APPLICATION OF REMOTE SENSING AND GIS TECHNIQUE FOR EFFICIENT URBAN PLANNING IN INDIA

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Abstract: Urbanization is an index of transformation from traditional rural economies to modern industrial one. It is a progressive concentration of population in urban unit. At the moment, India is one among the country of low level of urbanization. In the last fifty years the population of India has grown two-and-a-half times, but urban India has grown nearly five times. In 2001, 306.9 million Indians (30.5%) were living in nearly 3700 towns and cities spread across the country, and it is expected to increase to over 400 million and 533 million by 2011 and 2021 respectively. At the moment, India is among the counties of low level of urbanization. As a result, most urban settlements are characterized by shortfalls in housing and water supply, urban encroachments in fringe area, inadequate sewerage, traffic congestion, pollution, poverty and social unrest making urban governance a difficult task. The high rate of urban population growth is a cause of concern among India's urban and town planners for efficient urban planning. For this, the government of India has taken an important initiative to strengthen municipal governance, is the enactment of the Constitution (74thAmendment) Act (CAA), 1992. Through this initiative, an attempt is being made to improve the performance ability of municipalities/urban local bodies, so that they would be able to discharge their duties efficiently in the planning and development of urban areas. However, most studies undertaken to assess the functioning of municipalities in India, point out that the municipalities are confronted with a number of problems, such as non-availability of data, ineffective participation in the decision-making process despite adoption of the policy of reservation, delays in the transfer of funds to the municipalities despite constitution of State Finance Commissions, poor recovery from various tax and non-tax sources despite devolution of power etc. Therefore, there is an urgent need to adopt modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect lot of physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. These information systems also offer interpretation of physical (spatial) data with other socio-economic data, and thereby provide an important linkage in the total planning process and making it more effective and meaningful.

Keywords: Urbanization; Remote Sensing; GIS; Digital Map.

1. Introduction

Planning is a widely accepted way to handle complex problems of resources allocation and decision-making. It involves the use of collective intelligence and foresight to chart direction, order harmony and make progress in public activity relating to human environment and general welfare. In order to provide more effective and meaningful direction for better planning and development necessary support of the organization has become essential. Hence the need for a suitable information system is increasingly being felt in all planning and developmental activities, whether these are for urban or rural areas. Urban areas of today are more exactly described as sprawling regions that become interconnected in a dendritic fashion (Carlson and Arthur, 2000). The positive aspects of urbanization have often been overshadowed by deterioration in the physical environment and quality of life caused by the widening gaps between supply and demand for essential services and infrastructure.

Urbanization is inevitable, when pressure on land is high, agriculture incomes are low and population increases are excessive, as is the case in most of the developing countries of the world. Urbanization has become not only of the principal manifestation but also an engine of change, and the 21th century which has become the centre of urban transition for human society. In a way urbanization is desirable for human development. However, uncontrolled urbanization has been responsible for many of the problems, our cities experiences today, resulting in substandard living environment, acute problems of drinking water, noise and air pollution, disposal of waste, traffic congestion etc. To improve these environmental degradations in and around the cities, the technological development in relevant fields have to solved these problems caused by rapid urbanization, only then the fruits of development will reach most of the deprived ones.

The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect lot of physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. These information systems also offer interpretation of physical (spatial) data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful.

Recent technological advances made in domain of spatial technology cause considerable impact in planning activities. This domain of planning is of prime importance for a country like India with varied geographic patterns, cultural activities etc. The purpose of using GIS is that, maps provide an added dimension to data analysis which brings us one step closer to visualizing the complex patterns and relationships that characterize real-world planning and policy problems. Visualization of spatial patterns also supports change analysis, which is important in monitoring of social indicators. This in turn should result in improving need assessment.

The objectives of this paper are to explain remote sensing and GIS applications in various stages of planning, implementation and monitoring of the urban area.

2. Urban planning theory

The urban is a compound system of human and nature. It is also a high-dense geographical synthesis of population, resources, environment, social economic and so on. As one sign of civilization and social progress, the city's effects on national politics, economics and culture become prominent increasingly. In other words, the urbanization's level is a significant parameter to measure a country's extent of civilization, social progress and economic. So it is very important to make reasonable and fit urban planning and management (Fan Wenbing, 2006).

According to the urban development aims, urban planning constitutes the urban character, scale and development direction, makes use of the urban land reasonably. Urban planning relates to politics, economic, society, technology, art and comprehensive domains of human life. It is not only integrated, but also concerned with the policy and practice (Zheng Chaogui, 2004).

The primary phase of urban planning is present situation investigation. In the past, it always consumed a lot of labor force, material and money. The result was not timely and exact. Nowadays, the remote sensing technology can be used to investigate urban terrain, physiognomy, lakes, plants, sights, traffic, land utilization and building distribution quickly. As a main method to obtain and update urban geometric information and some attribute information, the remote sensing technology is quick, exact and economical (Xu Zhenhua, 2005).

3. Urbanization in India

Urbanization is an index of transformation from traditional rural economy to modern industrial one. It is a progressive concentration (Davis, 1965) of population in urban unit. At the moment, India is one among the country of low level of urbanization. Number of urban agglomeration/town has grown from the year 1827 in the year 1901 to 5161 in the year 2001. During the last fifty years the population of India has grown two-and-a-half times, but urban India has grown nearly five times. In 2001, 306.9 million Indians (30.5%) were living in nearly 3700 towns and cities spread across the country, compared to 62.4 million (17.3%) who lived in urban areas in 1951. This is an increase of about 390% in the last five decades. This process of urbanization in India is shown in Figure 1. It reflects a gradual increasing trend of urbanization. India is at an acceleration stage of the process of urbanisation and expected to increase to over 400 million and 533 million by the years 2011 and 2021 respectively.

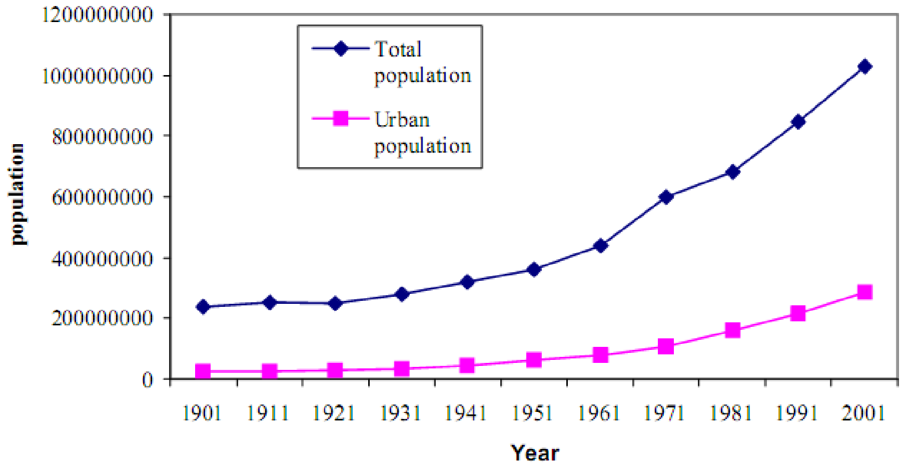

Fig 1: Process of urbanization in India

However, India's urbanization is often termed as over-urbanization, pseudo-urbanization, because not due to urban pull but due to rural push. The push factors like population growth and unemployment etc. (demographic factors) and pull factors like opportunities (economic factors) in the urban area. The globalization, liberalization, privatization are addressing negative process for urbanization in India. The big cities attained inordinately large population size leading into virtual collapse in the urban services and followed by basic problems in field of shortfalls in housing and water supply, inadequate sewerage, traffic congestion, pollution, poverty and social unrest making urban governance a difficult task. For this, the government of India has taken an important initiative to strengthen municipal governance, like the enactment of the Constitution (74^{th}Amendment) Act (CAA), 1992. Through this initiative, an attempt is being made to improve the performance ability of municipalities/urban local bodies, so that they are able to discharge their duties efficiently in the planning and development of urban areas. Urban Local Bodies [ULBs] which are statutorily responsible for provision and maintenance of basic infrastructure and services in cities and towns are under fiscal stress. According to Census of India 2001, there were 5621 ULBs in the country classified into three major categories of municipal corporations (500), municipalities (50-500) and town committees (5-50).

The 74th Constitutional Amendment Act (CAA74) mandates compulsory reconstitution of municipal bodies within a stipulated time-frame, thus ensuring continuity of local representatives. The twelfth schedule (Article 243W) of the CAA74 has listed 18 functions and responsibilities to local bodies. Thees are:

1. Urban planning, including town planning;
2. Regulation of land use and construction of buildings;
3. Planning for economic and social development;
4. Roads and bridges;
5. Water supply for domestic, industrial, and commercial purposes;
6. Public health, sanitation, conservancy, and solid waste management;
7. Fire services;
8. Urban forestry, protection of the environment, and promotion of ecological aspects;
9. Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded;
10. Slum improvement and up-gradation;
11. Urban poverty alleviation;
12. Provision of urban amenities and facilities such as parks, gardens, and playgrounds;
13. Promotion of cultural, educational and aesthetic aspects;
14. Burials and burial grounds; cremation grounds and electric crematorium;
15. Cattle pounds, prevention of cruelty to animals;
16. Vital statistics, including registration of births and deaths;
17. Public amenities including street lighting, parking lots, bus-stop, and public conveniences;
18. Regulation of slaughterhouses and tanneries.

Importantly the 12th schedule of CAA74 expressly recognizes a role for the ULBs within the constitutional framework and provides devolution of financial powers from the state government for strengthening of municipal finances. The CAA74 also provides for constitution of Ward Committees in municipalities with a population of more than three lakhs, Metropolitan Planning Committees and District Planning Committees for consolidation and preparation of plans of spatial, economic and social development. From a "top down" approach, the emphasis has thus shifted to the “bottom up" approach. In view of the challenges facing by ULBs the planners have to prepare themselves for a new role and much wider responsibilities. As a bridge between the civil society and the politico-economic structure, the planners have to perform the role of the catalysts of change. With the ongoing globalization, economic liberalization and devolution of power to local bodies, have been diluted armchair professionals activities.

4. Observed Constraints

A review of the attempts made for introducing Remote Sensing and GIS based urban planning practices brings forth a set of problems common across our planning organizations. They are highlighted below;

Technical

- Lack of appropriate base maps necessary for micro-level and utility planning.
- Difficulty in correlating remote sensing data with corresponding cadastre information.
- Limitation on availability and digitization of certain data products.

Financial

- Inadequate funds to acquire and upgrade periodically the hardware and software.
- Absence of provision for repair and maintenance service due to which upkeep of hardware suffers.
- Inability to procure digital data products and carry out surveys for collection of attributed data.

Institutional

- Absence of a dedicated team that would continue for a reasonable period to establish GIS database.
- Tendency to hold on to information due to which GIS database creation cost is not shared.
- Lack of support to young GIS professionals by the peers who feel threatened.
- Rigidity in work culture not encouraging experimentation that is so vital for GIS implementation.

Most of these problems have their origins in the fact that urban planning falls under the public sector namely; State Government and Urban Local Bodies whose limited financial resources and capacity to innovate do not help the cause of the GIS. However, of late, various schemes of the Government of India, promotion of public-private sector joint ventures and interest shown by many international agencies for collaboration in the field of geo-informatics has brought some changes in the situation. Since the problems are identified it would not be impossible to overcome them, especially since the power of GIS and remote sensing in the field of urban planning is well recognized.

5. Stages of urban planning

Urban areas face many critical environmental problems which are manifested at the time of crises. To avoid such occurrences the prime requirement is quantification or "resource potentiality", its availability and consumption in the urban areas which requires a comprehensive Urban Information System (UIS) to be developed to cater the developmental needs of the growing urban areas.

- Thematic map preparation from satellite data using visual interpretation techniques.
- Generation of spatial framework in GIS environment for perspective and development plans.
- Integration of thematic maps using GIS techniques for urban sprawl analysis and urban land use change analysis.
- Area required for urbanization will be determined on the basis of population projection of the city and its growth centers.
- Calculation of land requirements for urban development based on the carrying capacity of the region.
- Projection of urban land use suitability analysis.
- Urban environmental sensitivity analysis based upon both physical as well as air quality parameters.
- Determination of composite functionality index to setup various amenities such as educational, medical, recreational etc.

6. Remote sensing and GIS applications in urban planning

In India, the complexity of urban development is so dramatic that it demands immediate attention and perspective physical planning of the cities and towns (Sokhi and Rashid, 1999). The dynamic nature of urban environmental necessitates both macro and micro level analysis. Therefore, it is necessary and fundamental for policy makers to integrate like remote sensing into urban planning and management. Traditional approaches and technique designed for towns and cities may prove to be inadequate tools when dealing with metropolis. New approaches are required, and new methods must be incorporated into current practice. Until recently, maps and land survey records from the 1960's and 70's were used for urban studies, but now the trend has shifted to using digital, multispectral images acquired by EOS and other sensors. The trend towards using remotely sensed data in urban studies began with first-generation satellite sensors such as landsat MSS and WAS given impetus by a number of second-generation satellites: Landsat TM, ETM+ and SPOT HRV. The recent advent of a third-generation of very high spatial resolution (<5 meter/pixel) satellite sensors is stimulating. The high resolution PAN and LISS III merged data can be used together effectively for urban applications. Data from IRS P-6 satellites with sensors on board especially LISS IV Mono and Multispectral (MX) with 5.8 meter/pixel spatial resolution is very useful for urban studies

Advancement in the technology of remote sensing has brought miracle in the availability of the higher and higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 meter resolution in multispectral mode, IRS-1D Pan image with 5.8 meter resolution, Cartosat-I imagery of 2.5 meter resolution with stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space Imaging with 4 meter in multispectral mode and 1 meter in panchromatic mode, Quickbird imagery of Digital Globe with 61 cm resolution in panchromatic mode and so on. These high resolutions of the sensors provide a new methodology in the application with newly raised technical restrictions.

Apart from Cartographic applications, P-6 data will be useful in cadastral mapping and updating terrain visualization, generation of a national topographic database, utilities planning and other GIS applications needed for urban areas. The satellite will provide cadastral level information up to a 1:5,000 scale, and will be useful for making 2-5 meter contour map (NRSA 2005). The output of a remote sensing system is usually an image representing the scene being observed. Many further steps of digital image processing and modeling are required in order to extract useful information from the image. Suitable techniques are to be adopted for a given theme, depending on the requirements of the specific problem. Since remote sensing may not provide all the information needed for a full-fledged assessment, many other spatial attributes from various sources are needed to be integrated with remote sensing data.

This integration of spatial data and their combined analysis is performed through GIS technique. It is a computer assisted system for capture, storage, retrieval, analysis and display of spatial data and non-spatial attribute data. The data can be derived from alternative sources such as survey data, geographical/topographical/aerial maps or archived data. Data can be in the form of locational data (such as latitudes/longitudes) or tabular (attribute) data. GIS techniques are playing an increasing role in facilitating integration of multi-layer spatial information with statistical attribute data to arrive at alternate developmental scenarios.

Application of Remote Sensing technology can lead to innovation in the planning process in various ways;

1. Digitisation of planning basemaps and various layout plan has facilitated updating of basemaps wherever changes have taken place in terms of land development etc. Digital maps provides flexibility as digital maps are scale free. Superimposition of any two digital maps which are on two different scales is feasible. This capability of digital maps facilitates insertion of fresh survey or modified maps into existing basemaps. Similarly superimposition of revenue maps on basemaps with reasonable accuracy is great advantage compared to manually done jobs.
2. Since information and maps are available in digital formate, correlating various layers of information about a feature from satellite imagery, planning maps and revenue maps is feasible with the help of image processing software like ERDAS Imagine, ENVI and PCI Geomatica, ILWIS. Such super imposed maps in GIS software like Map info, Geomedia, Arc View, Auto CAD Map and Arc GIS provide valuable information for planning, implementing and management in urban areas.
3. Remote Sensing techniques are extremely useful for change detection analysis and selection of sites for specific facilities, such as hospital, restaurants, solid waste disposal and industry.

An attempt has been made here to demonstrate the potentials of remote sensing techniques in base mapping, land-use and land-cover mapping, urban change detection and mapping, urban infrastructure and utilities mapping, urban population estimation, management.

6.1 Aerial photography and satellite data in urban studies

Aerial photographs have long been employed as a tool in urban analysis (Jensen 1983, and Garry, 1992). In India, city planning has been largely confined to aerial photography. It is being used for generation of base maps and other thematic maps for urban areas as it is proved to be cost and time effective and reliable. Wealth of information pertaining to land features, land use, built up areas, city structure, physical aspects of environment etc. are available from the aerial photography. Various types of cameras and sensors black and white, color, color infrared are used for aerial photography. Because of security concerns related to aerial photography, the use of photogrammetric techniques was confined to smaller cities.

Aerial photographs provide information that can significantly improve the effectiveness of city and town planning and management in India. They are also relatively low in cost, accurate, reliable and can be obtained on desired scale, but they are not useful in large metropolitan areas.

As discussed above, India very much dependent on photogrammetry to provide information for urban planning purposes. But since the March 17, 1988 launch of its first satellite (IRS1A) equipped with the LISS-I sensor acquiring 72.5 meter/pixel data, the application of remotely sensed data (from various sensors) in urban and regional planning processes has gained momentum. LISS-I gathered data in four spectral bands (0.45 µm - 0.86 µm) and was mainly used for broad land-use, land-cover, and urban sprawl mapping. The IRS-1C and 1D satellites launched in 2003, carrying LISS-III and LISS-IV sensor with spatial resolutions of 23.5 meter/pixel and 5.8 meter/pixel using Landsat MSS optical bands (0.52 µm - 0.86 µm), have contributed to the effectiveness of urban planning and management.

Early experiments with the first generation satellites found the data very useful for mapping large urban parcels and urban extensions. The development of Landsat TM data with 30 meter/pixel spatial resolution has helped in mapping Level-II urban land use classes. Some of the salient features of different satellite sensors and the extractable levels of urban information are summarized in Table 1. Cities and towns in India exhibit complex land use-patterns, with the size of urban parcels varying frequently within very short distance. The extraction of urban information from remotely sensed data therefore requires higher spatial resolution.

Table 1: Remote sensing platforms and sensor application in urban studies

Platform and Sensor System	Spatial resolute (m, pixel)	Year of operation	Mapping scale	Extractable Information
Landsat (MSS) IRS-1A & 1B (LISS-I)	80 72	1972 1988 & 1991	1: 1,000,000 1: 250,000	Broad land-use/land-cover and urban sprawl
Landsat TM IRS-1A & 1B (LISS-II) IRS-1C & 1D (LISS-III) SPOT HRV-I (MLA) IRS-1D(LISS-IV)	30 36 23 20 5.8	1982 1988 & 1991 1995 & 1997 1998 2003	1: 50,0000 1: 5,000	Thematic data for broad structural plans and spatial strategies
ASTER VNIR (0.52-0.86 µm) SWIR(1.60-2.43 µm) TIR(8.125-11.65 µm)	 15 30 90	1999	1: 250,000 1: 50,000	Land-use/land-cover, urban sprawl, ecological monitoring data
SPOT HRV-II (MLA) IRS-1C &1-D (PAN)	10 5.8	1998 1995 & 1997	1:25,000 1:10,000	Data for land-use/land-cover for urban area
MOMS-II	4	1983	1:8,000	Land-use/land-cover details
IKONOS Quickbird	1.0 0.61	1999 2001	1:4,000 1:2,000	Cadastral map, detailed information extraction for urban planning and infrastructure mapping
CARTOSAT-1 CARTOSAT-2	2.5 1.0	2005 2007	1:4,000 1:1,000 1:2,000	Large scale cartographic work and DM generation cartographic applications at cadastral level, urban and rural infrastructure development and management
ALMAZ	1.0		1: 4,000 1: 2,500	Ground plans and urban design.
RESOURCESAT-I (LISS-IV)	5.8	2003	1:10,000 /1:4,000	Monitoring the urban growth, Inventory of land-use/ land-cover.

Source: Modified after Atiqure Rahman (2006)

6.2 Base maps for urban areas

Base map, a pre-requisite for urban planners, refers to the large scale maps, which depict broad physical and cultural features. The base maps are produced at a scale ranging from 1:10,000 to 1:4,000 and 1:1,000/1:500 for specific urban applications (Shown in Table 2). Base maps at a scale of 1:4,000 that were prepared by ground survey in 1969 and 1971 are available for some areas. But now base maps are being produced at scales ranging from 1:4,000 to 1:10,000 depending upon the specific urban applications for which they are prepared.

Base maps can be also made from orthophotographs for inaccessible areas that are difficult to survey, high altitude towns like Leh, Puri, Himachal Paradesh etc. In such situations, remote sensing has made information collection possible for base maps where field surveying has fallen shot due to prohibitive faction such as cost, timing and terrain. These base maps can provide the backbone for development of information that was previously unavailable to the community, urban regional, and natural resource planners and management. IRS P-6 (multispectral) data with 2.5 m/pixel spatial resolution can meet the ever-growing demand for current, accurate base maps at a scale of 1:5,000 for urban planning purposes and for development new residential sites

Table 2: Urban planning stages and base map requirements

S. No	Planning stage	Base map scale
1.	Master Plan / Landuse Plan	1:10,000 & larger
2.	Zoning Plan	1:4,000
3.	Inner City/Urban Cadestre	1:1,000 to 1:2,000
4.	Urban slums/Unauthorised Developments/ Encroachments	1:5,000 to 1:1,000

6.3 Land-use and land-cover mapping

Land is one of the prime natural resources. Urban population growth and urban-sprawl induced land use changes coupled with industrial development are resulting in unplanned use as well as misuse of land leading to conversion of usable land into wastelands. The changes of land-use/land-cover pattern over a time period control the pressure on land (Sengupta and Venkatachalam, 2001). The complexity of urban development is so dynamic that it calls for an immediate perspective planning of cities and towns (Sokhi and Rashid, 1999). For a sustainable use of the land it is essential that proper planning and monitoring have been done. Timely and accurate information on the existing land-use/land-cover pattern and its spatial distribution and changes is a pre-requisite for planning, utilisation and formulation of policies and programmes for making any micro and macro-level developmental plan. Accurate, reliable and comprehensive spatio-temporal information on land use practices in a city is prerequisite for sustainable land management. Remote sensing offers cost-effective solutions to city planners data needs for both macro and micro level analysis of the land use planning leading to urban environment management. The better management and rationale use of land calls for accurate and timely changes in the dimension, nature, and spatial balance between exploitation and regeneration. GIS is best utilised for integration of various data sets to obtain a homogeneous composite land development units which helps in identifying the problem areas and suggest conservation measures. The remote sensing technology along with GIS is an ideal tool to identify, locate and map various types of lands associated with different landform units (Dhinwa, 1992; Palaniyandi and Nagarathinam, 1997; Murthy and Venkateswara, 1997; Khan et al., 1999). The timely information about the changing pattern of land use plays significant role in land use planning and sustainable land development. The mapping and monitoring of the land use/land cover requires a land use classification system. One of the most widely used data format for information extraction about the land-use and land-cover is the infrared False Colour Composite (FCC) image. The extraction of information from such images about ground reality is done by image interpretation for which generally three methods namely photo interpretation, spectral analysis and data integration are used. Prasad and Sinha (2002) describe the image characteristics and visual interpretation techniques of various land-cover and land-use categories, which is summarized in the Table 3.

Table 3: Land-cover/land-use and their image characteristics

Land-cover/land- use	Image characteristics
1. Settlements	Light grey clustering with particular patterns for the urban area. There may be brownish maroon patches for in between vegetation. For the rural settlement there occur no particular patterns of such image characteristics.
2. Agriculture	Identify rabi if the month of data acquisition is January or February or March and colour is brown red. (a) For the kharif crops same characteristics in image occur if the image data are acquired in the month of September, October or November. (b) Fallow land is identified by light grey colour within cropped area (red colour). (c) Plantation occurs as brownish maroon patches.
3. Forest (a) Dense forests (b) Degraded forest (c) Forest blank (d) Forest plantation	Dense forests are identified by dark red colour patterns. In the case of degraded forest the dark red colour patterns contain small brown or white patches. The blanks in the forest show creamy patches in the dark red/background. Forest plantations are identified by dark red colour sign of particular pattern.
4. Waste Land (a) Muddy water logging (b) Clear water logging (c) Temporary water logging (d) Permanent water logging (e) Marshy area water logging (f) Gullied land (g) Land with scrub (h) Land without scrub (i) Sandy area	Muddy water logging occurs as blackish or deep blue spots while clear water logging area is identified by dark/bright blue patches. Comparing the images of rainy season and out of rainy season identifies temporary and permanent water logging. Marshy area is recognized as a sign of vegetation (red/pink spots) in the water logged (blackish blue/bright blue) area. Gullied land occurs as white/grey spot. The image of land with scrub contains white patches in the land area. Sandy area is classified as bright white coloration along the course of river.
5. Water bodies (a) River/stream (b) Canal (c) Lake/ reservoirs (d) Embankments	River/stream is identified as long non-linear path coloured with dark blue/bright blue line in white background. Canals are identified as line segments sign of water bodies. Lake/reservoirs are identified as patterns along the river. Embankment occurs as light grey structure along the river.
6. Others	Grasslands are identified as uneven appearance characterized by red (light to medium grey tones) Snow is identified as white patches on the hills.

Source: Prasad and Sinha (2002)

6.4 Urban change detection and mapping

Land-use change detection and mapping require high resolution imageries to obtain detailed information and multispectral optical data to make fine distinction among various land-use classes. While many urban features can be detected on radar and other imagery visible and near infrared (VNIR) data of a high resolution permit fine distinction among subtle land-use/land-cover classes (shown in Table 3).

Urban areas are highly dynamic. Remote sensing can enable urban planners and decision makers to assess land-use conversions from agricultural to non-agricultural (i.e residential, commercial, and industrial), loss of greenry and water bodies, development along main transport routes and drainages lines, and changing quality of the urban environmental. Detection of large-scale conversion of agriculture land into non-agriculture land has been useful for determining the extent of built-up areas on the day the government decides to acquire land (Uttarwar, 2001).

It is also useful in dealing on urban change detection using Survey of India toposheets at 1:50,000, Landsat MSS, IRS LISS-I and II, and SPOT HRV data. With the use of IRS LISS-I False Color Composite (FCC), the transformation of agricultural land into residential and industrial land was carried out by the Kukatpally municipal area in Hydrabad city in 1990. Land-use/land-cover change detection mapping of Delhi has been done in ERDAS Imagine Software and Arc GIS using Landsat TM and IRS LISS-III data from 1992 and 2004 respectively.

Urban change-detection mapping can be done with digital image processing (DIP) software using satellite data from different time periods (Yuan et al. 1998).

6.5 Urban sprawl/urban spatial growth

In India, unprecedented population growth coupled with unplanned developmental activities has led to urbanization, which lacks infrastructure facilities. This also has posed serious implications on the resource base of the region. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the city and in rural countryside is often referred as sprawl (Theobald, 2001). The direct implication of such urban sprawl is the change in land use and land cover of the region. The ability to service and develop land heavily influences the economic and environmental quality of life in towns (Turkstra, 1996). Identification of the patterns of sprawl and analyses of spatial and temporal changes would help immensely in the planning for proper infrastructure facilities.

Patterns of sprawl and analyses of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographic Information System (GIS) and Remote Sensing (RS) along with collateral data (such as Survey of India maps, etc.). IRS-1C/1D/P4 provides data with good spectral resolution (LISS data) and the spatial resolution of 5.6 m in panchromatic mode. The remote sensing satellites with high resolution sensors and wide coverage capabilities provides data with better resolution, coverage and revisit to meet the growing applications needs. The image processing techniques are also quite effective in identifying the urban growth pattern from the spatial and temporal data captured by the remote sensing techniques. These aid in delineating the specific growth patterns of sprawl which could be linear or radial or both. The spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data (remotely sensed data) along with conventional ground data (Lata et al., 2001). Mapping urban sprawl provides a "picture" of where this type of growth is occurring, helps to identify the environmental and natural resources threatened by such sprawls, and to suggest the likely future directions and patterns of sprawling growth. However, the physical expressions and patterns of sprawl on landscapes can be detected, mapped, and analyzed using remote sensing and geographical information system (GIS) (Barnes et al., 2001) with image processing and classification. The patterns of sprawl are being described using a variety of metrics and through visual interpretation techniques. Ultimately the power to manage sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues.

Epstein et al. (2002) bring out the techniques for mapping suburban sprawl. They evaluate the traditional unsupervised classification and proposed GIS buffering approach for mapping the suburban sprawl, and Yeh and Li (2001) use Shannon's entropy, which reflects the concentration of dispersion of spatial variable in a specified area, to measure and differentiate types of sprawl. This measure is based on the notion that landscape entropy or disorganization increases with sprawl. The urban land uses are viewed as interrupted and fragmented previously homogenous rural landscapes, thereby increasing landscape disorganization. Lata et al. (2001) have also employed a similar approach of characterizing urban sprawl for Hyderabad city, India.

6.6 Urban infrastructure and utility mapping

The civic amenities like potable water for domestic consumption, educational institutions, recreational sites, power plants, means of transportation and waste disposal sites form some of the major urban infrastructure and utility services. The urban planners need large volume of data both at pre-planning and plan implementation stages to ascertain the status of the available facilities and to determine the actual/projected demands for the same. The remote sensing techniques provide accurate, orderly and reliable information repetitively for planning and management of urban utility services. Whereas the aerial photography at a scale of 1:10,000 and larger provides information about the spatial distribution of most of the urban infrastructural facilities, the SPOT and IRS 1C & 1D data in panchromatic mode offers capabilities for mapping and analysing urban transport network, effluent discharge zones and urban greenery.

The large scale aerial photography was used in making the quantitative assessment of habitant and its refuse and in identifying disposal sites of Kanpur (HUGSAG, 1998). Similarly, an assessment of the population served by the urban facilities and services in Bhubaneshwar was studied using 1:8,000 scale photography and USEMAP-4, GIS software (Mohanty, 1995). The SPOT MS and PLA data have been used in evaluating urban landuse-transportation system relationship along Ring railway transport system in Delhi (Sokhi, 1983). Konkan railway and pipeline routing have also been studied using the satellite data (NRSA, 1993-94).

6.7 Urban hydrology

The urban agglomerations in India are facing atleast four hydrological problems, i.e, the mobilisation of sufficient volume of water for domestic and industrial consumption, urban water pollution and quality, flood control and urban storm water run-off disposal. Indian cities face problems of insufficient water for domestic & industrial purposes, poor water quality & inadequate urban stromwater runoff disposal. However, Runoff can not be directly measured by remote sensing techniques. The role of remote sensing in runoff calculation is generally to provide a source of input data or as an aid for estimating equation coefficient and model parameters. The remote sensing techniques are also being applied in obtaining information pertaining to surface water quality parameters,soil, drainage, land-use, ground water, and slope of catchment or watersheds relevant to carry runoff and water estimation studies. For example, a remote sensing based approach was evolved to deal with the metrowater supply problems of Madras (Roa, et al, 1985). Similarly, Chkaraborty discussed an approach for urban storm water, runoff modeling, water supply assessment and water quality surveillance of Delhi Urban Complex, Najafgarh, Patna, and Hydrabad (NRSA-TR, 1989). The operational utility of remote sensing techniques in water resources assessment of Hydrabad city has been dealt with using Landsat TM and IRS LISS-I and II data (Roa, 1991).The attempt has also been made to identify and delineate different hydrogeomorphological units in and around the immediate environs of Jhansi city and correlate them with the well yields using Landsat TM FCC. Remote sensing can be applied to drainage studies using proxies or surrougates. Satellite data have been successfully used to map surface drainage pattern.

The GIS technology has the ability to capture, store, manipulate, analyze and visualize the geo-referenced data. On the other hand hydrology is inherently spatial and distributed hydrological models have been large data requirements. The integration of GIS and hydrology involves three majors components: 1. Spatial data construction, 2. Integration of spatial model layers, 3. GIS and model interface. GIS technique have been applied for groundwater vulnerability mapping with the DRASTIC model in Aligarh city, using the weighted sum overlay method. The DRASTIC model considers seven groundwater parameters, depth of water, net recharge, aquifer media, soil media, topography, impact of vadose zone & hydraulic conductivity. Seth and Dee (1993) have conducted studies on studies on hydrology by using a GIS-based solution for watershed analysis of Maryland State, They constructed a model named as GISHYDRO. Miller and Semmens (1995) have developed automated geo-spatial watershed assessment tool (AGWA) in GIS for analyzing the water resources. The key components of AGWA are the hydrological models used to evaluate the effects of land-cover and land-use on water response.

6.8 Effective traffic management

The transportation network is an important infrastructure element of the whole urban area. It allows connectivity and movement of people, traffic and goods both within and between urban centres. Radar RS data can be used effectively for urban transportation network management. All roads with a width of 3m or more can be seen on high resolution (IKONOS) satellite data; such data facilitate the identification of roads that need to be widened to ease congestion. Using satellite images, road information can be updated and the approximate width of a road can be determined. Road width can be assessed using data from SPIN-2 with 2 m/pixel resolution. ADEOS multispectral data with 16 m/pixel resolution and LANDSAT TM with 30 m/pixel resolution. A 5 m wide road can be measured with a maximum error of 1m using SPIN-2 data. A 35m wide road varies from 34m-36m in SPIN-2 data giving a maximum error of 1m. Width of the same road or road section varies from 32m - 40m & 30m - 40m in ADEOS pan data and SPOT pan data respectively, with a maximum error of 5 m in each case. The effects of urban traffic on the environment in jaipur, in terms of population affected by air and noise pollution, was studied using predictive and dispersion models in a GIS environment using 1998 data from IRS-1C, LISS III, FCC and PAN. The study showed that a significant percentage of the population was affected by air (94.3%) & noise (34.8%) pollution. About 52% of the total population residing in a 0- 425m buffer zone was affected by all air pollutants and 41.6% of the total population living in 425-1500m buffer zone was affected by suspended particulate matter. Such data are vital for formulating strategies to mitigate traffic related air and noise pollution hazards, such as mass transit, telecommunicating and enacting stricter automobile emission standards.

6.9 Solid and hazardous waste

Solid waste is a potential nightmare for India's large and growing population, due to inadequate and legislative instruments and to the deplorable organisational and financial capabilities of local urban governments. The informal sector should be organised and the private sector should participate more widely in collection and recycling of solid waste.

In this context, the most acceptable strategy for solid waste management is first to categorize waste streams as biodegradable, non degradable and recyclables. Then the problem is where to dispose of it and it is not easy to locate the disposal site. A geospatial database generated from remotely sensed satellite data could be used to help solve this problem. Efforts should be made to reclaim abandoned landfill sites. Attention should be focussed on identification of suitable new sanitary landfill sites to isolate waste from human society and the ecosystem and monitoring of the existing landfill sites for environmental impact assessment. RS data can aid in identification and location of such landfill sites and in monitoring the changes in land-use within and near hazardous waste and sanitary landfill and these data integrate with GIS, has been useful to identify potential waste disposal sites using IRS, LISS IV, PAN imagery with 5.8

m/pixel resolution and ASTER visible to near IR data with 15 m/pixel resolution. Path optimization can be carried out using a network analysis model in GIS for solid waste dumping.

7. Modifications in the urban planning approach:

For a more dynamic urban planning exercise, the following modifications in the planning approach are recommended:

i. Flexibility: Plans must have flexibility to provide for ever-growing and ever-expanding city boundaries and provide quality of life to all inhabitants. The plan should be flexible to respond not only to the present needs but also the changing conditions in foreseeable future.

ii. Role of Actors: People's participation in preparation of policies, perspective plan, development plan and annual plans should be ensured through elected representatives in the municipal council/corporation and ward committees.

iii. Information system: A well maintained information system can make possible the fine-tuning of the plan proposals at the various stages of implementation of the plan according to the changing urban scenario.

iv. Urbanisable Areas: The development potential may be assessed for the areas located in the periphery of the developed areas. A profile of the development potential and the possibility of optimizing the existing infrastructure should determine the prioritisation of development of these areas.

v. Growth Centers: Given the paucity of resources, it would be more feasible and desirable to promote strategic development initiatives in the selected secondary cities, growth center and their hinterlands. In the growth centers, the location of infrastructural and environmental services could form the core of the Development Plan.

vi. Policy Guidelines: Policy guidelines notified under law, can help in identifying priority areas, subsequent modifications in the plans and administration in general.

vii. Mixed Land Use: With a view to provide for development, the zoning regulations need to be simplified. The land use package should not be allowed to be changed by any authority, except as a part of the review of the Development Plan at the city/town level.

viii. Financial Planning: Land development and infrastructure investment need to be coordinated through integration of physical, financial and investment planning. There is a need to link spatial development plan with resource mobilization plan focusing on credit enhancement mechanisms.

ix. Land Policy and Management: As opposed to the process of compulsory land acquisition, and the related issue of low compensation rates, the ULBs should adopt collaborative approaches within the existing legal framework.

x. Legal Framework: Plan implementation would call for a legal framework so as to make it enforceable and mandatory. The legal framework has to be supported by an effective and efficient machinery which would see that no distortion of master plan proposals take place at the ground level.

xi. Standards: Plot sizes, layout and social overheads need to be designed to reduce costs aligned to the affordability of different income groups and also the sale price for lower income groups can be reduced by differential pricing.

xii. Building Bye-laws: Building bye laws and zoning regulations for the city/town should match the local needs. However, the existing bye-laws need to be simplified and transparent, and there should not be an element of discretion. Adequate provision for parking facilities should be made.

xiii. Database at Metropolitan, district and state levels: The planning exercise need continuous data collection, analysis interpretation and updating of data. A computer-generated data base and information system in GIS environment should be developed at various levels which would provide support to planners in development of planning.

8. Conclusions

Planning and managing cities in the new era of globalisation and economic liberalisation would be a demanding task calling for new skills and approach. Indian cities will have to compete with others to attract investments and, therefore, issues like quality of infrastructure, energy efficient services provision and environmental conditions in a city besides economic stability would play a significant part in such competition. Urban planning profession in general will have to address these issues and respond rapidly. It is worthwhile noting that spatial dynamics of cities is complex to fathom and urban theory is still static. In other words, the urban planning authorities and agencies in every parts of the country should adopt new technologies like remote sensing and GIS. These have capability to provide necessary physical input and intelligence for preparation of basemaps, for planning proposals and act as monitoring tool during implementation phase(s). Satellite remote sensing with repetitive and synoptic viewing capabilities, as well as multispectral capabilities, is a powerful tool for mapping and monitoring the ecological changes in the urban core and in the peripheral land-use planning, will help to reduce unplanned urban sprawl and the associated loss of natural surrounding and biodiversity.

On the other hand, moving further, interfacing of urban planning models with GIS should now receive due attention. Incorporation of land-use transportation models, water distribution network analysis, simulation of urban activities to evaluate different urban development alternatives in the GIS framework needs to be explored for added advantage.

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