INTEGRATED SPATIAL PLANNING SUPPORT SYSTEMS FOR MANAGING URBAN SPRAWL

H. S. SUDHIRA
Research Scholar
Department of Management Studies and Centre for Sustainable Technologies
Indian Institute of Science
Bangalore – 560 012
India
Tel: +91 80 2293 2786
Fax: +91 80 2360 4534
E-mail: sudhira@mgmt.iisc.ernet.in

T. V. RAMACHANDRA
Associate Faculty
Centre for Sustainable Technologies and Centre for Ecological Sciences
Indian Institute of Science
Bangalore – 560 012
India
Tel: +91 80 2293 3099
Fax: +91 80 2360 1428
E-mail: cestvr@ces.iisc.ernet.in

M. H. BALA SUBRAHMANYA
Associate Professor
Department of Management Studies
Indian Institute of Science
Bangalore – 560 012
India
Tel: +91 80 2293 3066
Fax: +91 80 2360 4534
E-mail: bala@mgmt.iisc.ernet.in

Abstract: The paper addresses the issues and problems that concerns managing urban sprawl in India. Three essential steps to strengthen policy, planning and decision making are outlined while identifying the gaps. In India, as per constitutional provisions, there is a mandate with urban local bodies for administering, managing and preparing master / development plans. Mostly these plans are static maps with limited forecasting capabilities and there is a dearth of models for planning process and hence leading to ad hoc decisions. Besides this, these plans mostly restrict to demarcate only land use zones with little or no effective regulation for the same. Further, with planning authorities restricting to mostly land uses, there is hardly any coordinated effort to involve or integrate transport, water and sanitation, etc. in the planning process. This results in organisations involved or catering to different services (transport, health, water, energy, etc.) work in isolation to address basic amenities. Lack of coordination among many agencies has lead to unsustainable use of land and other resources and also uncoordinated urban growth. Urban governance and administration requires keeping track of various processes, activities, services and functions of the urban local body, which is possible through an information system. In the absence of any such systems, at the basic level, there is a strong and pressing need for an information system to cater to all these. In the next level, it becomes essential to build models based on the information systems involving simulation and analysis for specific urban contexts. The subsequent level involves evolving different strategy and policy options using the models and information systems. Thus, at the outset, there are three essential steps to address the problem of sprawl and to strengthen planning and decision making – information systems, models and policies. Review of the different geospatial modelling techniques (operations research, system dynamics, geospatial, agent-based, etc.) being used in the urban context highlights the increased dependence on geo-based models and also the need for an integrated spatial planning support system.

Keywords: urban sprawl, modelling, planning support systems
1. URBAN SPRAWL: THE INDIAN EXPERIENCE

Urban sprawl is the outgrowth along the periphery of cities and along highways. Although accurate definition of urban sprawl may be debated, a general consensus is that urban sprawl is characterized by an unplanned and uneven pattern of growth, driven by multitude of processes and leading to inefficient resource utilization. Urbanisation in India has been never as rapid as it is in the recent times. As one of the fastest growing economies in the world, India faces stiff challenges in managing this urban growth leading to sprawl and ensuring effective delivery of basic services in urban areas.

Urban growth, as such is a continuously evolving natural process due to population growth rates (birth and death). An increased urban population and growth in urban areas is inadvertent with an unpremeditated population growth and migration. In India, urban population is currently growing at around 2.3 percent per annum. The number of urban agglomerations and towns in India has increased from 3697 in 1991 to 4369 in 2001. It is projected that the country’s urban population would increase from 28.3 percent in 2003 to about 41.4 percent by 2030 (United Nations, 2004). By 2001, there were 35 urban agglomerations / cities having a population of more than one million from 25 urban agglomerations in 1991. Of the 4000 plus urban agglomerations, about 38 percent reside in just 35 urban areas, thus indicating the magnitude of urbanisation prevailing in the country. This clearly indicates the magnitude of concentrated growth and urban primacy, which also has lead to urban sprawl.

The urban areas contribute significantly to the national economy (about ... percent of GDP), while facing critical challenges in accessing basic services and necessary infrastructure, both social and economic. The overall rise in population of urban poor or increase in travel times owing to congestion in road networks are indicators of the effectiveness of planning and administration in assessing and catering to the demand. Thus the administration at all levels: local bodies, state government and federal government, are facing the brunt of this rapid urban growth. It is imperative for planning and administration to facilitate, augment and service the requisite infrastructure over time systematically. Provision of infrastructure and ensuring delivery of basic services cannot happen overnight and hence planning has to facilitate in forecasting and provisioning these services with appropriate mechanisms.

This paper addresses the sprawl in the Indian context. The subsequent section analyses the status of planning practices in India with emphasis on utility of spatial planning tools and an overview of the institutional dynamics contributing to sprawl. As a synthesis of the prevailing situation analysis the ensuing section brings about the critical challenges for addressing sprawl. Finally the paper concludes highlighting the need for an integrated spatial planning support system suggesting a framework demonstrating rudimentary simulations for managing urban sprawl.

1.1 Urban Sprawl: Pattern, Process, Causes and Consequences

Earlier studies characterise urban sprawl (Barnes et al., 2001; Hurd et al., 2001; Epstein et al., 2002; Sudhira et al., 2004b) using spatial metrics while highlighting the implications of sprawl on natural resources and how inefficient the unplanned growth could be. Among the undesirable effects of sprawl are unplanned outgrowths, which are not aesthetic and sprang in an unhygienic manner. Thus, there have been varied connotations to ascribe what constitutes sprawl. Galster et al. (2001) have addressed this issue as 'lost in semantic wilderness’, by describing the sprawl under six broad
categories:

  a) By example that embodies characteristics of sprawl, such as Los Angeles
  b) Aesthetic judgement and general development pattern
  c) Cause of an externality
  d) Consequence or effect independent variables
  e) Pattern of development
  f) Process of development

Extending Torrens and Alberti (2000)'s notion of urban sprawl, Galster et al. (2001) defines it as a pattern of land use in an urban agglomeration that exhibits low levels of some combination of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity. Ascribing sprawl as a pattern of land use alone would not throw light on the underlying processes, causes and hence consequences. In a developing country like India, where population density is high with significant urbanization rates, urban sprawl obviously cannot be characterised by pattern alone but processes, causes and their consequences. Hence, we suggest a modification to the definition of urban sprawl as the pattern of outgrowth emergent during the process of urban spatial expansion over time caused by some externalities and a consequence of local planning and administration. Hence, characterizing urban sprawl can only be achieved by acknowledging the complexity of urban systems and capturing these in different dimensions.

Apart from the eight distinct dimensions suggested by Galstner et al. (2001), the pattern of outgrowth is also captured by the spatial metrics like, patchiness, and entropy (dispersion). The details of metrics to capture the pattern of sprawl are presented in Table 1.

### Table 1: Urban Sprawl Metrics

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Metrics</th>
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<tr>
<td>1.</td>
<td>Entropy</td>
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<td>2.</td>
<td>Density</td>
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<tr>
<td>3.</td>
<td>Continuity</td>
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<tr>
<td>4.</td>
<td>Concentration</td>
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<td>5.</td>
<td>Clustering</td>
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<td>6.</td>
<td>Centrality</td>
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<td>7.</td>
<td>Nuclearity</td>
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<tr>
<td>8.</td>
<td>Mixed Uses</td>
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The process of urban sprawl can be characterized by change in pattern over time, like proportional increase in built-up surface to population leading to rapid urban spatial expansion. Analyzing the causes of urban spatial expansion the externalities can be modelled as agents in a geospatial environment like location of jobs, housing, access to services, level of economic activity, etc. Benenson and Torrens (2004) demonstrate this through Geographic Automata Systems (GAS) in an integrated geospatial and agent-based modelling framework for capturing the interactions amongst various entities and study their emergent behaviour.

Management of urban sprawl entails quantifying the pattern of sprawl and capturing the processes requires analysis of causal driving factors. This requires understanding and visualisation of the consequences of policies, local planning and administration on sprawl, like lack of effective public transport system with varying work-home distances, giving rise to independent motor vehicles and the resultant congestion and spatial expansion. This necessitates integrated spatial planning support systems for managing sprawl. The effect of mobility offered by the transportation networks in relation to the spatial expansion along with other socio-economic and physical processes, the self-organization of traffic flows in spite of high volumes and the consequential micro-level changes due to micro-planning and testing effects of policy interventions are some important questions operational planning seeks to answer with the aid of spatial planning support systems. The framework of such planning support system is discussed in the section on Integrated Spatial Planning Support Systems.

2. PLANNING AND MANAGEMENT PRACTICES IN INDIA: AN OVERVIEW

2.1 Of Static Comprehensive Development Plans and Master Plans

In India, as per the 73rd Constitutional Amendment Act passed in 1993, there is a mandate with urban local bodies for administering, managing and preparing master / development plans. Mostly these plans are static maps with limited forecasting capabilities and there is a dearth of models for planning process and hence leading to ad hoc decisions. Besides this, these plans mostly restrict to demarcate only land use zones with little or no effective regulation for the same. Further, with planning authorities restricting to mostly land uses, there is hardly any coordinated effort to involve or integrate transport, water and sanitation, etc. in the planning process. This results in organisations involved or catering to different services (transport, health, water, energy, etc.) work in isolation to address basic amenities. Lack of coordination among many agencies has lead to unsustainable use of land and other resources and also uncoordinated urban growth. Much of this growth is normally attributed to migration of people from other places. Migration takes place mainly due to uncertain employment in rural areas where the majority relies on agriculture, which is dependent on unpredictable monsoons. In the absence of effective rural-employment guarantee schemes and prevalent macro-economic initiatives, catering to urban areas further fuel rural-urban migration with some formal or informal employment in the offing. Thus, for certain critical issues administration and planning cannot confine itself even to limited boundaries of the urban area, but acknowledge conditions and
factors to address and plan effectively at a regional level. In this perspective, planning and administration have to be responsive to local and regional issues while ensuring requisite infrastructure and delivery of basic services.

2.2 Multiple Stakeholders: Planning for Operations through Coordination

The key organisational structure responsible and representing the citizens in urban areas are the elected local bodies. In the case of Bangalore, the Bangalore urban agglomeration until recently was composed of nine urban local bodies comprising Bangalore City Corporation, neighbouring seven City Municipal Councils and one Town Municipal Council. Recently, the state government has issued notification of Greater Bangalore City Corporation through merger of nine local bodies. Planning for this region in the form of land use zoning and their regulation are vested with Bangalore Development Authority (BDA), a parastatal agency. Significant administration and decision-making in these areas with regard to delivery of various services rests with other parastatal organisations, which are elaborated in Table 2. Apart from the City Corporation and Municipal Councils represented by the local elected representatives, all other organisations responsible for essential services are parastatal bodies controlled by the state government.

From the observation and analysis on the nature of local governance and administration, the operation plans drawn are ineffective in addressing smooth coordination with other agencies concerned with delivery of services. Essentially much of the chaos is contributed due to the disengagement with the planning organisation and the organisation involved with daily operations. A stark contrasting fact with the planning organisation is its lack of acknowledgement of any city functions: mobility, jobs, economy, energy, etc. The planning organisation on the one hand is focused on land use plans and its regulation alone with any acknowledgment of integrating land use with transportation for enhancing mobility. On the other hand, the local administration has to wake overnight to act for daily operations management with little realisation on the implications of the planning organisation ignoring the city functions. With numerous organisations responsible for addressing various city functions, it is imperative that these organisations acknowledge their interdependencies formally through appropriate mechanisms. Thus the possible way out to break the gridlock, is facilitating systems and practices that ensures feedback and coordination effectively. Essentially the interplay of these organisations involved with different city functions has to be acknowledged and bridged from short-to-medium (5 to 10 years) time frame planning undertaken by BDA to near-to-short term operations undertaken by City Corporation. Thus, it is essential to link the daily-operations with the planning of 10 year time period so that future chaos is arrested.

<table>
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<tr>
<th>Organisations</th>
<th>Functional Areas (Scope of Work)</th>
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Table 2: Organisations Concerned with Bangalore
Greater Bangalore City Corporation [Bruhat Bangalore Mahanagara Palike (BBMP)]

Urban local body responsible for overall delivery of services - Roads and road maintenance including asphaltalting, pavements and street lighting; solid waste management, education and health in all wards, storm water drains, construction of few Ring roads, flyovers and grade separators.

Bangalore Development Authority (BDA)

Land use zoning, planning and regulation within Bangalore Metropolitan Area; Construction of few Ring roads, flyovers and grade separators.

Bangalore Metropolitan Region Development Authority (BMRDA)

Planning, co-ordinating and supervising the proper and orderly development of the areas within the Bangalore Metropolitan Region, which comprises Bangalore urban district and parts of Bangalore rural district. BDA’s boundary is a subset of BMRDA’s boundary.

Bangalore Water Supply and Sewerage Board (BWSSB)

Drinking water – pumping and distribution, sewerage collection, water and waste water treatment and disposal.

Bangalore City Police

Enforcement of overall law and order; Traffic Police: Manning of traffic islands; Enforcement of traffic laws; Regulation on Right of Ways (One-ways).

Bangalore Metropolitan Transport Corporation (BMTC)

Public transport system – Bus-based

Bangalore Metro Rail Corporation Ltd (BMRC)

Public transport system – Rail-based (Proposed)

Regional Transport Office (RTO)

Motor vehicle tax; Issue of licenses to vehicles

Bangalore Electricity Supply Company (BESCOM)

Responsible for power distribution.

Lake Development Authority (LDA)

Regeneration and conservation of lakes in Bangalore urban district

2.3 A Common Jurisdictional Unit: Key for Coordination

A key reason for the persistence of lack of effective coordination is the absence of “common jurisdictional unit”. Much of the mess, the planning or the administration currently facing are the implications of having different jurisdictions for different
stakeholder organisations. With multiple organisations addressing mobility, it is rather incomprehensive that none of these organisations have a common jurisdictional unit! Due to this, it is not possible to collate and assimilate data for different city functions, which has lead to isolated interventions evident from the current practices. The landscape of Bangalore has been formally extended with the amalgamation of neighbouring municipal councils and villages forming Greater Bangalore. However, with the demarcation of regions, zones and wards based on possibly census and settlement patterns, it is imperative a common jurisdictional unit is mooted with the involvement of all the stakeholders in this region. By ensuring that all other stakeholder organisations comply with the same jurisdictional unit, planning for operations would become effective. The advantage of having common jurisdictional unit would also ensure easy collection, collation and dissemination of the data at a common place. Thus the integration and coordination has to begin for having a common jurisdictional unit.

2.4 Critical Challenges

Noting the various studies and prevailing conditions on urban fabric in India, it is found that lack of good governance and administration in the local bodies have resulted in unplanned and uncoordinated urban outgrowth. Urban governance and administration requires an information system for keeping track of various processes, activities, services and functions of the urban local body. In the absence of any such systems, at the basic level, there is a strong and pressing need for an information system to cater to all these. In the next level, it becomes essential to build models based on the information systems involving simulation and analysis for specific urban contexts. The subsequent level involves evolving different strategy and policy options using the models and information systems. Thus, at the outset, there are three essential steps to address the problem of sprawl and to strengthen planning and decision making – information systems, models and policies.

3. PLANNING IN THE DIGITAL AGE: GIS/SPATIAL ANALYSIS AND PLANNING TOOLS

The emergence of spatial tools notably Geographic Information Systems (GIS), mapping and monitoring urban areas became extremely popular. Monitoring the spatial patterns of urban sprawl on temporal scale can be analysed using the temporal remote sensing data acquired from spaceborne sensors. These help in inventorying, mapping and monitoring the growth patterns viz. linear growth and radial growth patterns. In the recent past, the geospatial domain has seen significant thrust in modelling urban systems using approaches ranging from operations research to system dynamics and agent-based models. Models of urban systems are essentially built to aid in planning for understanding, evaluating, visualising and deciding various interventions. Thus underlying geospatial models have become inseparable aspect of a planning support system. In India, there are some attempts to address urban sprawl using geospatial tools (Jothimani, 1997; Lata et al., 2001; Subidhi and Maithani, 2001; Sudhira et al., 2003 & 2004a) and modelling the process (Subudhi and Maithani, 2001; Sudhira et al., 2004b).

Simulation tools based on the concepts of discrete-event system simulation approaches are being used extensively in recent times to capture and emulate urban system and its dynamics. With the emergence of multi-agent systems from artificial intelligence domain, these are now being used to aid in simulation of urban systems.
Another approach to model the urban dynamics is the System Dynamics (SD) framework. The SD framework captures the system based on complexity involving dynamic relations represented by stocks and flows determined by various activity volumes in the city, which were synthesised from casual knowledge and observation. Although operations research approaches and SD framework have been applied quite rigorously in urban systems, in the recent times, geospatial modelling aided by visualisation has been very effective.

Globally, modelling urban sprawl dynamics has closely followed traditional urban growth modelling approaches. Subsequently, with the need to manage urban sprawl, modelling urban sprawl by relating to nature of growth and its implications has been undertaken since 1960s. Urban development models were developed much earlier, however modelling dynamics of urban sprawl has been undertaken only recently (Batty et al., 1999; Torrens and Alberti, 2000). The key initial studies in the developed countries based on traditional approaches of urban model building include Lowry (1967 In: Batty and Torrens, 2001), Walter (1975), Allen and Sanglier (1979), and Pumain et al. (1986). The traditional approach of model building involved linking independent to dependent variables, which were statistically significant, additive as in a linear model or a non-linear model but tractable in a mathematical way. However, these models although used mostly for policy purposes, could not be useful when processes involved rule-based systems, which in practice cannot be tractable mathematical operations (Batty and Torrens, 2001).

Models developed using cellular automata (CA) and agent-based models would prove beneficial to pinpoint where sprawl takes place (including causal factors), which would help in effective visualisation and understanding of the impacts of urban sprawl. Further to achieve an efficient simulation of urban sprawl, modelling has to be attempted in both spatial and non-spatial domain. Modelling urban sprawl in non-spatial domain is mainly by the application of statistical techniques while CA models and agent-based modelling are known to complement modelling in spatial domain. The fusion of geospatial and agent-based models has been formalised as Geographic Automata Systems (GAS) by Benenson and Torrens (2004). Although research in geospatial modelling has matured towards arriving at simulation framework this is yet to be graduated into an effective spatial planning support system.

4. INTEGRATED SPATIAL PLANNING SUPPORT SYSTEMS

For effectively managing the problem of urban sprawl; testing, building and visualising different scenarios, it is imperative to have a robust Spatial Planning Support Systems (SPSS). An ideal SPSS would not only aid in managing but also in planning, organising, coordinating, monitoring and evaluation of the system in question. These systems include instruments relating to geoinformation technology that have been primarily developed to support different aspects of the planning process, including problem diagnosis, data collection, mining and extraction, spatial and temporal analysis, data modelling, visualisation and display, scenario-building and projection, plan formulation and evaluation, report preparation, enhanced participation and collaborative decision-making (Geertman and Stillwell, 2004). Integration of different processes associated with the dynamics of sprawl phenomenon is required for addressing the problem of urban sprawl. Moreover, a key challenge for technology is to facilitate collaborative decision-making for evaluating different policy options through participatory simulations by different stakeholders.

The framework for planning and decision making process involves different phases of intelligence, design and decision/choice (Sharifi, 2003) is depicted in Figure 1. The intelligence phase confines to defining, understanding and assessing the existing situation along with evolving appropriate metrics for quantifying urban sprawl. In the design phase, the dynamics of urban sprawl are captured and subsequently modelled. The design phase would conclude with the generation of alternatives. In the Decision/Choice phase, the review and evaluation of the different policy options are undertaken to arrive at policy recommendations for managing and mitigating the urban sprawl.

![Figure 1: Planning and decision-making process (Sharifi, 2003)](image)

Most of the existing simulation framework allows simulations only on stand alone systems, wherein each stakeholder has to choose/decide the options on same system/platform. This would suggest that all stakeholders have to meet physically to evaluate and decide. Moreover such initiatives are not normal and very difficult to moderate. In this context, it becomes necessary for a distributed simulation framework to support SPSS, so that all stakeholders and managers/administrators are able to interact, organise, plan, evaluate and decide through a network. Then the challenges are two fold: one, to integrate different models that are required to carry out the simulations and then, to synchronise the model’s inputs, feedbacks and outputs over space and time.

Currently there are few popular frameworks that try to emulate SPSS with an objective to make planning interactive and participatory. Among such existing SPSS are What-If? (Klosterman, 1999), RAMCO (Ujlee et al., 1999) etc. What-If? (Klosterman, 1999) is an interactive GIS-based planning support system that responds directly to both achieving the ideals of communicative rationality and traditional comprehensive land use plans. It uses geographic data sets to support community-based efforts to evaluate the likely implications of alternative public policy choices. The package can be customised to a community’s existing geographic data, concerns, and desires, that provides outputs in easy to understand maps and reports which can be used to support community-based collaborative planning efforts. The system requires that given a set of factors and factor weights for determining the
suitability, projections for future land use and subsequent allocation can be based on user requirements. Although this system is claimed to be interactive, the dynamics of the factors and hence their interactions are less captured with only a final land use scenario obtained as output and doesn’t support a distributed (simulation) framework.

The RAMCO (Rapid Assessment for Management of Coastal zones) is a prototype information system for regional planning in a generic decision support environment for the management of coastal zones through the rapid assessment of problems (Uljee et al., 1999). The system was developed integrating GIS, CA and System Dynamics. Subsequently, White and Engelen (2000), the developers of RAMCO, also support the integration of GIS, CA and system dynamics with the usage of multi-agent systems for a high-resolution integrated modelling of spatial dynamics of urban and regional systems. This has currently set the standard of technology that can be used for achieving an integrated spatial planning support system. However, this also doesn’t yet support a distributed framework.

UrbanSim and OBEUS are two other established frameworks and supporting packages for integrated modelling of urban systems. UrbanSim is implemented as a set of packages under Open Platform for Urban Simulation (OPUS) (Waddell et al., 2005). This is fairly comprehensive in the sense that the framework integrates land-use, transportation, economic, demographics and environment variables. However, this framework doesn’t support participatory simulations. The OBEUS (object-based environment for urban systems) is more robust and is an emerging trend to integrate various processes as agent-based models to simulate them spatially and hence is termed as geosimulation (Benenson and Torrens, 2004). The notion of geographic automata systems (GAS), formalising the fusion of agent-based and cellular automata models in a spatial framework is demonstrated here. However, again the key drawback here is that this doesn’t support participatory simulations. Also, if one may wish to consider each agent-based model as individual discrete-event simulation model, the OBEUS addresses this using synchronous or asynchronous updating. It may well be a good frame of reference to build a distributed simulation framework for enabling participatory decision-making possible.

5. PROTOTYPE SPSS THROUGH NETLOGO

Keeping in line with the framework for planning and decision-making process suggested by Sharifi (2003) a prototype of the SPSS was arrived with the following four components: Patterns, Processes, Causes and Consequences. Accordingly the evolution of planning support system is depicted in Figure 2.

Accordingly the model is being implemented using the tool – NetLogo (Wilensky, 1999), an agent-based modelling environment. The agent-based modelling tool NetLogo developed by the Centre for Connected Learning and Computer Based Modelling, Northwestern University, USA was used to develop prototype planning support system since it offers adequate monitors and plots to visualize pattern, capture processes through agents, model the causes and evaluate the consequences through simulation. This was tested for Bangalore city. A preliminary prototype is depicted in Figure 3.
The research here in this direction is yet to validate the SPSS. Validation of agent-based land use models has been a contentious issue in recent times. However, recent work by Brown et al. (2005) has attempted to clear this debate by acknowledging path dependence and bringing out the distinction of achieving
predictive accuracy and process accuracy. Consequently, it is important that any SPSS should have greater process accuracy and be able to generate patterns resulting out of numerous processes. But planners and decision-makers would always want some amount of predictive accuracy informing them what type/pattern of growth will emerge at which locations. Thus SPSS should be ideally achieving reasonable predictive and process accuracies. The process accuracy and predictive accuracy of this tool is yet to be ascertained. However, the tool in its current state allows the modeller or experimenter to test for various options and evaluate the consequences.

6. CONCLUSIONS

Proper implementation of master plans / development plans is a critical aspect in regulated development of urban areas. Although 1200 master plans / development plans for important towns and cities have been prepared in India, so far their implementation has not been satisfactory due to a variety of reasons, which in turn have resulted in mushrooming of slums and squatters, unauthorised and haphazard development and above all environmental degradation, lack of basic amenities and transportation problems within and around urban areas. The city planning mainly addresses preparation of land use plans through zoning for catering to projected population. However, civic authorities also need to plan for meeting the demand of infrastructure facilities and ensuring delivery of basic services. This has been dismal in the current planning practices since these are normally static master plans or development plans mostly addressing land use. These plans are also less equipped to review and evaluate any policy decisions dynamically so as to visualise the potential implications of a policy directive and also the regions of potential sprawl. It is therefore necessary to enable the administrators and planners to graduate and equip with better understanding, methods and tools to tackle the problem of urban sprawl. Further, administrators and planners need to be informed of possible areas of sprawl to take corrective actions to mitigate the implications. In this regard, there is a need for a deeper understanding of urban sprawl phenomenon, capturing the dynamics and modelling it to visualise, review and evaluate various policy options.

The implications of urban sprawl are not well understood and can potentially be a threat for achieving sustainable urbanisation. Hence, it is very essential to understand the phenomenon of urban sprawl especially from the perspective of a developing country, like India. This would eventually aid in evolving any policy and management options for effectively addressing the problem of urban sprawl. Further, the problem of urban sprawl is observed to be an outcome of improper planning, inadequate policies and lack of good governance due to various reasons. The inability of the administration and planning machinery to visualise probable areas of sprawl and its growth is persistent with the lack of appropriate spatial information and indicators. Added to this, is the inability of administration and planning to capture the feedbacks arising out of different decisions, essentially with lack of dynamic spatial models with feedback mechanisms. Furthermore, inappropriate policy decisions are fuelling sprawl as there is no mechanism to evaluate for different policy implications, with the lack of spatial planning support systems to test and validate different policy options.

Thus, in the present context, with the escalating problem of urban sprawl, the challenges for future research is to arrive at an integrated spatial planning support system to effectively plan, review and evaluate different policy options while capturing the dynamics involved. Such an SPSS could also be used to regularly
monitor and check the nature of sprawl for compliance of policy recommendations dynamically over time. The contribution of research by way of spatial planning support system would only be a short-to-medium term solution to this problem. The significant driver of sprawl in developing countries is the migration of people from rural areas aspiring for livelihood to urban areas, which is compounding the problem of sprawl. Hence, a long term solution can only be achieved through an overall economic development of the region by the way of better employment and livelihood generation activities in the rural areas that can lessen the migration of people from rural areas to urban areas and mitigate urban sprawl.

ACKNOWLEDGEMENTS

We thank Indian Institute of Science for financial and infrastructure support. The Global Land Cover Facility (GLCF), Institute for Advanced Computer Studies, University of Maryland, USA, is duly acknowledged for making available the requisite remote sensing satellite data for the study.

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