

INFLUENCE OF PLANNING AND GOVERNANCE ON THE LEVEL OF URBAN SERVICES

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A theoretical framework to analyse the interaction of planning and governance on the extent of outgrowth and level of services is proposed. An indicator framework for quantifying sprawl is also proposed and the same is operationalised for Bangalore. The indicators comprise spatial metrics (derived from temporal satellite remote sensing data) and other metrics obtained from a household survey. The interaction of different indicators with respect to the core city and the outgrowth is determined by multidimensional scaling. The analysis reveals the underlying similarities (and dissimilarities) that relate with the different governance structures that prevail here. The paper concludes outlining the challenges in addressing urban sprawl while ensuring adequate level of services that planning and governance have to ensure towards achieving sustainable urbanisation.

Keywords: Urban Sprawl; Planning; Governance; Bangalore

URBANISATION AND URBAN SPRAWL

India's urban population is currently growing at about 2.3% per annum and it is projected that the country's urban population would increase from 28.3% in 2003 to about 41.4% by 2030.¹ By 2001, there were 35 urban agglomerations (cities having a population of more than one million), as compared to 25 urban agglomerations in 1991. This increased urban population and growth in urban areas is inadvertent due to an unpremeditated population growth and migration. Urban growth, as such, is a continuously evolving natural process due to growth of population (birth and death). The number of urban agglomerations and towns has increased from 3,697 in 1991 to 4,369 in 2001.² An imminent urbanisation coupled with economic development has transformed societies and cultures, apart from the landscapes and the natural environment. Cautioning against attributing simply

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¹ United Nations, **Executive Summary, World Urbanisation Prospects: The 2003 Revision** (New York: Population Division, Department of Economic and Social Affairs, United Nations, 2004).

² Census of India, **Migration Data for Urban Agglomeration in Karnataka - D Series** (New Delhi: Directorate of Census Operations, Government of India, 2001).

the growth of cities to urbanisation, Davis³ notes that urbanisation refers to the proportion of the total population concentrated in urban settlements or the rise in this proportion. It is argued that since urbanisation would account for the total population composed of both urban and rural, the proportion of urbanisation is a function of both of them. Accordingly, cities can grow without urbanisation, provided the rural population grows at an equal or greater rate. Thus, the process of urbanisation is fairly contributed by rural-urban migration leading to the higher proportional population growth of urban-rural and infrastructure initiatives, resulting in the growth of villages into towns, towns into cities and cities into metros.

Towns and cities are expanding in certain pockets with a change in the land-use along the highways and in the immediate vicinity of the cities due to ad hoc approaches in regional planning, governance and decision making. This outgrowth along highways and roads connecting a city and in the periphery of the cities is caused by the uncontrolled and uncoordinated urban growth. This dispersed development outside compact urban and rural centres, that is along highways and in rural countryside, is referred to as sprawl. Sprawl generally refers to some type of development with impacts such as losses of agricultural lands, open spaces and ecologically sensitive habitats in and around the urban areas. These regions lack basic amenities due to the unplanned growth and lack of prior information and forecasts of such growth during policy, planning and decision making.

The magnitude and nature of urban sprawl is quite different in the developed countries from that of a rapidly developing and largely rural-agrarian populated country like India. The problem of sprawl is magnified in the developed countries after reaching saturation levels of urbanisation. Conversely, most of the developing and underdeveloped countries are now urbanising rapidly and already prone to the problem of sprawl at an even worse magnitude. A significant difference in the urbanisation patterns of developed and developing countries is that of population densities. The developed countries embraced urbanisation after industrialisation wherein the population growth rates and densities were lower, with a prosperous economy and technology to support. Conversely, developing countries are having high population growth rates and densities, in the midst of economic development, with lack of basic amenities and urbanisation taking place at a rapid rate. In India, already 28% of the population live in urban areas and these cities are expanding like never before, with inadequacies in facilities for transportation, water supply and sanitation, energy demands, etc. With a booming economic activity on the one side and large population in unorganised sectors of employment with inadequate housing on the other, rise of slums and squatters in urban areas seems inevitable.

PLANNING AND GOVERNANCE IN URBAN EVOLUTION

In India, urban areas contribute significantly to the national economy (about 50 to 60% of gross domestic product), while facing critical challenges in ensuring

³ K. Davis, "The Urbanisation of the Human Population," *Scientific American*, Vol. 213 (1965), pp.40-53.

access to basic services and necessary infrastructure, both social and economic. The overall rise in population of urban poor and increase in travel times owing to congestion in road networks are indicators of the performance of planning and governance in assessing and catering to the demand. Agencies of governance at all levels, local bodies, State and Central governments, are facing the brunt of this rapid urban growth. It is imperative for planning and governance to systematically facilitate, augment and service the requisite infrastructure over time. Provision of infrastructure and ensuring delivery of basic services cannot happen overnight and hence planning has to facilitate forecasting and provisioning these services with appropriate mechanisms.

Governance Structures

The urban governance is characterised by an urban local body and numerous parastatal agencies responsible for delivery of services and ensuring access to basic amenities and infrastructure. On the supply side, the urban local body along with the parastatal agencies is responsible for allocating resources to the residents and creating a favourable ecosystem for conducting the businesses. In a typical case, the urban local body being the elected body has the greater onus and powers to administer, plan and regulate the delivery of services and allocation of resources.

However, a strange paradigm that exists in the country is the presence of a large number of parastatal organisations. Although the parastatals are primarily responsible for the delivery of services and ensuring access to resources, they are not directly answerable to the citizens, but only to the state government. Since they are managed by the state government the urban local bodies have little say in the function of these bodies while the actions of the parastatal directly affect other stakeholders of the city.

Constitutionally, the urban local bodies are supposed to be vested with adequate powers and mechanisms to carry out all the functions and activities the parastatal organisations are currently undertaking. In most of the large urban local bodies, the state has not devolved adequate powers and thus manages the activities through creation of parastatal organisations. In certain cities, with the dissolution of the body of elected representatives, the state government is wresting control over the same. Eventually, the state government assumes the role of planning and governing the city. Although the governance by the locally-elected body is absent, nevertheless, the urban local body has the primary responsibility to deliver basic amenities and ensure access to resources and infrastructure.

The level of service assesses the access to essential services and amenities. This also comprises provision of certain infrastructure like outer ring roads, residential development, etc. The level of service, access to infrastructure and other amenities are measured based on a household survey across the region discussed in the subsequent sections.

Planning Matters

Planning refers to the process of formulating the road map towards achieving the objectives for promoting development. The specifics of planning vary with the desired goals of separate nation states. Normally, planning refers to the prevalent land-use planning or spatial planning as practiced by the state. However, planning also concerns the formulation of policies and programmes towards economic development, apart from land-use planning for promoting sustainable urban development. In the context of sprawl, land-use planning plays a very important role in limiting the extent of outgrowth by zoning and notifying areas for future growth. The forecast and allocation of land-uses to the expected demand for housing, industrial, commercial and retaining open spaces are considered in land-use zoning. Thus, planning here restricts to land-use planning only. However, the effectiveness of land-use planning in its effort to manage urban sprawl rests on the goals of planning and policies therein. Noting the importance of land-use planning, the state or city governments either own planning functions or facilitate appropriate organisation structure to oversee that. The performance of planning can be measured by the presence of formal structures (with or without state capture), publication of master plans (process of preparation, periodicity of publication and its enforcement) and community participation in planning.

With the presence of parastatal planning agencies, formally called development authorities, planning function too is in a situation of state-capture. However, in certain cities, the functions of water supply and sanitation rest with the urban local body, but for the rest, they are with parastatal agencies.

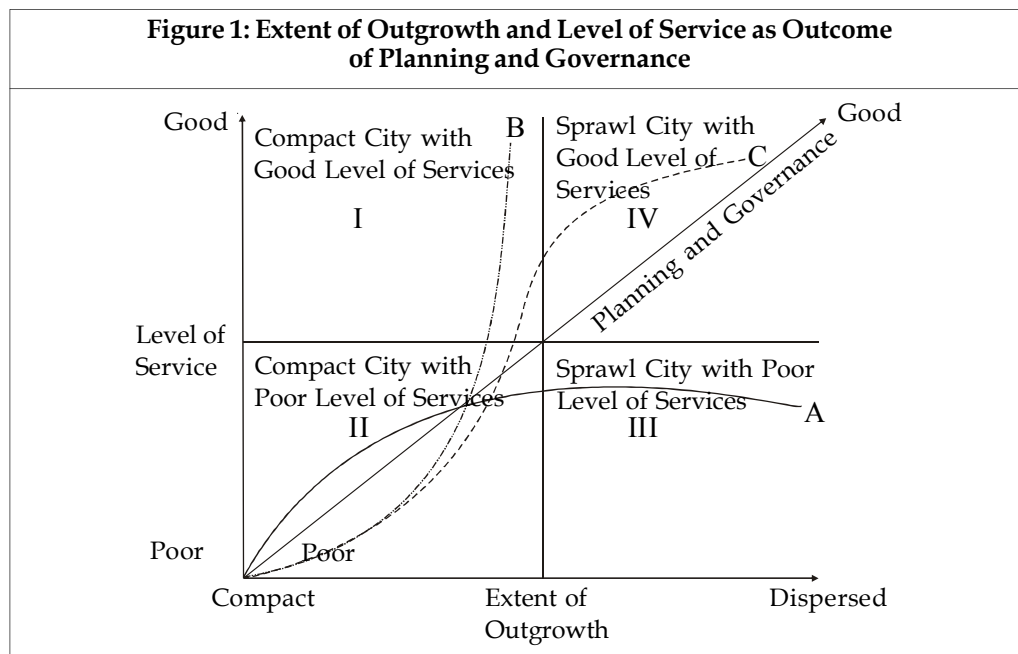
Extent of Outgrowth (Sprawl)

The extent of outgrowth or the sprawl is measured primarily through the amount of paved surface extending beyond the municipal boundaries. In the recent times, the extent of outgrowth has also been fuelled by speculative land market dynamics in the periphery of the city. The outgrowths beyond the municipal limits are also aided by minimal or no restrictions on building guidelines. Thus, the outgrowths are marked by the process of land-use changes. However, it is important to characterise these outgrowths and forecast such outgrowths by the local governments to systematically ensure the delivery of services and attempt planned development in these regions.

Theoretical Framework

Development of suburbs because of increased population growth and infrastructure facilities around the cities is a well-established reasoning for urban sprawl. The key aspect surrounding urban sprawl is the extent of outgrowth around the periphery of the city or along the highways, which is factored by land-use change, the level of services and access to basic services and amenities in these areas. These three important variables, planning, governance (level of service) and extent of outgrowth, are analysed based on this framework.

To emphasise the role of planning and governance in addressing urban sprawl (Figure 1), the above-mentioned aspects are categorised. In Figure 1, two are outcomes (level of service and extent of outgrowth) while the key input is planning, depicted along the diagonal. With this diagram, distinguishable states on the effectiveness of planning and governance are defined. Accordingly, planning and governance either attempt to contain the outgrowth or deliver the requisite level of services to the citizens through provision of basic amenities and infrastructure.



Trajectories of Possible Urban Evolution: In the framework presented in Figure 1, there can be four possible states for cities:

- I. Compact city with good level of services
- II. Compact city with poor level of services
- III. Sprawl city with poor level of services
- IV. Sprawl city with good level of services

It is obvious to note that most cities would fall into any one of the four states. Accordingly, during the evolution of cities, cities may target reaching the states I or IV. There can also be three possible trajectories of urban evolution: A, B and C, as depicted in Figure 1. In trajectory A, a city would evolve with dispersed growth, which can lead to poor level of services with limited planning and governance. The city would have managed to grow with limited planning capabilities resulting in the delivery of services lesser than the desirable levels. A city can evolve with compact growth while ensuring desired level of services aided by sound planning and governance as seen in trajectory B. A city can also

evolve according to trajectory C, allowing for outgrowth with delivery of desirable services augmented by planning for the newly developed regions. Balachandran and Haran⁴ have pointed the distinction of planning following development for cities of Bangalore and Hyderabad, while development followed by planning is evinced in Ahmedabad.

STUDY AREA: BANGALORE, INDIA

Bangalore is the principal administrative, cultural, commercial and industrial centre of the state of Karnataka. The city of Bangalore is situated at an altitude of 920 m above mean sea level. Geographically, it is located on 12.95° N latitude and 77.57° E longitude. The city enjoys a pleasant and equable climate throughout the year. Its tree-lined streets and abundant greenery have led to it being called the 'Garden City' of India. Early 1990s boom in the software sector, with consequent infrastructure initiatives, has contributed to the rise in population, mainly due to migration. It is now home to more than 1,000 high-tech companies apart from numerous establishments in manufacturing and processing industries. The population of Bangalore as per the 2001 census was 5,686,844, while it was 163,091 in the beginning of the last century (1901). With booming economic activity, migration in search of livelihood and availability of land favoured by salubrious climate all round the year, sprawl has been prevalent in and around Bangalore. Recently, the city administrative jurisdiction was expanded to 741 sq. km agglomerating neighbouring outgrowth. The expansion of Bangalore in recent times, with concentrated development of industries and commercial establishments, has posed great challenges to urban governance and planning in terms of provisioning adequate infrastructure, delivery of services, amenities, etc.

METRICS OF URBAN SPRAWL

Evolving appropriate measures to quantify urban sprawl is a prerequisite to develop an understanding of urban sprawl. Often, there is a lack of appropriate indicators and information concerning the cities or its status from a holistic perspective that captures not only the economic aspects but also ecological and socio-economic aspects, including livelihood of people. Given the problem of urban sprawl and its inadequate understanding to precisely determine its nature, pattern and rate of growth, there is an urgent need to characterise urban sprawl, more so from the perspective of achieving sustainable urbanisation in developing countries. Thus, a significant challenge is to identify the appropriate indicators towards achieving sustainable urbanisation.

Torrens and Alberti⁵ note that despite the level of importance given to the problem of sprawl, there remains little understanding of its determinants and its constituents, since sprawl is most often confused with sub-urbanisation. However,

⁴ B. R. Balachandran and S. Haran, *Land Management Mechanisms in Indian Cities*, National Seminar on Urban Imbroglio in the Global City, (Bangalore, India: St. Joseph's College of Business Administration, 2008).

⁵ P. M. Torrens and M. Alberti, "Measuring Sprawl," Working Paper Series (London: Centre for Advanced Spatial Analysis, University College, 2000).

some researchers in the recent past have attempted to characterise urban sprawl⁶ using spatial metrics.

Essentially, the urban sprawl metrics aid in quantifying the process, monitoring the extent of urban sprawl and also become useful as indicators for measuring the implications of policy decisions. Although some of the indicators for achieving sustainable development have been evolved by Meadows⁷, still there isn't any broad consensus on the appropriate indices representing all of the factors and disciplines. For managing urban sprawl in north-western European cities, Gayda and others⁸ have evolved metrics, adopted as indicators to achieve sustainable development. Furthermore, on the lines of sustainable development framework, there also exists quantification of metrics based on the carrying capacity approach. In this case, the carrying capacity of an urban system is evaluated based on the different functions and activities of the urban systems and accordingly a certain threshold for development is set, beyond which it is detrimental to the entire system itself. The concept of carrying capacity has been in news since the seminal work by Meadows and others⁹ on the notion of 'Limits to growth'. In India, the National Institute of Urban Affairs (NIUA)¹⁰ has evolved a framework for the carrying capacity-based regional planning. The essence of carrying capacity-based approach on the lines of achieving sustainable development lies in the fact that a host of factors (such as assimilative and supportive capacities) are under consideration in the planning processes.

Some of the existing works on sprawl ascribe spatial extent of built-up areas derived from remote sensing data or other geospatial data as the measure of sprawl. On the spatial metrics for sprawl, entropy, patchiness and built-up density have been suggested.¹¹ In addition to this, the percentage of population residing

⁶ K. Barnes, J. I. Morgan, M. Roberge, and S. Lowe, **Sprawl Development: Its Patterns, Consequences, and Measurement** (Towson: Towson University, 2001); J. Hurd, E. Wilson, S. Lammey, and D. Civco, **Characterisation of Forest Fragmentation and Urban Sprawl Using Time Sequential Landsat Imagery**, Proceedings of the ASPRS Annual Convention (St. Louis, MO, USA: ASPRS, 2001); J. Epstein, K. Payne, and E. Kramer, "Techniques for Mapping Suburban Sprawl," **Photogrammetric Engineering and Remote Sensing**, Vol. 63 no. 9 (September 2002), pp.913-918; and H. S. Sudhira, T. V. Ramachandra, and K. S. Jagadish, "Urban Sprawl: Metrics, Dynamics and Modelling Using GIS," **International Journal of Applied Earth Observation and Geoinformation**, Vol. 5 no. 1 (February 2004), pp.29-39.

⁷ D. Meadows, **Indicators and Information Systems for Sustainable Development** (Hartland, USA: The Sustainability Institute, 1998).

⁸ S. Gayda, F. Boon, N. Schailleé, M. Batty, E. Besussi, N. Chin and others, **The SCATTER Project - Sprawling Cities and Transport: From Evaluation to Recommendations** (Strasbourg, Germany; Author please check is it

⁹ D. H. Meadows, D. L. Meadows, J. Randers, and W. W. Behrens, **The Limits to Growth: Report for the Club of Rome Project on the Predicament of Mankind** (New York, USA: Universe Books, 1972). France

¹⁰ National Institute of Urban Affairs (NIUA), **Urban Environmental Management: The Indian Experience** (New Delhi, India: Human Settlement Management Institute, HUDCO, 1996).

¹¹ A. Yeh, and X. Li, "Measurement and Monitoring of Urban Sprawl in a Rapidly Growing Region Using Entropy," **Photogrammetric Engineering and Remote Sensing**, Vol. 67 no. 1 (2001), pp.83-90; Sudhira, Ramachandra, and Jagadish, "Urban Sprawl: Metrics, Dynamics and Modelling Using GIS". Torrens and Alberti, "Measuring Sprawl".

over the built-up area to arrive at population-built-up density was considered metric for sprawl.¹² However, it still remains largely unanswered as to how and what are the appropriate metrics or indicators of urban sprawl that are sufficient to represent the process of sprawl. Although some attempts are made to capture sprawl in its spatial dimensions, still they fail to capture sprawl in other dimensions (like mobility, accessibility, resource usage, etc.), and neither do they indicate their intensity (density metrics). It is thus imperative for research to address intensity of sprawl through appropriate metrics or indicators for effective regional planning.

Sprawl Indicators for Bangalore, India

Author please provide full forms From an overview of the above-discussed indicators, it is seen that amongst the most relevant sprawl indicator frameworks are that of the Costs of Sprawl (TRB) and SCATTER (EU). It is further noted that the set of indicators suggested above fit very well for countries wherein the rates of urbanisation are almost stagnant, converse to the situations in countries with high urbanisation rates. It is with this motivation, the current paper arrives at the indicators for sprawl on the lines of indicators developed by TRB and SCATTER, with strong relevance to the prevailing local conditions. In this regard, the suggested metrics for quantifying urban sprawl extends the city sprawl indicators of SCATTER¹³ to chiefly accommodate migration, population densities and literacy levels amongst others. The sprawl indicators are grouped under four themes:

1. Demography and Economy;
2. Environment and Resources;
3. Mobility; and
4. Planning and Governance.

Demography and Economy: The first set of indicators reflects the demographic and socio-economic characteristics of the city across different zones (core to agglomeration). The basic demographics reflect the population – native and migrant, household size, housing condition, population densities: alpha and beta density, and among the economic aspects are income levels.

Environment and Resources: The second set of indicators capture the environmental variables and the resource consumptions that chiefly include land-use, solid waste generation and collection, water consumption and wastewater generation, and energy: consumption, sources and end-uses. The different land-uses considered are: built-up, water bodies (include tanks and all wetlands), open

¹² S. Gayda, G. Haag, E. Besussi, K. Lautso, C. Nol, A. Martino, and others, **The SCATTER Project - Sprawling Cities and Transport: From Evaluation to Recommendations**, Final Report, Version 2, Contract No. EVK4-CT-2001-00063 (European Union, 2005); and H. S. Sudhira, T. V. Ramachandra, K. S. Raj, and K. S. Jagadish, "Urban Growth Analysis Using Spatial and Temporal Data," **Photonirvachak, Journal of Indian Society of Remote Sensing**, Vol. 31 no. 4 (2003), pp.299-311.

¹³ Gayda, Haag, Besussi, Lautso, Nol, Martino, and others, **The SCATTER Project - Sprawling Cities and Transport: From Evaluation to Recommendations**.

land (includes barren land, rocky outcrop and dry grassland), and vegetation (includes agriculture plantations, parks, forest cover, and all green cover). For the built-up areas, some of the established sprawl metrics like density and patchiness were computed. The solid waste management metrics consider per capita generation and mode of collection. The water consumption per capita per day and the corresponding wastewater generated and the treatment capacities form the metrics under water and wastewater.

Mobility: The third set of indicators about mobility is mode of transport, modal share of public transport, mobility patterns, road traffic, average road traffic speed and travel times. The modal share of public transport, passenger-km by public modes, mobility pattern considering the average home to work travel distance and average travel time (for all modes) are part of the metrics under mobility.

Planning and Governance: The last set of indicators captures the aspect concerning planning and governance. These variables include: preparation and publication of master plans, public participation and integration of city functions for measuring the effectiveness of governance, the level of accessibilities to city centre, different amenities, services (including healthcare) and infrastructure are estimated. The presence/absence of elected local body and their participation in planning are also considered.

DATA, METHODS AND TOOLS

The planning of resources and provision of amenities are interrelated and requires an understanding of the current consumption patterns and level of access to various services across different socio-economic classes. In the planning perspective, it is important to consider the effect of mobility on sprawl. It is in this context that it attempts to characterise the level of access to services, mobility patterns and consumption patterns of resources across Greater Bangalore.

Data Sources

The data for the current study comprises both primary and secondary sources. In order to characterise the level of accession to services across Bruhat Bangalore Mahanagara Palike (BBMP) jurisdiction, a questionnaire-based household survey was conducted. Further to augment this with the spatial patterns of urban growth, remote sensing data was used. The following sections describe the strategy, size and mode of sampling for household survey and discuss the satellite remote sensing data collection. The data were analysed by employing several analytical techniques discussed in the subsequent sections.

Questionnaire-Based Household Survey: In Bangalore, there are numerous agencies concerned with delivery of various services. Accordingly, most of their jurisdictions do not overlap, and hence collecting and collating data from these agencies to analyse and interpret are impossible. Thus, it required a questionnaire-

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based household survey across different zones of Greater Bangalore to determine the level of access to different services from healthcare to amenities and infrastructure.

Method of Sampling – Questionnaire-Based Survey: The sampling was carried out based on a structured questionnaire aimed at capturing the dimensions of:

- Nativity;
- House ownership, house type and criteria for housing;
- Access to energy sources;
- Access to water, mode of disposal of wastewater and solid waste;
- Mobility patterns; and
- Level of access to healthcare, amenities and infrastructure.

The questionnaire was initially piloted for a sample size of 20 households and then modified (tuned) appropriately based on the initial feedback.

Sampling Strategy and Sample Size: The entire study area was stratified into two groups: one, the erstwhile city corporation limits – BMP area, and two, the newly added regions of BBMP area. Map 1 depicts the regions accordingly.

The sample size was arrived at based on the following formula:

$$S = Z^2 * N * E(1 - E) / [(A^2 * N) + (Z^2 * E(1 - E))]$$

where,

S = Required sample size;

Z = Factor for the desired confidence level;

N = Population size;

E = Expected error rate; and

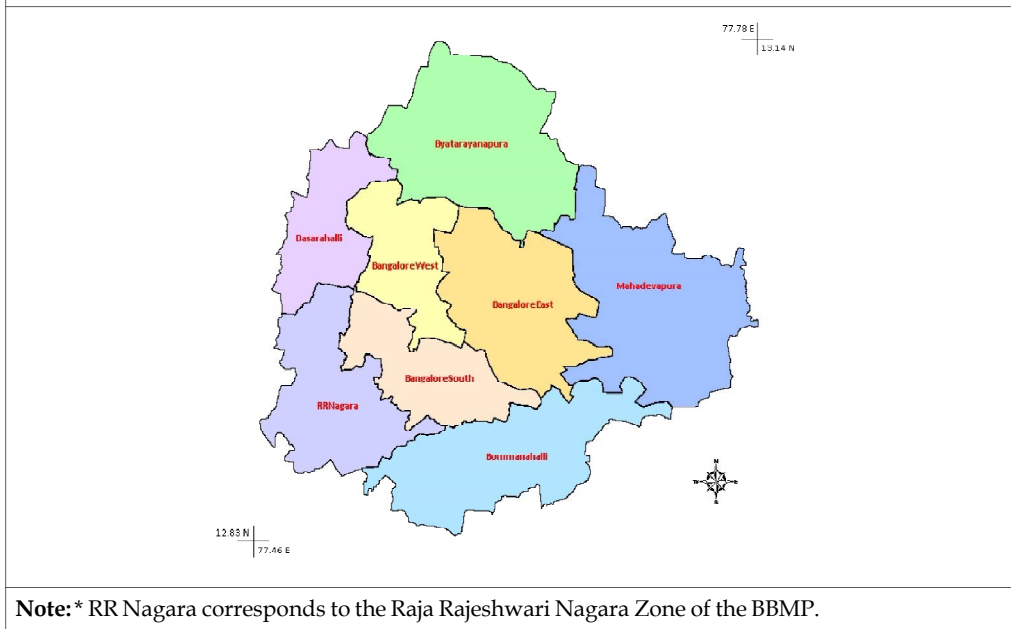
A = Precision range.

Eight zones of Bruhat Bangalore comprise three zones of erstwhile BMP (with a population of 4.5 million) and five new zones from City Municipal Council (CMC) and TMC (with a population of 2.5 million). For a sample size of 7 million, with an error rate of 5%, precision range of 3% at 95% confidence level, the requisite sample size is 203. Further, distinguishing the earlier BMP (three zones) region of 226 sq. km and five new zones as two separate clusters, the total sample size for the survey was 421 (greater than approximately 203 x 2).

Data Collection: Stratified random sampling was undertaken capturing all the socio-economic classes in each zone based on house type. The number of samples in

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Map 1: Zones Under Bruhat Bangalore Mahanagara Palike*



each zone was divided according to the low-income housing, middle-income housing and high-income housing as different starting points. Accordingly, in the Bangalore East, Bangalore West and Bangalore South zones the sample size was 75 each, with about seven starting points and 11 samples per starting point. In the five new zones, the sample size was about 42 each, with about seven starting points and six samples per starting point.

Satellite Remote Sensing Data: The remote sensing data for land cover by NASA's Landsat TM for 1992 and Landsat ETM+ for 2000 was obtained from the Global Land Cover Facility (GLCF - <http://www.landcover.org/>), Institute for Advanced Computer Studies, University of Maryland, United States of America. The land cover data, IRS LISS-III for 2006 was obtained from the National Remote Sensing Agency, Hyderabad, India.

Secondary Data: The secondary data collected included the demographic details from the primary census abstracts for 1971, 1981, 1991 and 2001 from the Directorate of Census Operations, Census of India. Several other relevant data were obtained from various government departments, including the BBMP, Bangalore Development Authority (BDA), Bangalore Water Supply and Sewerage Board, Bangalore Metropolitan Transport Corporation, Bangalore City Police, Directorate of Economics and Statistics (Government of Karnataka), Karnataka State Pollution Control Board, Planning Commission of India, and Ministry of Urban Development (Government of India).

Research Method and Tools

Analysis of Survey Data: The analysis of the survey data began with their tabulation, sorting and exploratory data analysis. Exploratory data analysis was restricted to estimation of averages and percentages for each of the parameter. The section on results presents these findings. The corresponding results were later tabulated according to the respective zones for undertaking further statistical analysis.

Multidimensional Scaling: In order to explore any structural underlying patterns, similarities or dissimilarities in the data, the multivariate statistical analysis using Multidimensional Scaling (MDS) was employed. MDS is a non-parametric version of the Principal Coordinate Analysis (PCOA). Given the association matrix between the units under comparison, the method attempts to find a representation of the units in a given number of dimensions while preserving the pattern/ordering in the association matrix. MDS pictures the structure of a set of objects from data that approximate the distances between pairs of the objects. The data, which are called similarities, dissimilarities, distances or proximities, reflect the amount of dissimilarity (between pairs of the objects). MDS programmes attempt to minimise stress in order to obtain the MDS solution, while there exist many versions of stress. The amount of stress may also be used for judging the goodness of fit of an MDS solution: a small stress value indicates a good fitting solution, whereas a high value indicates a bad fit.

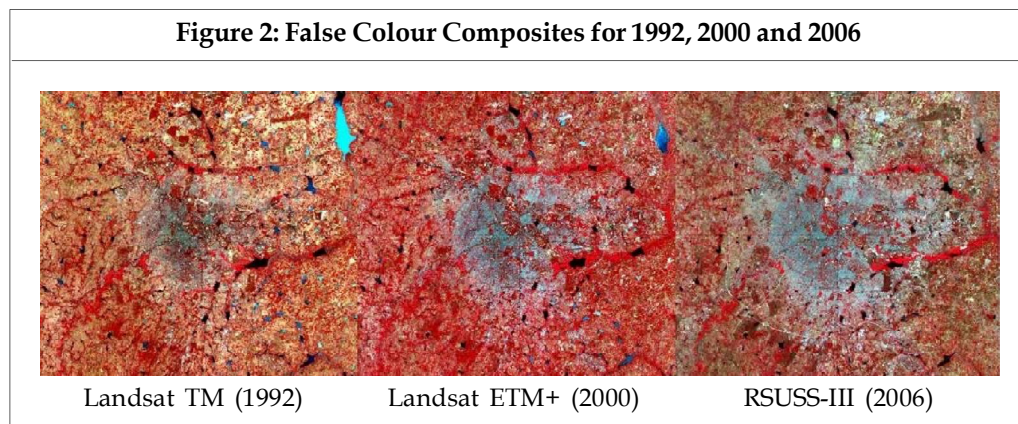
Remote Sensing Data Analysis: The remote sensing data are initially processed to quantify the land-use of Bangalore city broadly into four classes—built-up, agriculture and vegetation, open land and water bodies. The multi-spectral data of Landsat TM and Landsat ETM+ with a spatial resolution of 30 m each and IRS LISS-III with a spatial resolution of 23.5 m were analysed using IDRISI Andes.¹⁴ The image analyses included image registration, False Colour Composite (FCC) generation, enhancement and classification. The image geo-registration was rectified with respect to the ground control points collected from the geo-referenced Survey of India toposheets. The images were rectified using a linear mapping function for the ground control points and the nearest neighbourhood resampling type. After image geo-registration, the false colour composites were generated using the bands: green, red and near-infrared (Figure 2). The next step involved classification of the multi-spectral remote sensing data, which was carried through a two-stage classification process: unsupervised and supervised. The ISOCLUST module, which is an iterative self-organising unsupervised classifier based on a concept similar to the well-known ISODATA routine¹⁵ and cluster routines such as the H-means and K-means procedures, was used for performing the unsupervised classification. In the unsupervised classification, the number of clusters for classification was identified through the

¹⁴ J. R. Eastman, **Idrisi Andes** (Clark University, USA: Clark Labs, 2006), available at <http://www.clarklabs.org>

¹⁵ G. H. Ball and D. J. Hall, **A Novel Method of Data Analysis and Pattern Classification** (Menlo Park, CA, USA: Stanford Research Institute, 1965), in Eastman, **Idrisi Andes**.

number of distinct peaks obtained from the histogram. For the supervised classification, the signatures were derived from the training data obtained in the field using Global Positioning System (GPS) for distinctive land-uses and some of the land-use features obtained from unsupervised classification. The signatures were generated for each of the land-uses and were verified with the composite image. Based on these signatures, corresponding to various land features, supervised image classification was done using Gaussian Maximum Likelihood Classifier (Figure 2). The Maximum Likelihood Classification is based on the probability density function associated with a particular training site signature. Pixels are assigned to the most likely class based on a comparison of the posterior probability that it belongs to each of the signatures being considered. This is also known as a Bayesian classifier since it has the ability to incorporate prior knowledge using Bayes' Theorem. Prior knowledge is expressed as a prior probability that each class exists. It can be specified as a single value applicable to all pixels, or as an image expressing different prior probabilities for each pixel.¹⁶ Post classification from the IRS LISS-III data for 2006 was resampled to 30 m so as to enable comparison with the landsat data outputs.

Figure 2: False Colour Composites for 1992, 2000 and 2006



The classification accuracy was tested for the classified images using some of the training data collected and generated during the classification process. These were compared with the classified land-uses with the actual land-use. For the recent (2006) IRS LISS-III data, there were ground control points obtained from the field that were used in comparison. However, for the earlier time data (1992 and 2000), some of the control points with known land-use classes were used as reference along with the false colour composite image to ascertain the accuracy of classified land-use classes. The classification accuracies of Landsat TM (1992), Landsat ETM+ and IRS LISS-III were 76.9%, 84.6% and 71.8%, respectively.

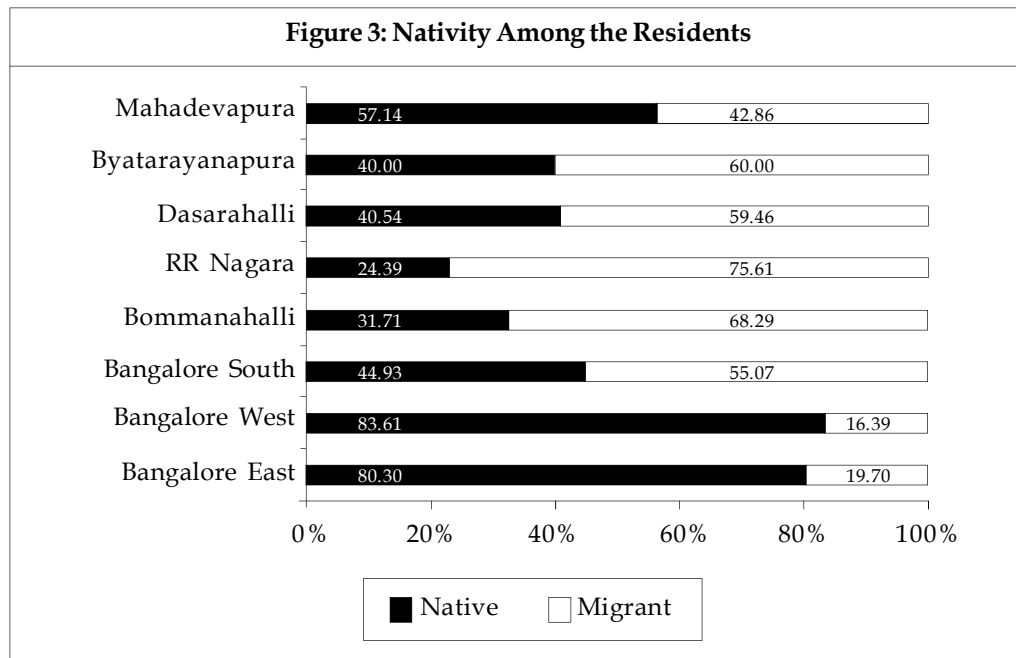
RESULTS AND DISCUSSION

Demography and Economy

Nativity: Among the first set of indicators that were enumerated based on

¹⁶ Eastman, Idrisi Andes.

the samples was the nativity of respondents (Figure 3) in different zones of BBMP. This indicates that Bangalore West and East zones had more than 80% natives while Bangalore South zone had only about 45% natives similar to most of the zones in the periphery. It appeared that most migrants were in Raja Rajeshwari Nagara zone, followed by Bommanahalli, Byatarayanapura, and Dasarahalli zones.



House Ownership, Type and Criteria for Housing: The next set of indicators addressed house ownership, housing type and criteria for housing. They appeared to be positively correlated, but the correlation was not statistically significant ($r = 0.68$; $p = 0.065$) with the houses owned and nativity. The percentage of residents living in rented houses appeared to be higher than those living in their own houses in Mahadevapura, Raja Rajeshwari Nagara, Bommanahalli and Bangalore South zones (Figure 4).

Further, a majority of the houses were brick-walled with RCC roofing, except fewer instances in Raja Rajeshwari Nagara and Bommanahalli, where a majority of the houses were brick-walled with asbestos sheet roofing (Figure 5). The hut/mud-walled type of houses mostly belonging to urban poor settlements were observed in Bangalore West and Byatarayanapura zones.

The criteria for choosing the new residence were ranked on a scale of 1 to 5, where 1 was the most preferred and 5 the least preferred. The choices provided were: access to services, access to education, access to workplace, land prices or rent value and proximity to city centre or main roads. Accordingly, the mean rankings for all the criteria are shown in Table 1 and Figure 6 with respect to each zone. It showed that 'access to workplace' emerged as the top criteria with a

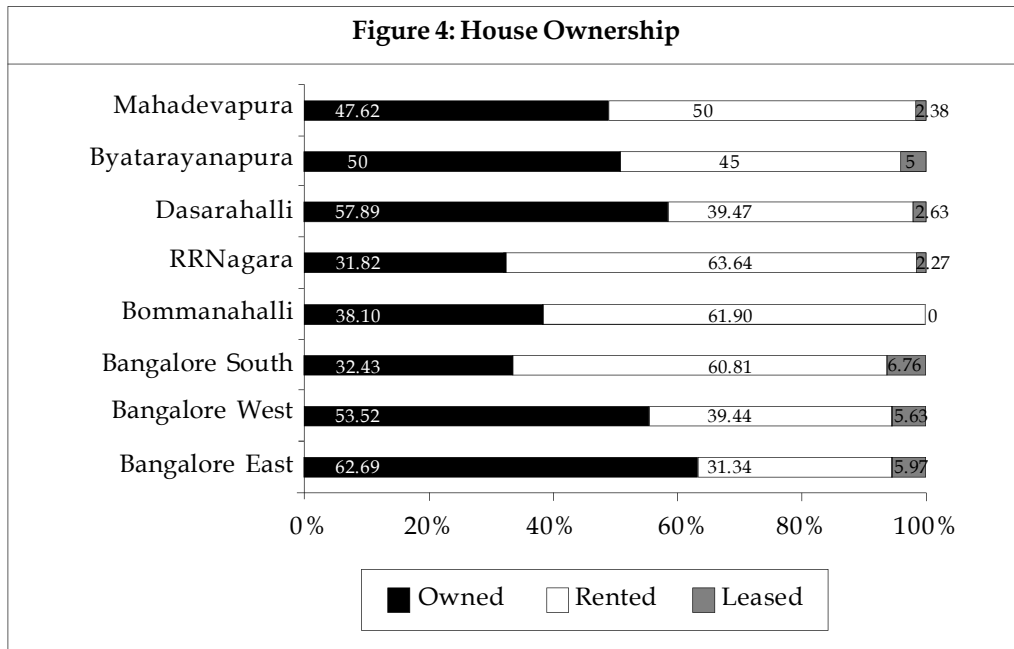


Table 1: Mean Ranking for Housing Criteria

Criteria for Housing	Mean Ranking
Access to Workplace	1.97
Access to Services	2.13
Land Prices/Rent Value	2.68
Access to Education	3.00
Proximity to City/Main Roads	3.04

mean ranking of 1.97, followed by access to services (2.13), land prices or rent value (2.68), access to education (3.00) and proximity to city centre or main roads (3.04). The criteria of proximity to city centre or main road getting the least rank amongst the rest of the ranks suggests that residents may actually prefer to stay away from the city (even in the outskirts) as long as it is closer to their workplace and they have access to services.

Environment and Resources

Land-Use: Typically, the degree of urban growth or sprawl is attempted by quantifying the amount of paved surface or built-up area in a given region obtained from the classification of remotely sensed data or other geospatial data.¹⁷

¹⁷ Torrens and Alberti, "Measuring Sprawl"; Barnes, Morgan, Roberge, and Lowe, **Sprawl Development: Its Patterns, Consequences, and Measurement**; G.Galster, R. Hanson, M. R. Ratcliffe, H.Wolman, S. Coleman, and J. Freihage, "Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept," **Housing Policy Debate**, Vol. 12 (2001) no. 4, pp.681-717; and Epstein, Payne, and Kramer, "Techniques for Mapping Suburban Sprawl".

Figure 5: House Type

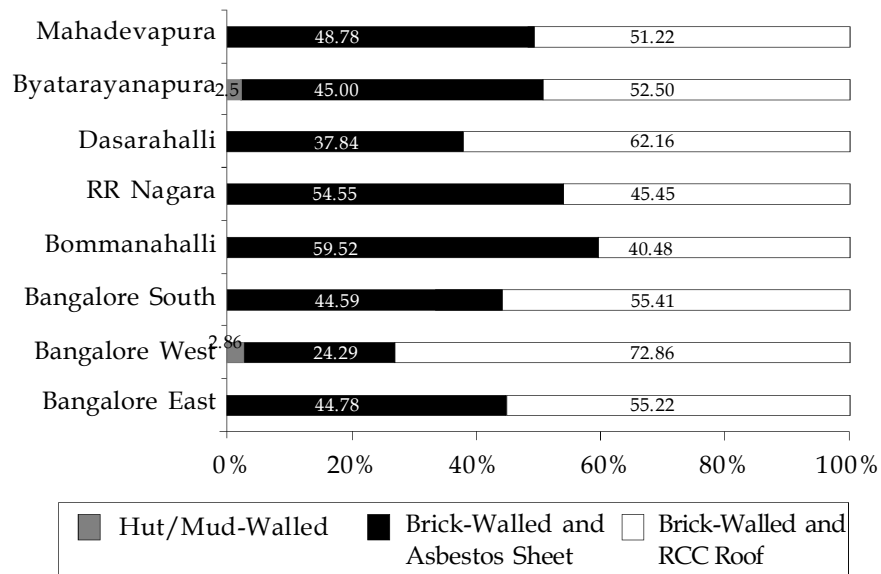
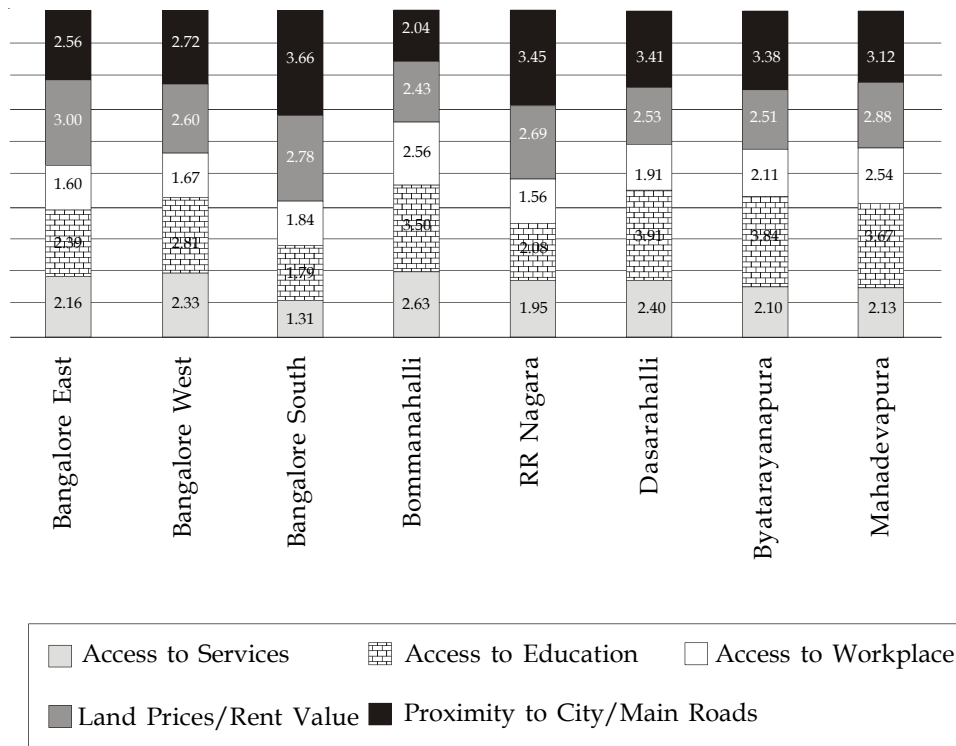


Figure 6: Criteria for Housing



Characterising the pattern of urban sprawl would then rest on noting the extent of built-up areas and its associated measures that depict sprawl based on the notion of built-up or paved area. A key aspect in the expansion of built-up area is its engulfing of surrounding open spaces within the landscape.

Land-Use Change Detection: The spatial analysis was performed at the landscape level extending beyond the Greater Bangalore’s administrative boundary. The classified images for land-use in 1992, 2000 and 2006 are shown in Map 2. The extent of land-use during 1992, 2000 and 2006 comprised built-up area with 142.54 sq. km, 186.42 sq. km and 301.27 sq. km, respectively. Similarly, the extent of non-built-up area comprising open land, vegetation and water bodies were 1,449.35 sq. km, 1,405.42 sq. km and 1,291.58 sq. km during 1992, 2000 and 2006, respectively. The land-use change analysis was carried out based on the differences in temporal land-uses. During 1992 to 2000, it is observed that the extent of built-up area increased by 30.8%, while the built-up area increased by 61.61% during 2000 to 2006 (Table 2). The extent of increase in built-up area depicts only the magnitude of change and does not suggest the pattern of this transition. Analysing the probable land-use change from various non-built-up classes to built-up, the cross-tabulation for the classified images was performed. It was noted that during 1992 to 2000, the land-use change from open land to vegetation was significant as the data corresponded to different seasons. The major land-use that contributed to the increase of built-up area was by the open land-use class. Similarly, during 2000 to 2006, the vegetation was the major land-use that was lost (by almost 180 sq. km) due to conversions into built-up areas.

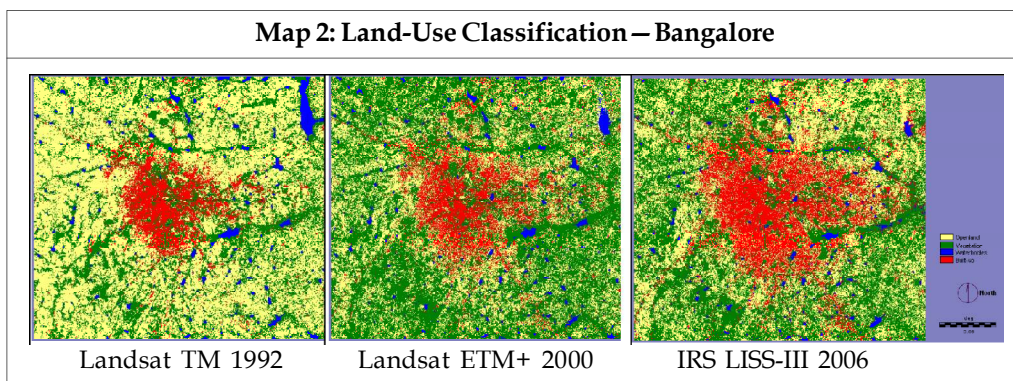


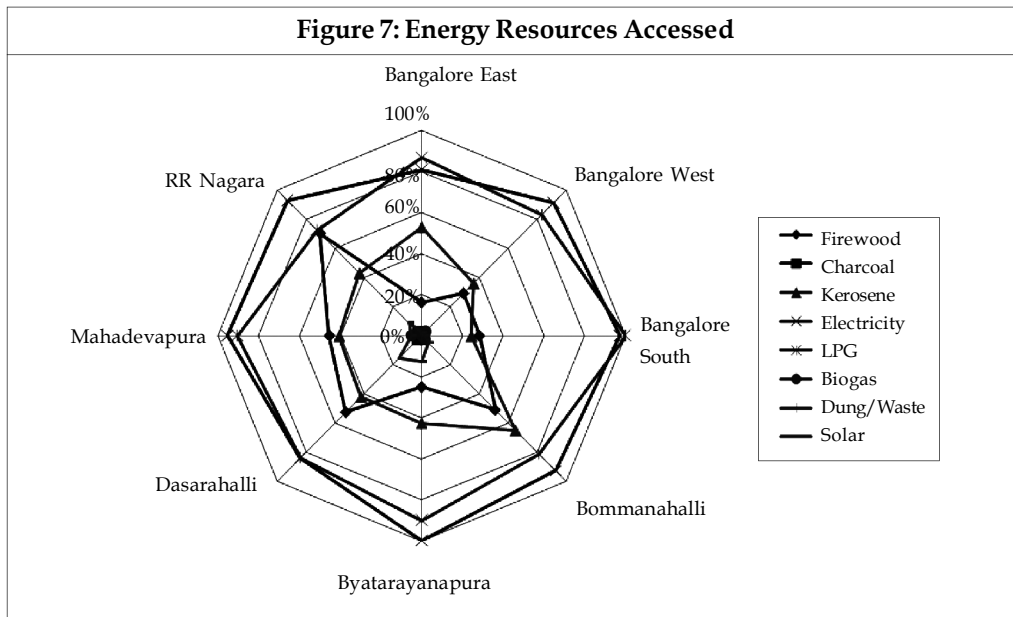
Table 2: Extent of Land-Use Change Among Built-Up and Non-Built-Up

Land-Use	1992 (sq. km)	2000 (sq. km)	2006 (sq. km)	Percentage Change (1992-2000)	Percentage Change (2000-2006)
Built-Up	142.54	186.42	301.27	+30.78	+61.61
Non-Built-Up	1,449.35	1,405.47	1,291.58	-03.03	-08.10

Land-Use Changes in Bruhat Bangalore: The proportion of land-use changes, especially the percentage built-up area, which is a key metric to measure sprawl, was estimated across all the zones of BBMP. The corresponding land-use changes within the BBMP region are shown in Table 3. It is clearly evident that on an average the increase in built-up area in the central zones was from 47.8% to 64.2%, while in outer zones built-up area shot from a mere 6.8% in 1992 to 25.6%. This implies that the change in built-up areas in the central zones was about 35%, while the change in built-up areas in the outer zones was nearly 300%. Perhaps, the relatively higher percentage of built-up areas during 1992 in Dasarahalli zone and Mahadevapura zones with 10.04% and 8.03%, respectively, may be due to the industrial estates in these locations, while by 2006 this had increased to 30.32% and 26.89%. Further, while the change in built-up areas in central zones increased modestly, this indicated that these zones were getting denser. However, it was noted that there was a slight reduction in the percentage built-up area in Bangalore West zone for 2000. Perhaps this should be viewed in the light of classification accuracies for the respective time data. Among the outer zones, Bommanahalli witnessed the highest relative change in percentage built-up areas from 5.05 to 27.90, indicating the magnitude of growth in the region. Indeed this change in land-use may be attributed to the IT-based companies located in the region and the proximity to the Electronic City along the Hosur Road.

	1992	2000	2006
Bangalore East	35.79	37.30	50.93
Bangalore West	58.09	54.23	69.38
Bangalore South	49.54	54.48	72.47
Bommanahalli	5.05	11.08	27.90
RR Nagara	4.70	8.24	18.87
Dasarahalli	10.04	16.56	30.32
Byatarayanapura	6.01	11.15	24.01
Mahadevapura	8.03	13.28	26.89

Energy Sources: The assessment of access to energy sources reveals that electricity and LPG were among the most widely accessed sources (Figure 7). Firewood is still used mostly in the new zones especially Raja Rajeshwari Nagara, Bommanahalli, Dasarahalli and Mahadevapura zones, followed by kerosene in Bommanahalli and Bangalore East zones. Perhaps, the availability of firewood in the periphery of the city explains the larger number of residents accessing this source. It is further interesting to note that solar energy was being tapped mostly in the newly constructed houses in the new zones. The other energy sources that were accessed, though not in large numbers, were: charcoal, biogas and dung/waste. Electricity was the most accessed source for lighting and less for water heating and cooking,



while LPG was the most accessed source for cooking. Firewood was used mostly for water heating followed by cooking.

Water, Mode of Disposal of Wastewater and Solid Waste: Water is one of the key resources and is therefore accessed from different sources. In the central zones of Bangalore, viz., East, West and South, the source of supply was mainly from Bangalore Water Supply and Sewerage Board (BWSSB) for nearly 90% of the residents (Figure 8). The erstwhile CMC administered water supply with as much as 80% to the outer zones of Byatarayanapura and Raja Rajeshwari Nagara. However, in the Bommanahalli, Dasarahalli and Mahadevapura zones, 60% of the respondents were serviced by CMC sources. This has resulted in residents sourcing water from private water supply (through tankers), followed by bore-wells, community taps and other sources in Bommanahalli, Dasarahalli and Byatarayanapura zones.

In spite of shortfalls in supplying water to all zones by the BWSSB and respective municipal councils, the sewage collection in the zones appeared to be well serviced through higher sewer connections (Figure 9). It was revealed that the central zones of Bangalore, East, West and South, followed by Mahadevapura zone, were serviced with sewer connections of almost 100%. However, the outer zones of Bommanahalli, Byatarayanapura, Dasarahalli and Raja Rajeshawari Nagara zones were serviced between 60 to 80%. Sewage disposal by way of septic tank was more prevalent in Dasarahalli, Byatarayanapura and Bommanahalli zones.

Similar to the water supply and sewage collection, the solid waste collection too indicated that the central zones of Bangalore, East, West and South, were better serviced with more than 85% of solid waste collected through door-to-door collection (Figure 10). Among the outer zones, only Byatarayanapura had a

Figure 8: Sources of Water Supply

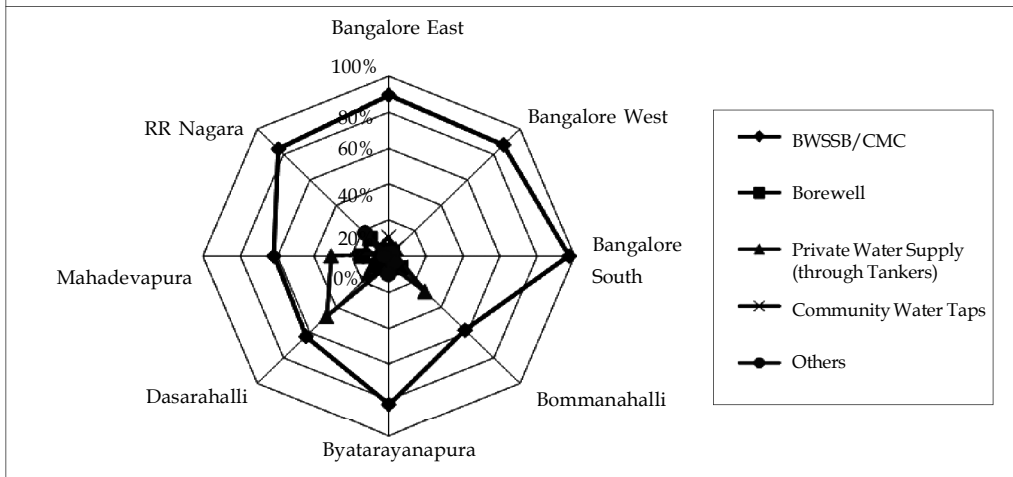


Figure 9: Mode of Wastewater Disposal

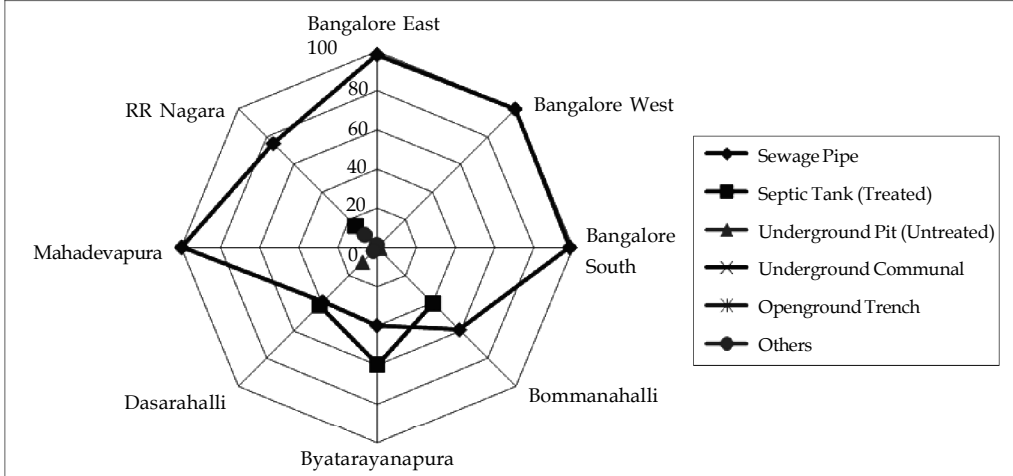
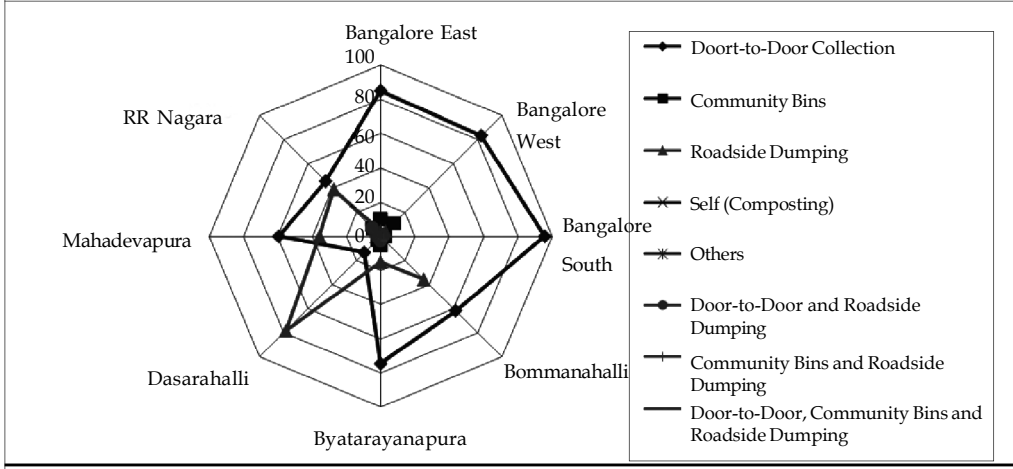


Figure 10: Solid Waste Disposal

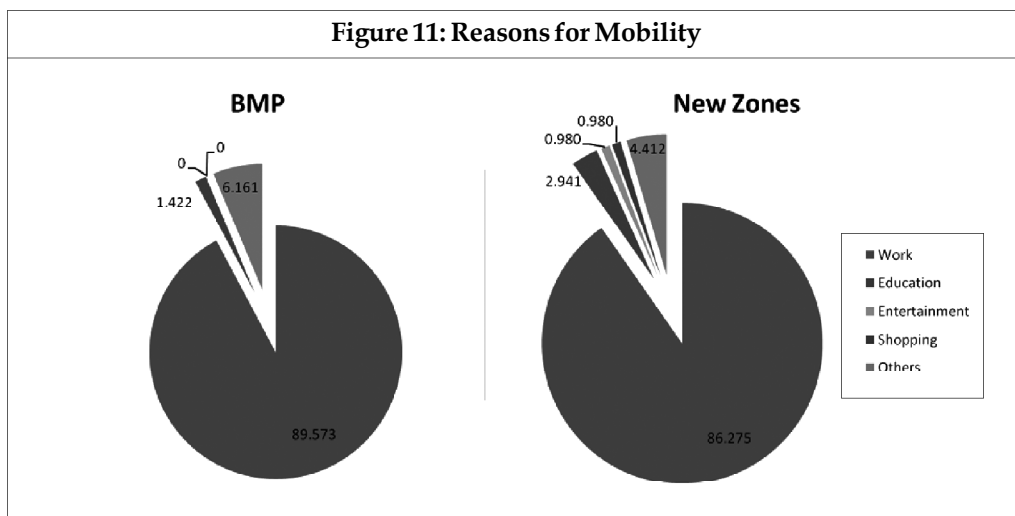


better coverage for the door-to-door collection with about 75%, while Mahadevapura and Bommanahalli zones had a coverage of about 60%. The Raja Rajeshwari Nagara zone had a coverage of about 50%, while Dasarahalli zone was the least covered with less than 20% for door-to-door collection. In the zones where the door-to-door collection was poor, road-side dumping was more prevalent (Dasarahalli, Raja Rajeshwari Nagara and Bommanahalli zones), followed by disposal in community bins and a combination of all the above three methods of disposal.

These indicators clearly depict that the central zones were well-served in comparison to the outer zones in terms of water supply, wastewater collection and solid waste collection. This also brings out how different zones fare in delivery of these services.

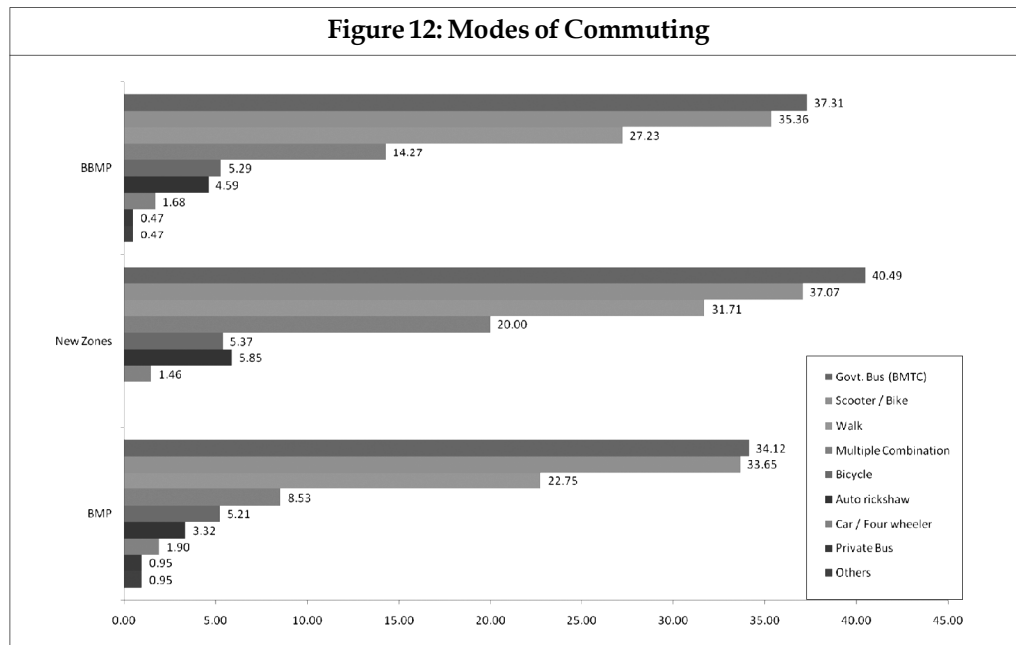
Mobility

One of the key city functions that is regarded as a metric is mobility, which determines why and how citizens are commuting within the city. This throws some light on the composition of people commuting for different purposes and modes employed for their commuting. This revealed that among the respondents in the central zones (East, West and South), almost 90% commuted for their work, while a few commuted for education and other purposes. However, in the outer zones, 86% commuted for work, about 3% for education, 1% each for entertainment and shopping, followed by 4.4% for other purposes (Figure 11).



Addressing the modes employed for commuting (Figure 12), it was revealed that in all, 37% used the bus-based public transport service Bangalore Metropolitan Transport Corporation (BMTC), followed by individual motor transport (two-wheelers with 35%). It was startling to note that 27% 'walked', while 14% used a combination of different modes. About 5.3% used bicycles, 4.6% used auto-rickshaws and only 1.7% four-wheelers. The rise in number of two-wheeler traffic

in the city (around 1.8 million) explains the large percentage of people plying on the roads (35%). However, the significant percentages who 'walk' strongly suggest adequate measures for facilitating safer pedestrian commuting. The percentage of respondents commuting by multiple combinations (14%) includes different modes such as bus, walk, two-wheelers, auto-rickshaws and four-wheelers, while this also masks the percentage of respondents exclusively commuting by four-wheelers (1.7%).



Planning and Governance

Planning: Planning and governance are imperative for ensuring effective service delivery and management of resources. As noted earlier, this set of indicators includes both quantitative and qualitative variables. The presence/absence of elected local body and their participation in planning are also considered. The indicators under planning and governance included: nature of urban local governance that prevailed until the formation of Greater Bangalore (BBMP), preparation and publication of master plans, public participation, and per capita expenditure in the budget of the local body (Table 4). The data to these were collected mainly from secondary sources. It can be seen that per capita expenditure is clearly more in case of the central zones (as it was under erstwhile BMP limits), while the neighbouring municipal councils have much lesser expenditure. Planning function is completely taken over by the parastatal agency, BDA, and thus the local bodies have to abide by the policies formulated by the parastatal body. However, the effectiveness of solid waste collection in all the zones, when compared with the per capita expenditure, is positively correlated ($r = 0.79$, $p = 0.018$).

Author please provide full form

Zones	Population [#]	Nature of Local Governance (Until Formation of BBMP)	Public Participation in Preparation of Master Plan	Preparation and Publication of Master Plan	Per Capita Expenditure (₹)*
Bangalore East	14,14,831	City Corporation	No	Yes (BDA)	1,653
Bangalore West	12,92,771	City Corporation	No	Yes (BDA)	1,653
Bangalore South	15,84,621	City Corporation	No	Yes (BDA)	1,653
Bommanahalli	2,01,652	City Municipal Council	No	Yes (BDA)	546
Raja Rajeshwari Nagara	1,38,840	City and <u>ZTown</u> Municipal Council	No	Yes (BDA)	583.5
Dasarahalli	2,64,940	City Municipal Council	No	Yes (BDA)	187
Byatarayanapura	2,72,571	City and Town Municipal Council	No	Yes (BDA)	602.5
Mahadevapura	3,22,013	City Municipal Council	No	Yes (BDA)	168.65

Note: [#] Based on Census of India (2001); * Based on recent budget estimates of BMP and other municipal councils.

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Accessibilities: The level of accessibilities to different amenities, services and healthcare was estimated based on the sample survey in all the zones. The level of access to services is meant as a proxy to assess the effectiveness of governance in different zones. The respondents were asked to rate according to the distance access to different amenities (Table 5). Different amenities that were assessed are given in Table 6.

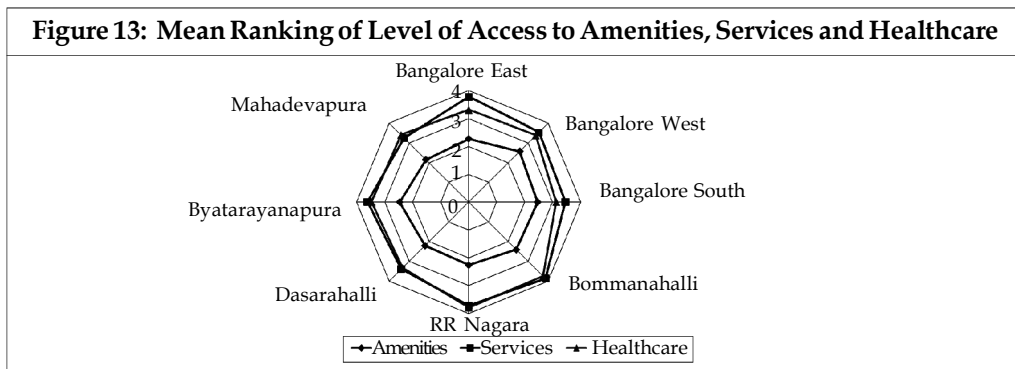
Rank	Distance
1	< 500 m
2	500 m to 1 km
3	1 km to 2 km
4	2 km to 5 km
5	> 5 km

The ranking based on distance was useful in enumerating the proximity of the different services as accessed by the respondents. The mean ranking was considered for determining the overall level of access in different zones. In all, it was observed that the level of access scores (ranking) was almost similar in all the zones irrespective of the administrative differences (town and city municipals

and city corporation limits) (Figure 13). This perhaps suggests that irrespective of the administrative jurisdictions, the level of services ranged almost similarly across the entire urban agglomeration. It was found that irrespective of governance and their level of services (mean rank of 3.57), the accessibilities to basic amenities (mean ranking of 2.34) were better and same in both central and outer zones. Further, there were no significant differences between services and healthcare ($p = 0.27$), while they were significantly different from amenities ($p = 0.00093$).

Table 6: Amenities, Services and Healthcare Assessed

Amenities	Services	Healthcare
Cooking gas/LPG	Water Supply Source and Sanitation (Wastewater)	Primary healthcare centres
Kerosene	Electricity	Government hospitals
Fuel wood	Road works	Local clinics/Small nursing homes
Grocery (including Rice, Sugar, Oil, etc.)	Street lighting	Private hospitals
Vegetables	Communication (Telephone)	Specialty hospitals
Milk	Park or other open space	Maternity homes

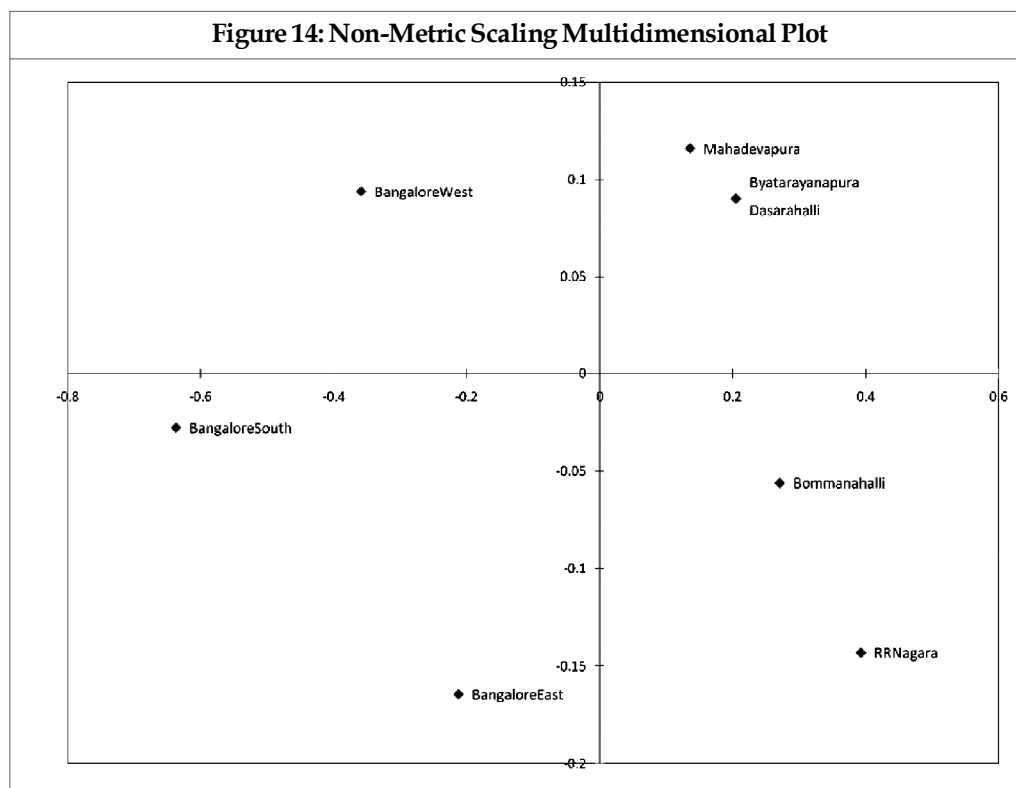


Implications of Planning and Governance on Sprawl and Level of Services

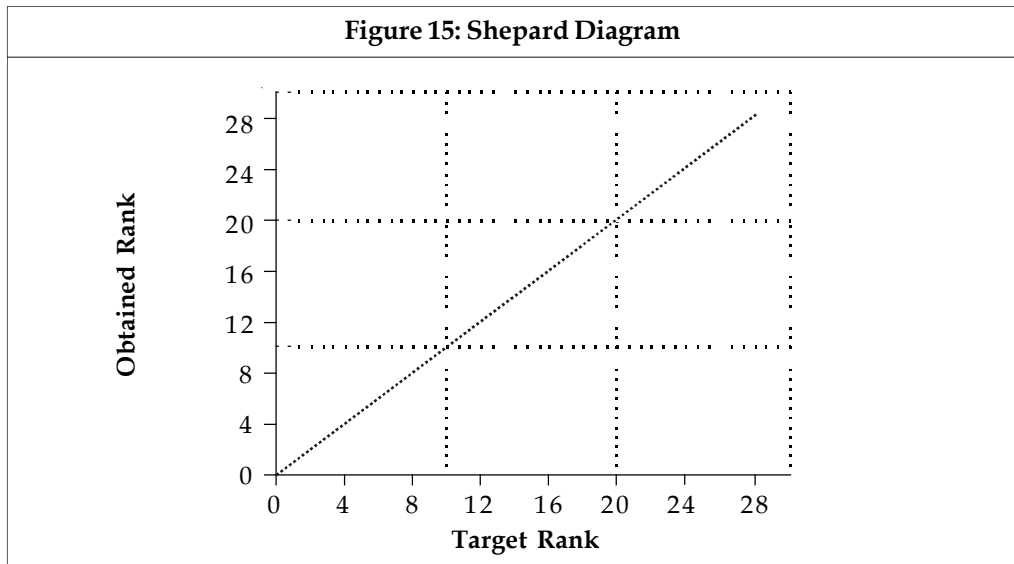
In order to first explore any underlying structure within the zones of Greater Bangalore using the above set of indicators, non-metric Multidimensional Scaling (MDS) analysis was carried out. The variables so considered were population, per capita expenditure, amenities score, services score, healthcare score, nativity, house ownership, house-type: brick-walled and asbestos sheet, and brick-walled and RCC roof; access to energy sources: electricity, LPG, kerosene, firewood, solar and biogas; access to water: BWSSB/CMC, bore-well, private water supply (tankers), community water taps, wastewater disposal by sewage pipe; and solid waste disposal: door-to-door collection, community bins and roadside dumping.

The statistical package PAST was used to perform the MDS. The resultant ordination plot is shown in Figure 14. Judging the goodness of fit is normally through the interpretation of the stress value. In this case, the stress was found to be 0, indicating a perfect fit. An additional technique commonly used in judging the adequacy of an MDS solution is by the Shepard diagram. The corresponding Shepard diagram (Figure 15) reveals a monotonically increasing line, implying that the MDS solution fits well.

The plot (Figure 14) reveals that the central zones of Bangalore: East, South and West are distinctively away from the outer zones. The outer zones, Mahadevapura, Byatarayanapura and Dasarahalli, are positioned very close to each other, while Bommanahalli and Raja Rajeshwari Nagara zones are slightly away. In any case, the analysis brings out the distinctions with respect to each of the zones, especially from those in the central and outer zones. This brings out the clear distinction depicting the structural similarities (or dissimilarities) with respect to the different indicators considered for characterising sprawl.



From the above analysis (through MDS) and enumeration of various indicators across the different zones of Greater Bangalore, it is evident that central areas and the outer areas were clearly different in several aspects. It is observed that the outer zones were considered the sprawl areas, though they have been only recently merged with Greater Bangalore. Although the level of access to different



services and amenities was the same across different zones, the access to resources (water supply, energy, wastewater and solid waste disposal) was different across the central and outer zones. Further, with the effectiveness of planning and governance on the overall level of services (including that of resources), the outer zones had poor delivery of services, while the central zones had a better delivery of these services. Further, it was also found that the per capita expenditure was positively correlated with the solid waste collection (the solid waste management is the onus of the urban local body and hence this resource was compared with the per capita expenditure of the respective local bodies). This conforms to the theoretical framework, proposed earlier in the paper, on the effect of planning and governance on services and extent of outgrowth (sprawl). Perhaps, with this outcome, this would suggest more effective governance in the outer zones to ensure better delivery of services through greater allocation of funds for the same. This can be further possible when planning and governance are proactive in forecasting the respective amenities and services along with necessary infrastructure in these zones.

CHALLENGES AHEAD

The efficiency of urban settlements largely depends on how well they are planned, how well they are developed economically and how efficiently they are managed. With rapid urbanisation in developing countries, urban sprawl seems inevitable. However, much of the understanding of sprawl in developing countries is still vague. A starting point for this is the development of appropriate indicators for measuring/quantifying urban sprawl in developing countries. It is now imperative to have robust information systems depicting the above-said indicators for effective communication, planning, review and monitoring of urban sprawl. Furthermore, such an information system when deployed over the Internet can be made accessible to a wider community with round the clock accessibility.

Combining the goals of achieving sustainability and addressing the problem of sprawl has been the underlying principle of the present description of sprawl indicators for developing countries. This would allow the concerned authorities of urban areas to regularly plan, review and monitor the direction in which urban growth heads towards achieving sustainable development. It is in this spirit the paper also reviewed existing indicator frameworks and arrived at the indicators for urban sprawl. Further, these were operationalised for the city based on both primary and secondary data collection.

The different dimensions of sprawl based on environment and resources, demography and economy, mobility, and planning and governance were ascertained and enumerated. The utility of spatial indicators, combined with non-spatial indicators, was useful in characterising the patterns of sprawl across the urban agglomeration. The estimation of different indicators and the subsequent analysis clearly brought out the distinction between the sprawl regions (outer zones) and the central city (central zones). Characterising urban growth using multi-temporal remote sensing data has been quite popular for a while, although there have been a few studies that addressed the extent of urban growth resulting in sprawl through appropriate metrics. In this paper, the utility of landscape metrics like patchiness and built-up density for characterising urban sprawl was demonstrated. However, a critical challenge is to identify ecologically sensitive habitats (like water bodies) that may be prone to sprawl and address the extent of low-density sprawl that results in inefficient resource usage. Further, the pattern of development taking place along the periphery of the Bangalore city should be used as a tool for effective monitoring and enhancing management options for land use. ©

Reference # 47J-2011-03-0x-01