.8). The best performance is with respect to social sustainability. The composite index value achieved by all the cities is around 0.8 (a few cities over 0.8 and a few slightly below it) with the sole exception of Mumbai. Further, both Bangalore and Mumbai, unlike the other three cities, perform better with respect to environmental sustainability compared to social sustainability. A lower economic development results in lower resource requirement and might be the reason for this deviation. A probable recommendation is to adopt environment-friendly pathways for economic development leading to enhancing the values of all the three composite indicators of sustainability.

Finally, the USI is compared for all the five cities (Figure 5). As with individual dimension index values, the rank order remains the same with Singapore and London cornering the top two positions in that order. In other words, Singapore scores as the most sustainable urban system among all the five cities studied.

5. DISCUSSION

The USI, the summation of the product of the total dimensions, permits an analysis of each city against the theoretical maximum possible score of 1. The median score of 0.669 is taken to represent average performance. The USI below the median is considered to be of below-average performance. An USI of a city with a total below 40 per cent of the maximum possible score can be rated as poor in relation to sustainability practice. However, as all the five cities are selected on the basis of recognised or potential achievements in sustainability, it is good to know that they have better values. If rational categorisation of USI values is made into nominal groups with the band 50–59 per cent (score 0.669 to 0.736) indicating above-average performance, 60–69 per cent (0.737 to 0.80) which can be classified as good and over 0.80 as excellent. In the present study, three cities received high values and can be classified as falling within the ‘good’ category, with Singapore achieving the distinction of ‘excellent’ category. The difference between the top (Singapore) and the bottom (Mumbai) performers is about 23%. However, in terms of sustainability performance, the difference in USI between the successive cities is small (about 10%).

As the results show, 35 per cent of Mumbai's territory is fully developed making it imperative for it to incorporate renewable and sustainable development in all areas of its planning. Since one third of Mumbai's land is dedicated to forests, better records of biodiversity and ecosystems need to be kept to track changes in ecological systems. Mumbai is a city with a substantial use of public transport. The share of public transport in Bangalore has decreased continuously since 1990 with its present share at only 20 per cent indicating terrible deterioration in public transport management and scope for improvement. Energy consumption is quite coherent with increase in the use of private transport. Mumbai has a high population density as well as 35 per cent of its total land area has already been developed. A combination of these two factors leads to a lower standard of living. Bangalore cannot sustain its population's needs for water. Only 20 per cent of its water comes from local water catchment areas whereas for Mumbai it is almost 100 per cent. The indicator on waste management reveals an insignificant rate of reuse and recycling in both Mumbai and Bangalore despite the former having introduced pioneering recycling schemes. The social indicator, particularly for Mumbai, reveals that nearly half of the population suffers from various degrees of exclusion (housing, water, energy). As much as 17 per cent of Mumbai's population is unemployed, while in Bangalore it is equally uncomfortable at 14 per cent.

With index values of 0.46 and 0.57 for economic sustainability both Mumbai and Bangalore respectively occupy a lower position on urban sustainability scale. Bangalore is better than Mumbai in this regard. The main reasons for this are lower sustainability scores obtained by both the cities for indicators related to income, infrastructure and transportation. With respect to social sustainability, both Mumbai and Bangalore have bettered their performance with index values of 0.63 and 0.72, respectively. This relatively better performance is due to high scores obtained for sustainability indicators like education, equity and access to basic needs. The results suggest that both the cities can further improve their social sustainability index values by focusing on issues related to safety of citizens and development of the health infrastructure. In relation to economic and social sustainability index values, both the cities perform slightly better with respect to environmental sustainability. The index values of 0.67 and 0.72, respectively, for Mumbai and Bangalore reflect this, and are relatively high because of better sustainability scores for indicators related to climate change, energy consumption and soil pollution. The very low score for urban green spaces is one of the contributors for lowering the environmental sustainability index values for both the cities. Individually, Bangalore has low sustainability scores for water pollution and Mumbai scores low on air pollution. Both the cities need to make targeted interventions with respect to indicator categories where they have got low normalised scores.

Of the five cities compared, Singapore emerges as the most sustainable city with an USI of 0.773. Bangalore is the fourth in the list with 0.658. In relation to social and environmental dimensions, all the cities have obtained least values for economic sustainability. This is a very positive finding from this comparative analysis. Basically, urbanisation leads to better access to basic needs, infrastructure, less resource intensive economic growth, better opportunity for employment, etc. Relatively low performance on indicators linked to economic sustainability has been the main reason for both Bangalore and Mumbai to rank fourth and fifth respectively, among the five cities. The relatively better performance with respect to environmental sustainability by both Bangalore and Mumbai is partially due to their lower achievements in economic development. Lower economic achievements mean lesser demand for fossil fuel-based energy resources and lesser economic activities.

Having a specific target sets a clear direction for the city. Hence, one of the first steps towards establishing benchmarking targets is to have strong policy commitment and a clear vision to achieve improvement strategies. Therefore, the target performance or benchmark level can be decided based on a combination of: (i) the city's current performance and its desired position in the future; and (ii) the background of the city in terms of future objectives for public policies regarding urban renewal. Of course, depending on the resource availability, and time frame, one may accept a lower performance level than the target. Therefore a future target should be set on the basis of practical incremental improvements (Theuns *et al.,* 2011).

While selected indicators should describe the existing state of urban systems and show undesirable trends, indicators should include policy implementation indicators to assess if programmes are effective in improving the quality of life of the inhabitants. The indicators need to be reviewed periodically to align them with the evolving urban system and used to inform new policies and programmes where required. There is also a need to develop feedback indicators which help in resource conservation. For example, introducing green building regulations help in reducing the amount of energy and materials used in construction. A public forum should be established to develop a clear vision and plan for implementing sustainable development programmes. The forum should consist of representatives from local communities, professionals, technical and social groups, including youth, women and disadvantaged groups of the population. Active participation of policy makers in this forum is critical to enable linkage of indicators to policies and corrective measures. The forum should focus on issues that it can control or influence and agree on indicators that need monitoring. The involvement of technical experts after the indicators have been identified is crucial to advise whether the indicators are practical, suitable, and measurable. The form can improvise the list of indicators, policy prescriptions and corrective measures through workshops and awareness campaigns.

6. CONCLUSIONS

The study involving Mumbai and Bangalore and three other megacities for comparison demonstrates the value of benchmarking and provides a better understanding of the practical and data-related aspects of benchmarking cities for sustainability. The study demonstrates the value of these comparisons in the context of four dimensions—economic, environmental, social and governance. Although it is not an in-depth research of the urban performance of Indian cities, it is a relatively quick demonstration of using the existing data sets that benchmarking can be an effective tool in identifying areas for improvement.

Measuring the sustainability of urban regions poses many challenges. It includes the processes of identification and collection of data which is valid, reliable and comprehensive. Another is of interpreting indicators and drawing conclusions from them for effective use in decision-making processes. An understanding of what constitutes a sustainable city is the best approach to be adopted. Studies suggest that the most beneficial approach may be the one which is based on the measurement of resource use and its impacts (water use, energy use, air pollution, etc.) and incorporate the metabolism approach without converting everything into a single unit of land.

The use of indicators for assessing urban sustainability performance is an important tool and is being adopted widely in recent times. Even though various indicators have been selected and applied, the final goal is the same, to attain urban sustainability. It must be noted that the selection of indicators should be done with the clear understanding of the needs where these are going to be applied. Initially, a short list of indicators is recommended and later more indicators can be added or eliminated depending on emerging needs. There is an urgent need to harmonize indicator development initiatives at all levels—local, national and global. Many studies have explored the potential of various urban regions to achieve sustainability and indicator-base can be used for tracking such progress and setting targets.

Institutional innovations and indicators are needed to provide fertile ground for socio-economic improvements and creativity. All actors have a major role to play in this process. It involves establishing a sense of urgency, developing a vision and strategy, communicating the vision of change and proposing new measures for evaluating progress. They must proceed with empowering people for broad-based action, winning short-term goals, consolidating gains, producing more changes and anchoring new changes in the life style of the inhabitants. Urban regions need paradigm shifts towards a new economic, political and socio-environmental equilibrium.

Sustainability issues are inherently interconnected, and any approach that needs implementation requires the administration to think across various sectors, viz., housing, transportation, education and workforce, and energy policy and act collaboratively to construct feasible sustainability plans.

Finally, to achieve sustainability a common commitment and effort to cooperate on initiatives must be adopted. This commitment must include the enhancement of capacities of the stakeholders and the political will to monitor and act on these issues to ensure a common minimal standard of global urban sustainability.

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Table 1: Demographic data for the cities of Bangalore and Mumbai (2011)

Description	**Mumbai**	**Bangalore**
Population (million)	18.48	8.43
Population Growth (decadal) (per cent)	10.4	65.2
Average Literacy	88.48	89.58
Area Sq. km	653	741
Population Density/km2	28330	11,371
Proportion to state Population (per cent)	16.41	13.78
Land use		
Residential	36.1	43.0
Business/industry	10.2	6.8
Transport/Roads	10.3	20.7
Green cover (forest, coastal wet land, agriculture, etc.)	37.3	21.5
Others	6.1	8.0

Source: For Mumbai: http://www.regionalplan-mmrda.org
For Bangalore: Bharath and Uttam (2009)

Table 2: Quantifying Indicators of Urban Sustainability─Economic Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Mumbai	Bangalore
Income	Per capita income (US$ PPP/year)	10,885	10,247
	Income distribution (GINI Coefficient)	0.35	0.32
	City GDP (US$ billion PPP)	209	83
	Per capita monthly expenditure (Rs./Month)	1800	2721
Growth/ Development	City GDP growth rate (%)	6.3	6.5
	City product as a % of country's GDP	5.76	2.29
	Consumer price index	37.33	31.96
	Share of organised employment (%)	35	31
	Share of Exports	14	2.22
	Unemployment rate (%)	17	14
	Share of IT Exports (%)	2.1	6.22
	Employment growth rate (%)	2.9	6.12
Consumption	Per capita water consumption (litres)	208	129
	Per capita electricity consumption (kWh)	1600	1576
	Share of Renewable Energy in electricity generation (%)	21	61
	Energy consumption per US$ GDP (MJ/US$)	6.5	4.6
Infrastructure, Services and Urban Equipment	Road length (km/1000 population)	0.102	0.65
	Hospitals/100,000 population	12.1	13.4
	Bank branches/100,000 population	7.9	17
	Colleges/100,000 eligible population	8.5	21.21
	Schools/1000 population	0.125	0.521
	No. of telephones landlines per 100,000 pop	12973	10,823
	No. of mobile phones per 100,000 pop	7070	6777
	No. of internet connections per 100,000 pop	1040	3847
	Share of households with access to telephones (Landline)	38.2	24.1
	Share of households with access to mobile phones	83	82.8
Transportation	Accessibility of public transportation infrastructure (%)	88	46
	Public suburban rail/metro transport seats (per 1000 population)	4.1	0
	Public bus transport seats (per 1000 population)	28.2	35
	Para-Public (Auto, Taxi, Maxicabs) transport seats (per 1000 population)	8.6	352
	Private Road Transport seats (per 1000 population)	6.5	10
	Cars per 1000 population	26.5	47
	Two-wheelers per 1000 population	49.1	258
	Share of non-motorized transport (including walking)	33	38
	Share of walking (%)	27	34
	Transport fuel consumption (GJ/capita/year)	0.92	2.78
	Vehicle km/capita/year	1064	1259
	Proportion of total motorised road PKM on public transport (%)	65.5	72.2
	Passenger car units (PCU)/1000 population	47.7	195.8
	Transportation fatalities per 100,000 population	3.29	9.4
	Transportation injuries per 100,000 population	32.1	70.0
	Transportation accidents per 100,000 population	155	84.9
	Average road network speed (km/h)	23	27
	Superior public transport network , covering trams, light rail, subway and BRT (km/km^2)	0	0
	Travel time (hrs/day)	1.8	0.5
	Automobile ownership (no/family)	0.36	1.7
	Average public transport cost/km (Rs.)	0.5	15.6
	Pedestrians killed (no/year)	350	348

Table 3: Quantifying Indicators of Urban Sustainability—Social Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Mumbai	Bangalore
Demographics	City population (million)	19.2	8.1
	% of population that are children	8.34	10.31
	% of population that are youth	62.8	64.2
	% of population that are above 65 years	6.4	5.4
	Gender ratio (Females/1000 males)	810	922
	Child sex ratio	910	941
	Literacy rate (%)	82.5	88.48
	Male literacy	87.9	91.82
	Female literacy	72.8	84.8
	Number of houses/1000 population	237	317
	Population growth rate (%/annum)	1.13	3.25
	Population density (persons/sq.km)	35400	17,723
	Average household size (no)	4.5	3.24
	Slum population (% of total)	58.2	10
	Migration rate (%)	17	13.4
Education	% of students completing primary and secondary education	83	83
	% of students completing secondary education	83	82
	% of students completing primary education	88	89
	School enrolment rate (No)	95.25	97
	Literacy rate (%)	82.5	88.48
	Teachers in govt. schools (per 100 students)	2.5	5
Health	Number of hospital beds per 10,000 population	19.2	22
	Number of physicians per 10,000 population	5.4	5
	Life expectancy at birth (years)	71	70
	Adolescent fertility rate	45.9	3.5
	Maternal mortality rate (per 100,000 pop)	63	125
	Birth rate (births/1,000 population)	13.8	27
	Death rate	6.9	7.2
	Infant mortality	34.6	31
	Child mortality rate (no/1000)	40	54.7
Equity	Households below poverty line (%)	20	18
	% of HH access to water	98.4	99.2
	% of HH access to sanitation	52	95.9
Poverty	Minimum wage (Rs/month)	3600	5044
	Share of people with unhealthy living conditions	48	1.09
	% of poor without electricity	3.2	1.4
	% of poor with LPG connection	68.5	75.9
Housing quality	Share of population living in pucca houses	46	61
Safety	Number of police officers per 100,000 population	140	283
	Crime rate per 100000 population	440	318
Access to basic needs (energy, water, sanitation)	Share of pucca houses (%)	38	61
	% of HH having piped water connection	69	79.00
	Households with electricity connection (%)	98	98.6
	HH with LPG connection (%)	65	75.9
	Population with access to sanitation (%)	49	94.82

Table 4: Quantifying Indicators of Urban Sustainability—Environmental Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Mumbai	Bangalore
Global Climate Change	CO_2 Emissions per person (tonne per capita)	1	0.5
	GHG emission/city GDP (kg/US$ PPP)	0.092	0.049
Air Pollution	SO_2 emissions (µg/m3)	34	15.1
	NO_2 emission (µg/m3)	86	41
	PM10 emission (µg/m^3)	132	90
Soil pollution	Per capita Solid waste (kg/cap/year)	209	266.5
	Average cost of waste disposal (Rs/tonne)	1600	1450
	Sewage disposal (%)	51	40
	Wet waste per capita (kg/person/day)	0.243	0.176
	% of solid waste that is recycled	32.4	80
	Dry waste capita (kg/cap/day)	0.027	0.082
	Biodegradable waste (%)	37	76
Water pollution	Waste water per capita (Litre/cap)	150	95
	Share of treated water (%)	89	70
	Share of population with access to treated water (%)	87.5	66.56
	Water system leakage (% of total)	13.6	39
	Cost of wastewater treatment (Rs/kl)	24,000	41,194
	Share of waste water treated (%)	67.6	42.4
Urban green spaces	Green spaces/person (m^2)	6.6	41
	Area of Green cover (Sq.m/1000 population)	30.6	23171
Land use pattern	Share of Green space (%)	35.6	28.83
	Share of area used for Roads (%)	9.5	24.3
	Share of residential area (%)	36.2	40.4
Energy Consumption	Electricity consumption per capita (kWh)	1600	1576
	LPG/Gas consumption/capita (kg)	32.3	30
	Diesel Consumption/capita (litre/year)	12.3	57.9
	Petrol consumption/capita (litre/year)	15.9	39.4
	Electricity price (US Cents/kWh)	7.2	9.6
	LPG price (Rs/kg.)	28	30
	T&D losses (%)	5.3	9.02
Water consumption	% of population with potable water supply service	97.6	94.8
	Share of houses with Sources of water within premises	68	76
	Consumption of water (l/day/person)	208	129
	Piped water supply reliability (no. of hours of supply/day)	7	4
	% of HH having piped water connection	69	79.00
	Price of water (RS./kl)	2.25	6

Table 5: Quantifying Indicators of Urban Sustainability—Institutional/Governance Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Mumbai	Bangalore
Government	Revenue generation per capita	9888	4448
	No. of Councillors per 1000 population	0.012	0.023
	Voter participation rates by men	40.8	46.23
	Voter participation rates by women	53.5	49.96
	Voter turnout (%)	46	48
	Per-capita capital expenditure	3433	1570

Table 6: Indicators of Urban Sustainability – Comparing with Threshold Values

Dimensions of sustainability	Categories of sustainability	Indicators of urban sustainability	Mumbai	Bangalore	Maxi-mum	Mini-mum
Economic framework	Income	Per capita income (US$ PPP/year)	10,885	10,247	45,578	5,004
		Income distribution [GINI Coefficient]	0.35	0.32	0.75	0.22
		City GDP (US$ billion PPP)	209	83	1479	24
	Growth/ Development	City GDP growth rate	6.3	6.5	13.3	1.1
		City product as a per cent of country's GDP	5.76	2.29	35.73	1.00
		Consumer price index	37.33	31.96	191.15	28.61
		Unemployment rate (per cent)	17	14	50	4.2
	Consumption	Per capita water consumption (litres)	208	129	527	53.1
		Per capita electricity consumption (kWh)	1600	1576	17619	352
		Share of renewable energy in electricity generation (%)	21	61	61	2
		Energy consumption per US$ GDP (MJ/US$)	6.5	4.6	14.8	1.2
	Infrastructure, Services and Urban Equipment	Bank branches/100,000 population	7.9	17	95.87	3.14
		Schools/1000 population	0.125	0.521	0.955	0.05
		Share of households with access to telephones (Landline)	38.2	24.1	100	17.5
		Share of households with access to mobile phones	83	82.8	100	37.6
	Transportation	Cars per 1000 population	26.5	47	587.1	26.1
		Two-wheelers per 1000 population	49.1	258	258	32
		Share of non-motorized transport (including walking)	33	38	65	8.1
		Transport fuel consumption (GJ/capita/year)	0.92	2.78	60.8	0.92
		Proportion of total motorised road PKM on public transport (per cent)	65.5	72.2	72.2	2.9
		Average road network speed (km/h)	23	27	49.3	18.7
		Superior public transport network , covering trams, light rail, subway and BRT (km/km^2)	0	0	0.55	0
Social framework	Demographics	City population (million)	19.2	8.1	32.45	4.796
		Seniors (65 years) as per cent of population	6.4	5.4	20.4	5.4
		Gender ratio (Females/1000 males)	810	922	1176	734
		Population growth rate (per cent /annum)	1.13	3.25	11.4	0.29
		Population density (persons/sq.km)	35400	17,723	43079	1700
	Education	per cent of students completing primary and secondary education	83	83	100	56
		School enrolment rate (No)	95.25	97	100	45
		Literacy rate (per cent)	82.5	88.48	100	22
	Health	Number of hospital beds per 10,000 population	19.2	22	137	3
		Number of physicians per 10,000 population	5.4	5	42	3
		Life expectancy at birth (years)	71	70	83.75	48.69
		Maternal mortality rate (per 100,000 pop)	63	125	540	25
		Birth rate (births/1,000 population)	13.8	27	50.06	6.85
		Death rate	6.9	7.2	17.23	1.55
		Infant mortality	34.6	31	61.27	2.65
	Equity	Households below poverty line (per cent)	20	18	70	3.8
		Per cent of HH with access to water	98.4	99.2	100	40
		Per cent of HH with access to sanitation	52	95.9	100	25
	Safety	Number of police officers per 100,000 population	140	283	558	55
	Access to basic needs (energy, water, sanitation)	per cent of HH having piped water connection	69	79.00	100	26
		Households with electricity connection (per cent)	98	98.6	100	86.3
		Population with access to sanitation (per cent)	49	94.82	100	12
Environ-mental framework	Global climate change	CO_2 emissions per person [tonne per capita]	1	0.5	9.7	0.5
		GHG emission/city GDP (kg/US$ PPP)	0.092	0.049	0.690	0.049
	Air pollution	SO_2 emissions (μg/m3)	34	15.1	90	11
		NO_2 emission (μg/m3)	86	41	130	23
		PM10 emission (μg/m^3)	132	90	150	11
	Soil pollution	Per capita solid waste (kg/cap/year)	209	266.5	995.6	146.8
		Per cent of solid waste recycled	32.4	80	100	32.4
	Water pollution	Water system leakage (per cent of total)	13.6	39	50.2	3.1
		Share of waste water treated (per cent)	67.6	42.4	100	10
	Urban green spaces	Green spaces/person (m^2)	6.6	41	166.3	1.8
	Energy consumption	Electricity consumption per capita (kWh)	1600	1576	17619	352
		Diesel consumption/capita (litre/year)	12.3	57.9	734.5	10.9
		Petrol consumption/capita (litre/year)	15.9	39.4	1129.8	6.1
	Water consumption	Consumption of water (l/day/person)	208	129	527	53.1
		per cent of HH having piped water connection	69	79.00	100	26

Table 7: Indicators of urban sustainability—Normalized indicator values

Dimensions of sustainability	Categories of sustainability	Indicators of urban sustainability	Mumbai	Bangalore
Economic framework	Income	Per capita income (US$ PPP/year)	0.14	0.13
		Income distribution [GINI Coefficient]	0.75	0.81
		City GDP (US$ billion PPP)	0.13	0.04
	Growth/ Development	City GDP growth rate	0.43	0.44
		City product as a per cent of country's GDP	0.14	0.04
		Consumer price index	0.95	0.98
		Unemployment rate (per cent)	0.72	0.79
	Consumption	Per capita water consumption (litres)	0.33	0.16
		Per capita electricity consumption (kWh)	0.07	0.07
		Share of renewable energy in electricity generation (per cent)	0.32	1.00
		Energy consumption per US$ GDP (MJ/US$)	0.61	0.75
	Infrastructure, Services and Urban Equipment	Bank branches/100,000 population	0.05	0.15
		Schools/1000 population	0.08	0.52
		Share of households with access to telephones (Landline)	0.25	0.08
		Share of households with access to mobile phones	0.73	0.72
	Transportation	Cars per 1000 population	0.00	0.04
		Two-wheelers per 1000 population	0.08	1.00
		Share of non-motorized transport (including walking)	0.44	0.53
		Transport fuel consumption (GJ/capita/year)	0.00	0.03
		Proportion of total motorised road PKM on public transport (per cent)	0.90	1.00
		Average road network speed (km/h)	0.14	0.27
		Superior public transport network (km/km^2)	0.00	0.00
Social framework	Demographics	City population (million)	0.52	0.12
		Seniors (above 65 years) as per cent of population	0.93	1.00
		Gender ratio (females/1000 males)	0.17	0.43
		Population growth rate (per cent /annum)	0.92	0.73
		Population density (persons/sq.km)	0.19	0.61
	Education	per cent of students completing primary and secondary education	0.61	0.61
		School enrolment rate (No)	0.91	0.95
		Literacy rate (per cent)	0.78	0.85
	Health	Number of hospital beds per 10,000 population	0.12	0.14
		Number of physicians per 10,000 population	0.06	0.05
		Life expectancy at birth (years)	0.64	0.61
		Maternal mortality rate (per 100,000 pop)	0.93	0.81
		Birth rate (births/1,000 population)	0.84	0.53
		Death rate	0.66	0.64
		Infant mortality	0.45	0.52
	Equity	Households below poverty line (per cent)	0.76	0.79
		Per cent of HH with access to water	0.97	0.99
		Per cent of HH with access to sanitation	0.36	0.95
	Safety	Number of police officers per 100,000 population	0.17	0.45
	Access to basic needs (energy, water, sanitation)	Per cent of HH having piped water connection	0.58	0.72
		Households with electricity connection (per cent)	0.85	0.90
		Population with access to sanitation (per cent)	0.42	0.94
Environ-mental ramework	Global climate change	CO_2 Emissions per person [tonne per capita]	0.95	1.00
		GHG emission/city GDP (kg/US$ PPP)	0.93	1.00
	Air pollution	SO_2 emissions (µg/m3)	0.71	0.95
		NO_2 emission (µg/m3)	0.41	0.83
		PM10 emission (µg/m^3)	0.13	0.43
	Soil pollution	Per capita solid waste (kg/cap/year)	0.93	0.86
		per cent of solid waste recycled	0.00	0.70
	Water pollution	Water system leakage (per cent of total)	0.78	0.24
		Share of waste water treated (per cent)	0.64	0.36
	Urban green spaces	Green spaces/person (m^2)	0.03	0.24
	Energy consumption	Electricity consumption per capita (kWh)	0.93	0.93
		Diesel Consumption/capita (litre/year)	1.00	0.94
		Petrol consumption/capita (litre/year)	0.99	0.97
	Water consumption	Consumption of water (l/day/person)	0.67	0.84
		per cent of HH having piped water connection	0.58	0.72

Table 8: Composite indicators of urban sustainability

Dimensions of sustainability	Categories of sustainability	Composite indicator values (categories)		Composite indicator values (dimensions)	
		Mumbai	Bangalore	Mumbai	Bangalore
Economic Framework	Income	0.450	0.475	0.459	0.567
	Growth/Development	0.635	0.666		
	Consumption	0.383	0.631		
	Infrastructure, Services and Urban Equipment	0.388	0.454		
	Transportation	0.384	0.580		
Social Framework	Demographics	0.642	0.649	0.630	0.724
	Education	0.777	0.816		
	Health	0.613	0.535		
	Equity	0.741	0.910		
	Safety	0.169	0.453		
	Access to basic needs (energy, water, sanitation)	0.644	0.857		
Environmental Framework	Global Climate Change	0.939	1.000	0.671	0.722
	Air pollution	0.479	0.770		
	Soil pollution	0.655	0.785		
	Water pollution	0.712	0.305		
	Urban green spaces	0.029	0.238		
	Energy consumption	0.844	0.823		
	Water consumption	0.629	0.780		
Composite Urban Sustainability Index (USI)				**0.594**	**0.675**

Table 9: Comparison of important indicators

Indicators	Bangalore	Mumbai	London	Singapore	Shanghai
City GDP (US$ billion PPP)	83	209	349	215	233
Per capita income (US$ PPP/year)	10,247	10,885	42,700	41,500	13,061
City GDP growth rate (%)	6.5	6.3	3	5.7	9.4
City population (million)	8.1	19.2	8.17	5.18	17.84
Population density (persons/sq.km)	10,034	27,137	5,206	7,025	3,030
Population growth rate (%)	3.25	1.13	1	2.1	1.1
Energy consumption per US$ GDP (MJ/US$)	1.57	6.5	1.4	5.31	14.66
Electricity consumption per capita (kWh)	1,576	1,600	5,200	7,949	6,446

Table 10: Quantifying Indicators of Urban Sustainability—Economic Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Indicator Values					Threshold values	
		Bangalore	Comparable Cities					
			Mumbai	London	Singapore	Shanghai	Maximum	Minimum
Income	Per capita income (US$ PPP/year)	10,247	10,885	42,700	41,500	13,061	65,500	5,004
	Income distribution (GINI Coefficient)	0.32	0.35	0.32	0.45	0.321	0.75	0.22
	City GDP (US$ billion PPP)	83	209	349	215	233	1479	24
Growth/Development	City GDP growth rate (%)	6.5	6.3	3.0	5.7	9.4	13.3	1.1
	City product as a % of country's GDP	2.29	5.76	33	100	4.5	100	1.00
	Consumer price index	31.96	37.33	110.69	104.86	70.44	191.15	28.61
	Unemployment rate (%)	14	17	8.1	2.1	4.8	50	2.1
Consumption	Per capita water consumption (litres)	129	208	161	308.5	411.1	527	53.1
	Final energy consumption (GJ/Capita)	10.95	15.14	74.49	158.37	140.54	215.96	10.95
	Per capita electricity consumption (kWh)	1576	1600	5150	7949	6003	17619	352
	Share of Renewable Energy in electricity generation (%)	61	21	1.2	0.0	0.5	61	0.0
	Energy consumption per US$ GDP (MJ/US$)	1.57	6.5	1.4	5.31	14.66	14.8	1.2
Infrastructure, Services and Urban Equipment	Bank branches/100,000 population	17	7.9	25.56	10.54	23.6	95.87	3.14
	Schools/1000 population	0.521	0.125	0.25	0.16	0.129	0.955	0.05
	Share of households with access to mobile phones (%)	82.8	83	100	100	100	100	37.6
Transportation	Cars per 1000 population	47	26.5	317.2	117	169	587.1	26.1
	Two-wheelers per 1000 population	258	49.1	15.47	134	700	700	15.47
	Share of non-motorized transport (including walking)	38	33	33	48	34	65	8.1
	Transport fuel consumption (GJ/capita/year)	2.78	0.92	53.00	25.34	27.48	60.8	0.92
	Proportion of total motorized road PKM on public transport (%)	72.2	65.5	52.6	57.1	66	72.2	2.9
	Average road network speed (km/h)	27	23	17	27	15	49.3	15
	Superior public transport network , covering trams, light rail, subway and BRT (km/km^2)	0.0	0.0	0.79	0.21	0.07	0.79	0.0

Table 11: Quantifying Indicators of Urban Sustainability—Social Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Indicator Values					Threshold values	
		Bangalore	Comparable Cities				Maximum	Minimum
			Mumbai	London	Singapore	Shanghai		
Demographics	City population (million)	8.1	19.2	8.17	5.18	17.84	32.45	4.796
	% of population that are above 65 years	5.4	6.4	11.5	8.45	10.2	20.4	5.4
	Gender ratio (Females/1000 males)	922	810	1010	1041	982	1176	734
	Population growth rate (%/annum)	3.25	1.13	1.0	2.1	1.1	11.4	0.29
	Population density (persons/sq.km)	10,034	27,137	5,206	7025.2	3030.2	43,079	1,700
Education	% of students completing primary and secondary education	83	83	100	100	97	100	56
	School enrollment rate (%)	97	95.25	100	100	100	100	45
	Literacy rate (%)	88.48	82.5	99	94	97	100	22
Health	Number of hospital beds per 10,000 population	22	19.2	33	26	51.9	137	3
	Number of physicians per 10,000 population	5	5.4	24	18	26.6	42	3
	Life expectancy at birth (years)	70	71	79	82	82.1	83.75	48.69
	Maternal mortality rate (per 100,000 pop)	125	63	9.3	3.0	9.61	540	3
	Birth rate (births/1,000 population)	27	13.8	16	9.5	4.9	50.06	6.85
	Death rate (deaths/1,000 population)	7.2	6.9	8.05	3.41	3.4	17.23	1.55
	Infant mortality	31	34.6	4.60	3.0	5.97	61.27	2.65
Equity	Households below poverty line (%)	18	20	8.0	0.0	10	70	0
	% of HH access to water	99.2	98.4	100	100	100	100	40
	% of HH access to sanitation	95.9	52	100	100	58	100	25
Safety	Number of police officers per 100,000 population	283	140	377	752	195	752	55
Access to basic needs (energy, water, sanitation)	% of HH having piped water connection	79	69	100	100	100	100	26
	Households with electricity connection (%)	98.6	98	100	100	100	100	86.3
	Population with access to sanitation (%)	94.82	49	100	100	72.5	100	12

Table 12: Quantifying Indicators of Urban Sustainability—Environmental Dimension

Categories of Sustainability	Indicators of Urban Sustainability	Indicator Values: Bangalore	Comparable Cities: Mumbai	London	Singapore	Shanghai	Threshold values: Maximum	Minimum
Global Climate Change	CO_2 Emissions per person (tonne per capita)	0.5	1	5.84	7.4	9.7	9.7	0.5
	GHG emission/city GDP (kg/US$ PPP)	0.049	0.092	0.137	0.178	0.743	0.743	0.049
Air Pollution	SO_2 emissions (µg/m3)	15.1	34	25	9	35	90	9
	NO_2 emission (µg/m3)	41	86	37	22	53	130	22
	PM10 emission (µg/m^3)	90	132	29	29	81	150	11
Soil pollution	Per capita Solid waste (kg/cap/year)	266.5	209	566	306.6	369.5	995.6	146.8
	Share of waste collected and adequately disposed (%)	80	32.4	100	100	82.3	100	32.4
Water pollution	Water system leakage (% of total)	39	13.6	22	5	10	50.2	3.1
	Share of waste water treated (%)	42.4	67.6	97	100	78.4	100	10
Urban green spaces	Green spaces/person (m^2)	41	6.6	20.5	66.2	18.1	166.3	1.8
Energy Consumption	Electricity consumption per capita (kWh)	1576	1600	5200	7949	6446.2	17619	352
	Diesel Consumption/capita (litre/year)	57.9	12.3	185.7	384.3	266.6	734.5	10.9
	Petrol consumption/capita (litre/year)	39.4	15.9	297.6	237	216.7	1129.8	6.1
	Electricity price (US Cents/kWh)	9.6	7.2	9.8	27	10	31.4	4.95
Water Consumption	Consumption of water (litre/day/person)	129	208	161	308.5	411.1	527	53.1
	% of HH having piped water connection	79	69	100	100	100	100	26

Table 13: Indicators of Urban Sustainability – Normalized Indicator Values

Dimensions of Sustainability	Categories of Sustainability	Indicators of Urban Sustainability	Bang-alore	Mum-bai	Lon-don	Singa-pore	Shan-ghai
Economic Framework	Income	Per capita income (US$ PPP/year)	0.09	0.10	0.62	0.60	0.13
		Income distribution [GINI Coefficient]	0.81	0.75	0.80	0.57	0.81
		City GDP (US$ billion PPP)	0.04	0.13	0.22	0.13	0.14
	Growth/Development	City GDP growth rate (%)	0.44	0.43	0.16	0.38	0.68
		City product as a % of country's GDP	0.01	0.05	0.32	1.00	0.04
		Consumer price index	0.98	0.95	0.50	0.53	0.74
		Unemployment rate (%)	0.75	0.69	0.87	1.00	0.94
	Consumption	Per capita water consumption (litres)	0.16	0.33	0.23	0.54	0.76
		Final energy consumption (GJ/Capita)	0.00	0.02	0.31	0.72	0.63
		Per capita electricity consumption (kWh)	0.07	0.07	0.28	0.44	0.33
		Share of Renewable Energy in electricity generation (%)	1.00	0.34	0.02	0.00	0.01
		Energy consumption per US$ GDP (MJ/US$)	0.03	0.39	0.01	0.30	0.99
	Infrastructure, Services and Urban Equipment	Bank branches/100,000 population	0.15	0.05	0.24	0.08	0.22
		Schools/1000 population	0.52	0.08	0.22	0.12	0.09
		Share of households with access to mobile phones	0.72	0.73	1.00	1.00	1.00
	Transportation	Cars per 1000 population	0.04	0.00	0.52	0.16	0.25
		Two-wheelers per 1000 population	0.35	0.05	0.00	0.17	1.00
		Share of non-motorized transport (including walking)	0.53	0.44	0.44	0.70	0.46
		Transport fuel consumption (GJ/capita/year)	0.03	0.00	0.87	0.41	0.44
		Proportion of total motorised road PKM on public transport (%)	1.00	0.90	0.72	0.78	0.91
		Average road network speed (km/h)	0.35	0.23	0.06	0.35	0.00
		Superior public transport network (km/km^2)	0.00	0.00	1.00	0.27	0.09
Social Framework	Demographics	City population (million)	0.12	0.52	0.12	0.01	0.47
		% of population that are above 65 years	1.00	0.93	0.59	0.80	0.68
		Gender ratio (Females/1000 males)	0.43	0.17	0.62	0.69	0.56
		Population growth rate (%/annum)	0.73	0.92	0.94	0.84	0.93
		Population density (persons/sq.km)	0.80	0.39	0.92	0.87	0.97
	Education	% of students completing primary and secondary education	0.61	0.61	1.00	1.00	0.93
		School enrolment rate (%)	0.95	0.91	1.00	1.00	1.00
		Literacy rate (%)	0.85	0.78	0.99	0.92	0.96
	Health	Number of hospital beds per 10,000 population	0.14	0.12	0.22	0.17	0.36
		Number of physicians per 10,000 population	0.05	0.06	0.54	0.39	0.61
		Life expectancy at birth (years)	0.61	0.64	0.86	0.95	0.95
		Maternal mortality rate (per 100,000 pop)	0.77	0.89	0.99	1.00	0.99
		Birth rate (births/1,000 population)	0.53	0.84	0.79	0.94	1.04
		Death rate (deaths/1,000 population)	0.64	0.66	0.59	0.88	0.88
		Infant mortality	0.52	0.45	0.97	0.99	0.94
	Equity	Households below poverty line (%)	0.74	0.71	0.89	1.00	0.86
		% of HH access to water	0.99	0.97	1.00	1.00	1.00
		% of HH access to sanitation	0.95	0.36	1.00	1.00	0.44
	Safety	Number of police officers per 100,000 population	0.33	0.12	0.46	1.00	0.20
	Access to basic needs (energy, water, sanitation)	% of HH having piped water connection	0.72	0.58	1.00	1.00	1.00
		Households with electricity connection (%)	0.90	0.85	1.00	1.00	1.00
		Population with access to sanitation (%)	0.94	0.42	1.00	1.00	0.69
Environ-mental Framework	Global Climate Change	CO_2 Emissions per person [tonne per capita]	1.00	0.95	0.42	0.25	0.00
		GHG emission/city GDP (kg/US$ PPP)	1.00	0.94	0.87	0.81	0.00
	Air Pollution	SO_2 emissions (µg/m3)	0.92	0.69	0.80	1.00	0.68
		NO_2 emission (µg/m3)	0.82	0.41	0.86	1.00	0.71
		PM10 emission (µg/m^3)	0.43	0.13	0.87	0.87	0.50
	Soil pollution	Per capita Solid waste (kg/cap/year)	0.86	0.93	0.51	0.81	0.74
		Share of waste collected and adequately disposed (%)	0.70	0.00	1.00	1.00	0.74
	Water pollution	Water system leakage (% of total)	0.24	0.78	0.60	0.96	0.85
		Share of waste water treated (%)	0.36	0.64	0.97	1.00	0.76
	Urban green spaces	Green spaces/person (m^2)	0.24	0.03	0.11	0.39	0.10
	Energy Consumption	Electricity consumption per capita (kWh)	0.93	0.93	0.72	0.56	0.65
		Diesel Consumption/capita (litre/year)	0.94	1.00	0.76	0.48	0.65
		Petrol consumption/capita (litre/year)	0.97	0.99	0.74	0.79	0.81
		Electricity price (US Cents/kWh)	0.18	0.09	0.18	0.83	0.19
	Water Consumption	Consumption of water (litre/day/person)	0.84	0.67	0.77	0.46	0.24
		% of HH having piped water connection	0.72	0.58	1.00	1.00	1.00

Table 14: Composite Indicators of Urban Sustainability

Dimensions of Sustainability	Categories of Sustainability	Composite Indicator Values (Categories)				
		Bangalore	Mumbai	London	Singapore	Shanghai
Economic Framework	Income	0.472	0.445	0.601	0.487	0.481
	Growth/Development	0.656	0.623	0.534	0.778	0.690
	Consumption	0.454	0.277	0.212	0.467	0.641
	Infrastructure, Services and Urban Equipment	0.522	0.424	0.608	0.583	0.593
	Transportation	0.467	0.390	0.625	0.466	0.574
Social Framework	Demographics	0.689	0.660	0.703	0.718	0.748
	Education	0.816	0.777	0.996	0.975	0.964
	Health	0.528	0.604	0.752	0.822	0.857
	Equity	0.898	0.727	0.963	1.000	0.802
	Safety	0.330	0.120	0.460	1.000	0.200
	Access to basic needs (energy, water, sanitation)	0.857	0.644	1.000	1.000	0.908
Environmental Framework	Global Climate Change	1.000	0.942	0.685	0.602	0.000
	Air pollution	0.757	0.469	0.845	0.959	0.637
	Soil pollution	0.785	0.655	0.793	0.911	0.738
	Water pollution	0.305	0.712	0.804	0.980	0.808
	Urban green spaces	0.240	0.030	0.110	0.390	0.100
	Energy consumption	0.823	0.844	0.647	0.684	0.619
	Water consumption	0.780	0.629	0.893	0.779	0.728

Table 15: Composite Indicators of Urban Sustainability and Composite USI

Dimensions of Sustainability	Composite Indicator Values (Dimensions)				
	Mumbai	**Bangalore**	**Shanghai**	**London**	**Singapore**
Economic Framework	0.446	0.519	0.600	0.539	0.569
Social Framework	0.628	0.715	0.789	0.836	0.926
Environmental Framework	0.671	0.720	0.601	0.726	0.784
USI	**0.590**	**0.658**	**0.669**	**0.711**	**0.773**

Figure 1: Benchmarking Economic Sustainability—Comparison of Cities

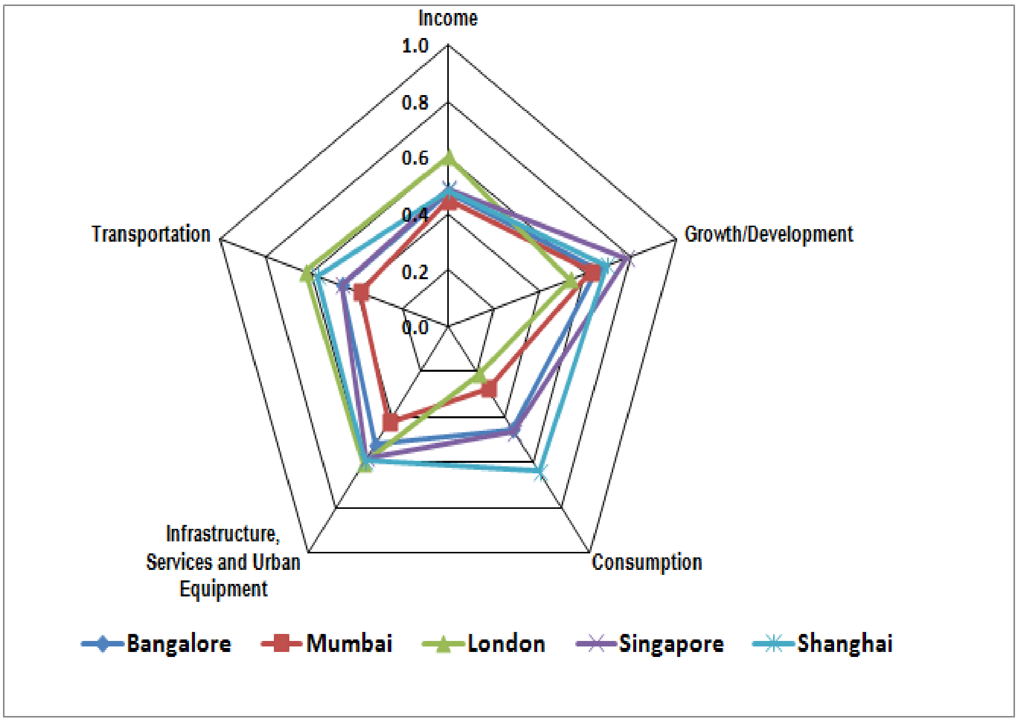

Figure 2: Benchmarking Social Sustainability—Comparison of Cities

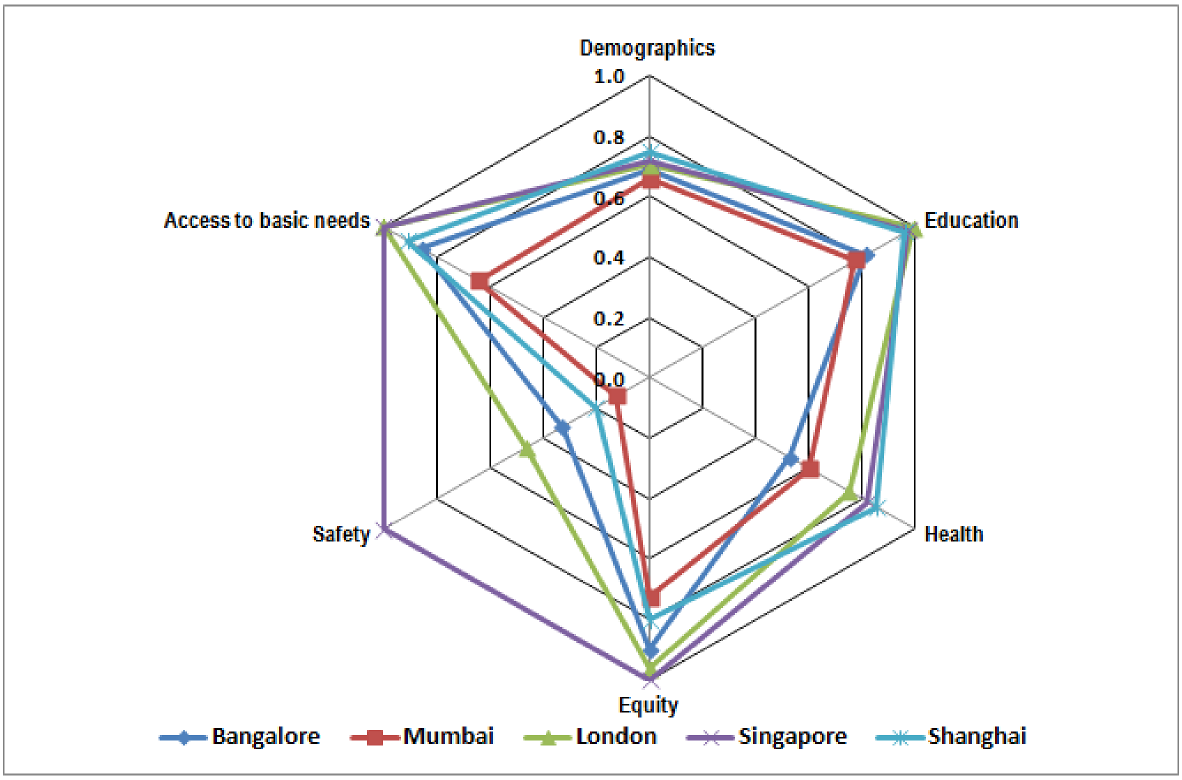

Figure 3: Benchmarking Environmental Sustainability—Comparison of Cities

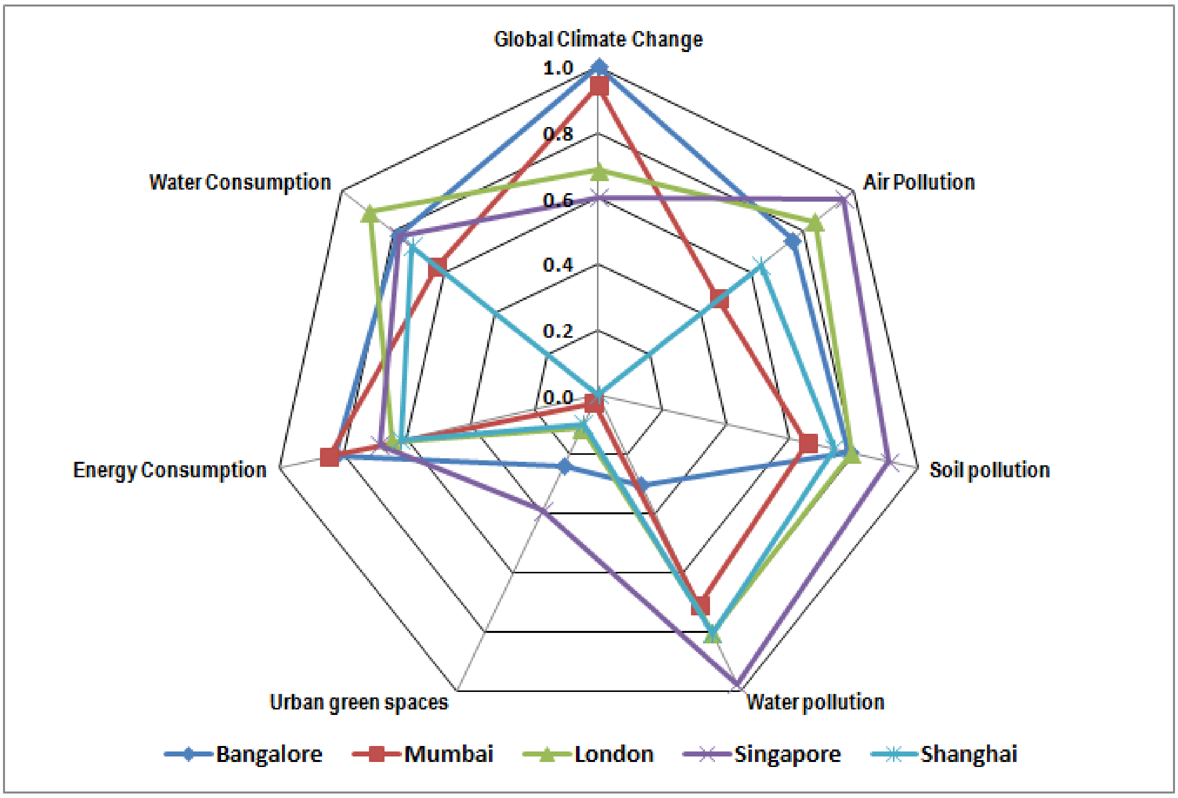

Figure 4: Benchmarking Urban Sustainability—Comparison of Cities

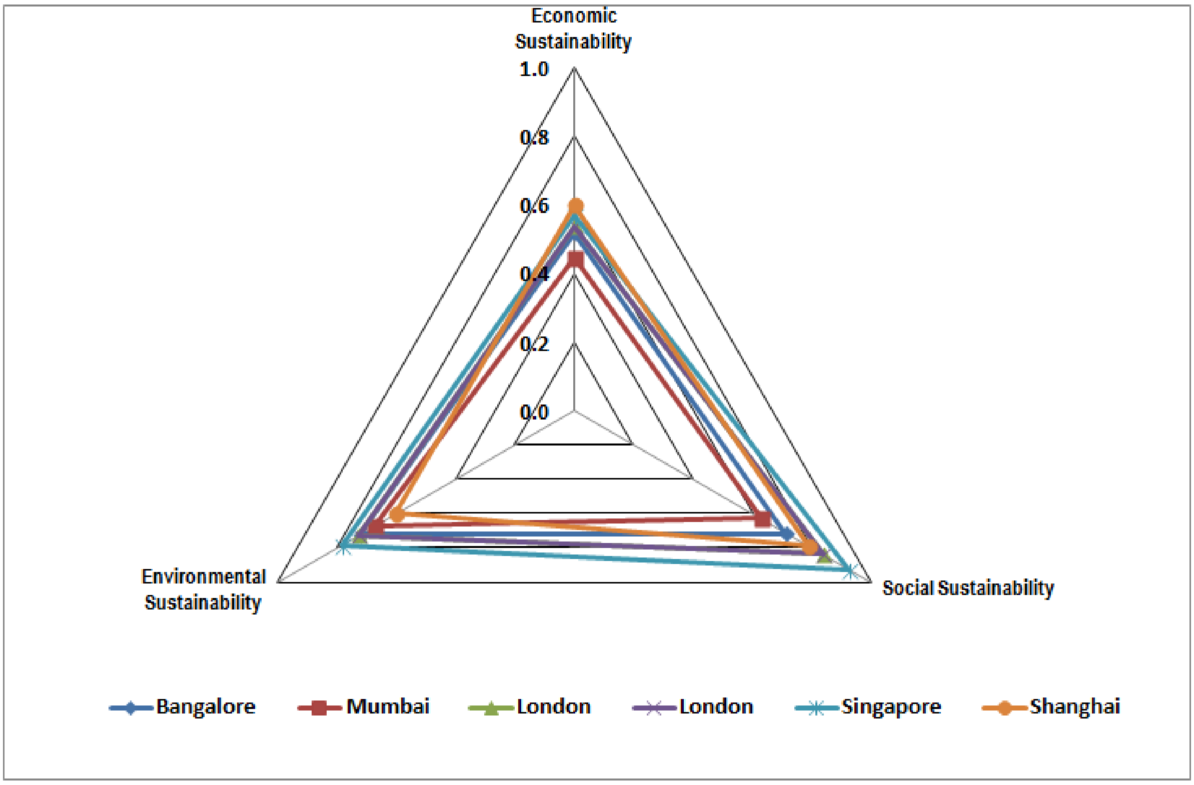

Figure 5: Comparing Urban Sustainability Index (USI)