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ROLE OF GEOINFORMATICS IN URBAN PLANNING

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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. During the last fifty years the population of India has grown two and a half times, but urban India has increased nearly five times. In 2001, 306.9 million Indians (30.5%) were living in nearly 3,700 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 countries of low level of urbanization. As a result, most urban settlements are characterized by shortfalls in stock housing and water supply, urban encroachments in fringe area, inadequate sewerage, traffic congestion, pollution, poverty and social unrest making urban governance a difficult task to maintain healthy urban environment. High rate of urban population growth is a cause of concern among India's urban and town planners for efficient urban planning. Therefore, there is an urgent need to adopt modern technology of remote sensing which includes both aerial as well as satellite based systems, allowing 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 overall planning process and making it more effective and meaningful.

Keywords : Urbanization; Geoinformatics, Remote Sensing and GIS.

Introduction

The majority of the world's population now resides in urban environments and information on the internal composition and dynamics of these environments is essential to enable maintenance of certain standards of living. The availability of urban land cover data is critical to policy makers, particularly for town planners, because of their ability to monitor impact of planning policies, the direction of urban growth and the development progress. Urban land cover in large urban centre including metropolitan areas continually changes over time and space, and local government must be able to update their database to reflect current land use. However, conventional methods of obtaining urban land cover data require a great deal of time, effort and money to meet fast growing cities.

Remote sensing can provide an important source of data for urban land use/land cover mapping and environmental monitoring (Patkar, 2003). Urban land cover/use mapping has received an increasing amount of attention from urban planners and scientists including geographers. A numbers of significant studies were made for environmental quality management. Thus, various techniques have been applied for mapping urban land use/land cover. It helps in encroaching urban problems even of very small magnitude and dire.

Planning is a widely accepted way to handle complex problems of resource allocation and decision-making. It involves use of collective intelligence and foresight to chart direction, order harmony and make progress in public activities relating to human environment and overall development. 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 gap between supply and demand for basic services and infrastructure.

Urbanization is inevitable, when pressure on land is high, agriculture incomes is low and population increases are excessive, as is the case of most developing countries of the world. Urbanization has been both one of the principal manifestation as well as an engine of change. The 21st century is the century of urban transition for human society. In a way urbanization is desirable for human development. However, uncontrolled urbanization has been responsible for several problems, our cities facing today, resulting in substandard living environment, acute problems of drinking water, noise and air pollution, disposal of waste, traffic congestion etc. To minimise these environmental degradations in and around cities, the technological development in related fields have to address to these problems caused by rapid urbanization, only then the fruits of development will percolate to the most deprived ones. The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect 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 data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful. Therefore, it is essential to know intensively about the characteristics and capabilities of these remote sensing data products available to the urban and regional planners.

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 for policy makers to integrate remote sensing with 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 1960 to 70 were used for urban studies, but now the trend has shifted to use 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. The recent advent of a third generation of very high spatial resolution (5m/pixel) satellite sensors is stimulating. The high resolution PAN and LISS III merged data may 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 m/pixel spatial resolution is very useful for intensive urban studies.

Advancement in technology of remote sensing has brought miracle in the availability of the higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 m resolution in multispectral mode, IRS-1D Pan image with 5.8 m resolution, Cartosat-I imagery of 2.5 m resolution with stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space Imaging with 4 m in multispectral mode and 1 m 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, IRS-1D LISS IV (P-6) data will be of great use 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 m 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 relevant information from the image. Suitable techniques are to be adopted for a given theme, depending on the requirement 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 nonspatial 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 significant role in facilitating integration of multi-layer spatial information with statistical attribute data to arrive at alternate developmental scenarios.

Application of Remote Sensing technology may lead to innovation in the planning process in various ways:

(i) Digitization of planning base maps and various layout plans has facilitated updating of base maps wherever changes have taken place in terms of land development etc. Digital maps provide 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 base maps. Similarly superimposition of revenue maps on base maps with reasonable accuracy is of great advantage compared to manually done jobs.

(ii) Since information and maps are available in digital format, 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, Arc View, Auto CAD Map and Arc GIS etc. provide valuable information for planning, implementation and management of urban areas.

(iii) 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 etc.

Remote Sensing Data in Urban Studies

Aerial photographs have long been employed as a tool in urban analysis. 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.

India is very much dependent on photogrammetry for providing information for urban planning purposes. But since March 17, 1988 with the launch of its first satellite (IRS-1A) equipped with LISS-I sensor acquiring 72.5 m/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) 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 m/pixel and 5.8 m/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 m/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.

The overwhelming advantages of remote sensing methods over tactile methods based on ground survey are the consistency which can be ensured in at least one stage of data collection, the rapidity of survey and the small number of skilled workers required at the data collection stage: it is possible, in principle at least. Unlike the preceding data sources, the direct use of satellite imagery ensures that a minimum of interpretation has been carried out by others. If the imagery is being collected especially for the purpose of the survey, the client will be able to specify time and environmental conditions which are best for his purposes, such as midday in winter conditions. For obtaining accurate land use data the following points should be considered:

(i) **Characteristics of imagery:** scale of the photography, geometric fidelity, contrast, sharpness, resolving power of film etc., waveband(s) used, photographic or digital format

(ii) **Characteristics of land use:** consistency of the relationship between form and function, degree of multiple use, the amount of ground control, change since imagery was obtained

(iii) **Characteristics of user** : interpretation skill, use of stereoscopic techniques etc.

Main Requirements for Urban Planners

Apart from topographical mapping, planners also look forward to remote sensing (data products) technology to provide them information on existing landuse and their periodic updating and monitoring. In addition, with appropriate technique and methodology the same data products can be used to:

- Study urban growth/sprawl and trend of growth
- Updating and monitoring using repetitive coverage
- Study of urban morphology, population estimation and other physical aspects of urban environment
- Space use surveys in city centers
- Slum detection, monitoring and updating
- Study of transportation system and important aspects both in static and dynamic mode
- Site suitability and catchments area analysis
- Study of open/vacant space

High spatial resolution satellite data are highly beneficial in the context of complex urban areas where relatively small size and complex spatial patterns of the component scene elements (e.g. buildings, roads and intra-urban open space) have restricted the use of the low-resolution space borne sensors. These new images thus increase the amount of information attainable on urban form at local level.

Urban Land Use Classification Criteria

Classification is, therefore, an activity of sub-dividing a group of objects in two or more groups, i.e. to arrange objects into classes according to some system or principle. This can be based on activity, economic function, physical appearance, or simple land cover. The guidelines could be:

i) The classification system should be applicable over a large area covering both city core and its surroundings.

ii) Classification should be suitable for using remotely sensed data obtained at different time periods

iii) The minimum interpretation accuracy and reliability in the identification of land use should be about 85 percent subject to level of classification of different land uses.

iv) The nomenclature, definition and framework to the extent possible should be compatible with existing terminologies adopted in planning agencies.

v) Classification should be easier to understand and flexible.

v) Aggregation of similar or multiple land use classes should be possible at different levels of requirement.

vi) The classes must be mutually exclusive, i.e. any geographical individual can only fall into one class

vii) Wherever possible, it must be based upon quantitative criteria

Urban Land Use Delineation

For most purposes, there is need to arrange detailed observations into groups, using some classification process. There is not a single ideal classification of land use and land cover. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources.

Meet most of their needs. A part of urban land use classification proposed for National Urban Information System (NUIS) is given in Table 1.

Table 1 : Remote Sensing Satellites/Sensors and its 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).

Table 2 : Urban Land Use Classification

Level I	**Level II**	**Level III**	**Level IV**
Built up	Built up (Urban)	High Density residential	High rise apartments/ flats
	Built up (Rural)	Medium Density residential	Medium rise apartments/flats
		Low Density residential	Low rise apartments/flats
			Row houses
			Slum and squatters
		Industrial	Service industry
			Light industry
			Extensive industry
			Heavy industry
			Hazardous
		Mixed built up	
		Recreational	Parks/gardens
			Playgrounds
			Historical monuments
			Cinema halls
			Swimming pools
			Major function halls
		Public and Semi Public	Educational
			Hospital
			Cantonment
			Religious
			Government institutions
			Petrol Pump
			Fire stations
			Police stations
			Others
		Communications	Post Office
			Telegraph office
			Radio TV station
			Others
		Public utilities and facilities	Water treatment plant
			Landfill/dumping
			Electric power plant
			Sewerage treatment plant
			Others
		Commercial	
		Transportation	Bus terminus
			Railway stations
			Air port
			Others
		Reclaimed/vacant land	Layouts/plotted land

Problems and Issues

When remote sensing is used data many problems arise during interpretation of different urban land use/land cover features, in which cloud patches on satellite data is important one. Another problem in remote sensing data depending upon urban building size and spectral contrast with the surrounding area is that some buildings in urban area may be identified, while others may not. On the other hand, while individual houses cannot be always being identified, groups of houses and city blocks can often be delineated and, in many instances, interpreted in satellite images.

In this context, urban remote sensing must be able to provide planners with certain key, data sets that are pertinent to urban studies, notably:

(i) The location and extent of urban areas;

(ii) The nature and spatial distribution of different land use categories within urban areas;

(iii) The primary transportation networks and related infrastructure;

(iv) Census related statistics and socio-economic indicators;

(v) The 3-D structure of urban areas for telecommunications (inter-visibility) and environmental Impact Assessment (EIA) studies; and

(vi) The ability to monitor changes in these features over time and space.

The following urban issues are analysed by using this technology :

Urban Land Use Inventory : It is quite natural that population growth increases the pressure on the land, and the non urban land is converted into urban areas. Population growth and city expansion ultimately influence the land use pattern of any urban centre. Knowledge of the patterns and intensity of land use is relevant in urban planning, but the preparation of a land use inventory by conventional method is expensive and time consuming. The advantage of satellite imagery interpretation in terms of accuracy, timeliness and cost is indisputable in comparison to conventional methods.

Study of Urban Sprawl and Growth Trends *:* Since satellite based remote sensing systems have unique capability to provide repetitive coverage for any pay of the world this makes it most suitable for monitoring and updating of urban expansion by using very high resolution multi-temporal remote sensing data especially for town and country planning.

Space Use in the Core Area : From the monitoring point of view of city area, information about land use only may not be sufficient for city administrators and planners in congested core areas. The true picture may only be visualized from available information on actual space use. Space, however defined, has a location, and data necessarily refer to a point in time. In the absence of suitable large scale maps for such detailed studies, the principal use of very high resolution IKONOS satellite data provide a base for the survey/ recording of various activities in the field. The rest were confirmed/ picked up during the field visit. Quantitative determination of space use allows in understanding the distribution pattern of various activities and functional characteristics within urban fabric, which is useful for quantifying the stress on existing infrastructure.

Travel Route Pattern : Physical infrastructure of an urban centre comprises of transportation, water supply, electric power supply, sewage etc. The transportation system is one of the keys to rapid modernization, particularly in developing countries. Irrespective of whether roads act as a catalyst for development or play a more passive role in development, it is necessary to work out a judicious plan so as to avoid congestion, pollution and cost. The main objective of this type of studies using Remote Sensing and GIS techniques is to make network analysis of tourist places considering two factors: time and cost. This type of study provides a methodology for analyzing the optimum transportation network of tourist cities, and can be very helpful when planning for other cities also.

Urban Environment Analysis : Green spaces in cities exist mainly as semi-natural areas, managed parks and gardens, supplemented by scattered vegetated pockets associated with roads and incidental locations. Embodying the garden city concept advocated by Ebenezer Howard (1898) and the large urban park idea expounded by Frederick Law Olmsted in the US (Wilson, 1989), public green spaces have been increasingly designated in cities since the 1880s to counteract environmental impacts of urban expansion and intensification. Plants notably trees, have a wide range of environmental benefits, and urban green spaces often accommodate varied assemblages of flora and small animals, providing readily accessible site with natural ingredients.

The role of remote sensing in the case of green / open spaces mapping and analysis has become important for managing, and maintenance of old and degraded spaces. However, in a number of cases remote sensing can supplement or partially replace tedious ground survey methods. Moreover, ground methods have limitations as whole area may not be accessed in one go and information collected may not be as accurate as possible through remote sensing, aided by limited ground survey. Remote sensing not only provides spatial data but also allows us to compare temporal variations in spatial data, which is essential for green/open spaces management.

Site Suitability Analysis :

A number of workers have identified various criteria including soils, hydrology, topography, vegetation, climate, existing built up areas, transportation route etc. to find out suitable sites for location of development activities. The most commonly technique for suitability analysis is weighted suitability method. Weighted suitability is more complex; in order not to bias the weighting the aspect scales should first be normalized that is used in the same numerical range.

The frequently used scale is in a 1-5 range :

5. Very good (much more than average)
4. Fairly good (more than average)
3. Good (average)
2. Fairly bad (less than average)
1. Very bad (much less than average)

Such a scale can accommodate qualitative and quantitative data, but the scoring of quantitative data to such a scale needs qualified professionals. The next step is assigning the weight factors. This is, of course, the critical element in this approach. Weight factors are often based on a mixture of implicit knowledge, personal experience and individual values that is usually called "professional judgment".

Social Infrastructure : In most Indian cities, the municipal bodies have primary responsibility to cater to the basic needs of the citizen by providing required essential services and infrastructure facilities. But during the last century, cities throughout the developing world have seen an extraordinary increase in their population size, which has put tremendous strain on the delivery of the basic infrastructure services. A major concern of municipalities in developing countries is the limited access to urban services of larger parts of the city population.

Equitable distribution is becoming the centre of concern in planning the infrastructure facilities. There is an urgent need to solve this problem of unbalanced distribution of infrastructure services. The social infrastructure facilities basically include banks, post-office, schools, medical facilities, etc. For each facility the proposed indicators are : (a) Number of facility/Total population of the ward, (b) Number of facility/Total area of the ward

Conclusion

Remote Sensing and GIS is capable of extracting urban land cover information with robust results. 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, network analysis, simulation of urban activities to evaluate different urban development alternatives in the GIS framework needs to be explored for added advantage.

Land use planning, community facilities planning, transport planning, and environmental planning all can benefit from this information. Rapid development in city poses several challenges including problems associated with urbanization for urban managers and policy makers. Meeting these challenges requires access to timely and reliable information.

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