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Geographic Information System Applications in Urban Management

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Geographic Information System (GIS) is the emerging field with diversified applications in civil engineering, geosciences, forestry, disaster mitigation, environment and ecology, infrastructure planning, utility mapping etc. Nowadays GIS is a billion dollar industry with applications in varied discipline, and it is being used by professionals from various disciplines. GIS was pioneered in the 1960's by Canadian forestry mapping initiative and continued to develop as Canadian, U.S., and other government and university researchers sought to represent the earth's geography using a computer data base, display on a computer terminal, and plot it on paper. They also developed computer programmes for quick search and analysis of data. Several corporations were supported in 1970's to develop and sell systems for computer mapping and analysis.

Two leading GIS software developers trace their roots to early days and emphasize on two different aspects of technology. Intergraph Composition of Huntsville, Alabama, focused on efficient input and storage of GIS data as well as preparation of computer generated maps that rivaled traditional maps for their cartographic quality. The Environmental Systems Research Institute of Redlands, California, focused on providing a tool kit of computer commands for the analysis of GIS data. Today there are over hundreds of web sites that publish GIS data on the World Wide Web. As a result, the worldwide market for all GIS products and services was about $7 billion in 1999. Significantly, developed countries are using GIS widely in many areas but developing countries are moving towards the development of GIS database for their resources. Remote Sensing, aerial photography,

cartography, surveying and other field instruments for attribute data collections contributes to the data acquisition. Cartography, surveying, geography, geology contributes for the mapping process, while disciplines like Computer Science and Statistics, Mathematics are involved in processing and analyzing data. Computer Science and Mathematics are involved in storage of data structure. GIS mapping has several advantages over paper map in the digital age. However, GIS data base creation is a time - consuming and tough job. Therefore it is dealt as a separate discipline in the name of Geometrics, Geoinformatics, and Spatial Information Technology.

Conceptualization

Commonly accepted definition of a GIS is a computer based system used to capture, store, edit, analyze, display and plot geographically referenced data. However, this broad definition applies to three principal types of computer systems, each of which has distinctly different characteristics and applications: CADD, AM/MF and GIS. Computer Aided Design and Drafting (CADD) technology is widely used by many professionals to help them design and produce design drawings. However, CADD can also be used to produce maps. It is an effective replacement for the traditional manual cartographic process. CADD can greatly reduce map production time and money over the traditional cartographic process. CADD offers many other benefits over traditional mapping techniques. However, CADD is not suited for analyzing map data. Automatic Mapping/Facility Management (AM/FM) is used by utilities to manage mapping and attribute data regarding their physical plans. AM/FM uses

graphic data elements to represent map features. The attributes of the utility system are also stored in a separate data table. A GIS is similar to CADD and AM/FM. Although, the GIS may divide the entire area being mapped in to separate files, it also stores attribute data. These are associated with the spatial data and provide further descriptive information.

Geographic Information System can also be defined as a set of integrated activities which provides tool to (i) integrate geographic data received from different sources such as maps, charts, tables, aerial photographs, satellite imagery, GPS in digital environment; (ii) attach thematic information to the geographic details; (iii) analyze results and build up queries or spatial information, (iv) get the results in a desired form.

Development of GIS

GIS has been developed due to combination of many disciplines - such as computer mapping, databases, computer science, geography, remote sensing, data processing, mathematics and statistics, Computer Aided Design (CAD), cartography etc. GIS was used in a few universities and organizations during 1960's. Today, GIS is a component of IT and used in diversified disciplines. The Romans first employed the concept of cadastral records i.e. land records. In India, the origin of organized land record system dates back to one thousand years when the Chola Kings initiated revenue surveys. During the 15th and 16th century, Raja Todermal under Akbar's regime is credited with the introduction of land management for revenue. In 1935, Municipal Committees of Nagpur after investigations found 'aerial survey' as the best solution and accordingly by 1936 completed

Nagpur city maps on 16 inches to a meter scale. During 1970-71, under UNDP, Cadastral Survey Pilot Project was undertaken by the Survey of India, covering an area of 8000 hectares, constituting 16 villages. However, GIS origin dates back to 1940's and 1950's. Successful implementation of computer aided graphical data processing at Massachusetts Institute of Technology and data base management system by General Electric in 1965 paved the way for GIS development at a much faster pace. Government agencies in USA, Canada, UK started using GIS for processing large amount of data. During 1960's, CGIS developed and regarded as first GIS used by Canada government agencies was used for land and resource management. USGS used Geographical Information Retrieval and Analysis System to analyze land use and land cover data. During 1970, Swedish Land Data Bank took steps to automate the land and property registration. Harvard Graphics Laboratory developed first vector GIS called as ODESSEY. Centre for Urban and Regional Analysis, University of Minnesota developed Minnesota Land Management Information System. During 1970's and 1980's, hundreds of packages related to GIS were developed. However, during 1990's, many types of software on GIS came into existence. During 1990 to 2000, GIS Technology was standardized and software were made available for various platforms. Since 2000, GIS is used in virtual reality through multimedia integration, mobile mapping and web based technology.

Components of GIS

There are four integrated components of GIS; data and database management systems and users. The data in a GIS are by nature geographic. Spatial data is the information pertaining to where the objects of interest are located. A fully functional GIS must have hardware to support data in-put, out-put, storage, retrieval, display and analysis. Some of the most popular GIS software are Arc Info, Arc GIS Map Info, Geo Media and TNT-MIPS. Each of these softwares offers different levels of functionality. Importantly, GIS is used by diverse professionals - from a cartographer to a commercial pizza dealer. Among the disciplines such as geology, hydrology and social sciences, GIS has become as indispensable a tool as word processing and spread sheet software such as MS Excel.

Applications of GIS

GIS is a tool that can be used in varied disciplines ranging from civil engineering to business. Remote sensing data is often brought into GIS to have a complete data set in many natural resources application areas. Remote sensing and GIS technology is useful in the important fields of protection of environment, water resources management, urban planning and transportation, watershed management, surveying, coastal zone management, natural disaster management, agriculture, land use planning, forestry, geosciences, demography, town and country planning, oil, water and soil resources, oceanography, tax assessment and physical and social environment.

Dataquest's market survey (1999) sub-divided GIS applications into the following nine categories:

- Base data includes the creation of vector data and vaster images representing physical features on earth's surface
- Land information includes the creation and maintenance of the data for land records, land planning and land use (21 per cent)
- Bio-logical uses include environmental, public health and safety, forestry, and agriculture (9 per cent)
- Geosciences applications includes oil, gas, and mineral exploration (16 per cent)
- Infrastructure management includes transportation, logistics, emergency services, and dispatch management (7 per cent)
- Utilities include water, sewer, storm water, electric, telephone, CATV, data communication, and stream systems (28 per cent)
- Business marketing and sales involves demographic, sales and location analysis (9 per cent)
- Geopolitics involves the military or other defense use (6 per cent).
- Cartography or map making (4 per cent)

GIS Techniques

Geographic Information System handles large volumes of data. GIS data is either spatial or aspatial. All locations on the earth's surface are spatial data. Spatial data consist of location; shape and size in earth, line point etc. Interestingly, remote sensing means acquiring information about objects without having physical contact with the object. Aerial Photography

is the remote sensing data, providing visual imagery of landscape on films. Remote sensing satellites take images in the visible and infra-red regions Radar microwave data are long wave producing land and water information much different from that of the visual region of the spectrum. Vector data input is the process of converting paper map into digital data while Global Positioning System (GPS) are used for the calculation of latitude, longitude and altitude for many users.

Roughly two thirds of the total cost of implementing a GIS involves building the GIS database. Many GIS programmes start with editing digital map data because of its relatively low cost. Subsequently, plans may be implemented to improve data with more accuracy and detail. Digitizing is the process of tracing paper maps into a compute format. There are two most widely used types of GIS data structure, viz. vector format and vaster format. The vector and vaster models for storing geographic data have unique advantages and disadvantages both of which models can be handled by a full function GIS. Vector digital map data is recorded as distinct points, lines, or areas. Vaster data files consist of rows of uniform cells covered according to data values.

Selecting and Implementing GIS

The benefits of GIS for government agencies and urban management are substantial and well documented. However, adoption of GIS technology requires thorough planning and vigilant control. The best way to begin a GIS programme is to carefully review the organization's needs, and then develop a strategic plan that will systematically guide the selection and

implementation of the system. A GIS Plan includes (i) introduction and background of GIS, (ii) existing operation; (iii) existing needs and problems; (iv) general description of GIS; (v) GIS hardware and software; (vi) GIS database, (vii) GIS data maintenance, (viii) data communication; (ix) staffing and organization; (x) training, (xi) schedule; (xii) financial analysis.

There are eight key components of a successful GIS operation. These are:

- management support, leadership and vision
- data conversion and maintenance
- hardware and software
- user training
- data communication
- software customization
- user support
- funding

There are three general types of costs associated with the implementation of a GIS:

- Services
- Hardware and software purchases
- Database creation

These costs also include ancillary charges such as taxes, insurance, shipping, and installation. Data base creation is usually the largest cost

component of a GIS programme. This category comprises of all costs required to create the GIS data base.

Importantly, ongoing cost of operations and the maintenance of the digital data base include:

- Data management
- Data maintenance
- User training
- System support
- User support
- System development
- Supplies

Implications for Uttar Pradesh

Uttar Pradesh is the most populous State in the country which accounts for 16.4% of the country's population. It is also the fourth largest State in geographical area covering 9.0% of the country's geographical area. The pace of urbanization has been lower in the State, and the level of urbanization has been reported lower than most of the other States. In 2001, 20.78 per centof its population was found living in urban areas. During 1991-2001, its urban population grew by 2.84 percent per annum. The pace of urbanization has declined during 1991-2001 from 1981-91 due to creation of a new state- Uttaranchal. As per the 2001 Census, there are 670 towns and cities in the State. There are 628 urban local bodies, out of which 12 are Municipal Corporations, 193 Municipalities and 423 Town Panchayats.

Urban property taxation is an important source of municipal revenue in most of the urban local bodies, however, the system of property taxation is manual and filled with discrepancies. There is need to enhance the revenue base in a structured manner. The models to enhance the property tax system by introducing GIS in Mirzapur and Kanpur have shown potential for GIS application in municipal revenue administration.

In order to develop a pilot model city programme consistent with Uttar Pradesh realities, the Ganga Institutional and Community Development Project (ICDP) in Mirzapur was developed by Governments of the Netherlands, India and Uttar Pradesh. The project provided a platform to develop and test a Geographic and Management Information System for improving the municipal administration of a small city in the state of Uttar Pradesh. It was a remarkable achievement which improved basic municipal data base and computerized system of resource mapping. Thus, Mirzapur become the first city where G.I.S. was introduced, allowing testing of the full range of applications for identifying, diagnosing and resolving administrative problems that had been unresolved for decades. The initiative cleared the misconceptions about the required data base, development, operation and application of a geographic information system in India. In 1995, municipal staff could not provide basic financial or infrastructure information because of the break - down of administrative activities and the absence of any information management system. The city was bankrupt and conditions were getting worse with a widening gap between income and expenditure. At the commencement of the ICDP programme, the municipality's current revenues were not sufficient to meet even the basic payroll, let alone to sustain the operation and maintenance of

basic urban services. In order to address the situation, ICDP developed a successful intervention package that included immediate service improvements, property reassessment and environment planning. The primary objectives were the computerization of property tax records, and the proper enumeration and mapping of all properties and infrastructure. The first objective of the programme was to collect and computerize the critical property tax assessment registers for the 23,590 properties. The assessment registers are the only official property tax records and any changes in taxation should have reference to them. Even though the registers may be disorganized and have not been updated for some years, they contain at least partial records of most of urban property data base. Any change or the creation of any registration system would need to be linked to the existing entry 'khatas' to modern usable computer files. The municipal tax department firstly had to conduct property enumeration to register new properties. After existing records were computerized they were easily printed out to be used in the field as the basis of property enumeration. Municipal staff conducted the enumeration between April and December, 1996 under the supervision of consultants. At the start of the project, the only property maps available were out-dated and rough outline maps. From these, revenue ward maps were extracted by rough boundaries for use in the property enumeration. National ward maps were taken to the field and used along with the assessment printout to verify and update property information. Surveyors made current notations both on records and on maps in the field. A property survey was conducted along side the enumeration based on a simple questionnaire, which emphasized location and basic property characteristics likely to effect property values, Land use, type of construction, floor level of unit, neighbourhood area and front/back street

access were the main contents of the questionnaire. At the end of every-day, enumeration survey information was checked, corrected and entered in computer files. Rough field notation maps were faired and fitted to the outline city map to create the first ever property tax maps for the city. The city property tax maps were scanned and digitized using maps into computer mapping software.

The methodology adopted was the representative neighbourhood approach where all the city's 610 Mohallas were classified into one of 7 neighbourhood types based on rental values. Once this coding was done, values for owner occupied properties were calculated. Mohalla and street coding formed the foundation of assessment of values. Property with values significantly higher or lower than surrounding properties were reviewed in the same way. After application of a computerized assessment programme property values were normally checked. The staff of Mirzapur Municipality were given technical and management training necessary to implement computerization and to supervise the field and office work.

Appreciation of geographical information system has increased revenues and improved services of municipality. The Mirzapur model has thus become the first initiative in improving the efficiency of municipal administration through implementation of GIS in India. The GIS tools are now available to increase municipal revenues and improving the urban basic services.

Conclusion

GIS offers solutions for data needs for both macro and micro level analysis of urban environment, development and governance to city planners. A comprehensive assessment of the efficacy of remote sensing and GIS techniques needs to be substantiated by a pragmatic and realistic evaluation of the emerging problems and opportunities in the urban sector. The local governments have been also empowered and strengthened through functional and financial devolution of powers in view of 74th constitutional amendment act. Accurate, reliable and comprehensive spatio-temporal information and GIS data on urban entities is a prerequisite for urban bodies and authorities to effectively perform the assigned functions. The GIS data-base provides an analytical framework for analyzing the emerging problems and constraints in urban development and governance as well as assessing the physical, social, and financial resources and effective management of urban services. Non-availability of reliable information base acts as one of the major constraints in preparing plans at local level where data base of physical features and resources are necessary. The conventional ground methods of obtaining the necessary data on physical, geographical, natural resources, land use and base maps are extremely slow and it is difficult to keep pace with the rapid changes in settlement and land use pattern. Moreover, there were inconsistencies in the statistical data obtained directly on the spatial phenomenon and the maps prepared therein. These inherent problems resulted in hurdles and constraints of severe nature at all levels of planning, implementation and monitoring. Therefore, application of remote sensing and GIS is imperative for holistic and planned development of the urban sector.

CASE STUDIES IN REMOTE SENSING OF INDIAN CITIES

City	Year	Urban Themes
Jaipur, Rajasthan	1983	Land use mapping Open space change detection; 1974-83
Coimbatore, Tamil Nadu	1984	Land use mapping and changes: 1979-84 Growth, distribution and morphology of slum during 1979-84 Residential area typology Estimation of population
Ujjain, Madhya Pradesh	1985	Land use inventory and changes Changes detection and growth 1983-95 Study of residential environment Development plan evaluation Population estimation Space use mapping in city centre
Hyderabad, A.P.	1986	Urban land use changes and its structure during 1984-86 Study of the residential environment, population estimation and housing density. Urban spatial growth and change detection during 1979-86
Rohini, Delhi	1987	Monitoring urban growth. Study of residential area: Shalimar Bagh
		Land use inventory. Inventory of derelict land.
Kanpur, Uttar Pradesh	1988	Mapping of urban land use/land cover. Study of commercial and industrial Land use in City centre. Quantitative assessment and qualitative judgment of habitat and its refuse. Identification of disposal sites, their capacity and projections.
Narela, Delhi	1988	Study of unauthorized development

Ujjain, Madhya Pradesh	1989	Residential land use inventory. Population Estimation and environmental impact assessment
Dehradun, Uttar Pradesh	1989	Land use inventory, change detection and residential environment
Jaipur, Rajasthan	1989	Mapping and monitoring of urban sprawl and land use/land cover. Site suitability analysis for residential development
Delhi	1989	Mapping and monitoring of urban sprawl and land use/land cover
Lucknow, Uttar Pradesh	1989	Mapping and monitoring of urban sprawl and land use/land cover.
Bhubaneshwar, Orissa	1990	Study of residential structure, potential of open/vacant spaces and growth of industrial area.
Bardez, Goa	1991	Implementation of zonal plan, housing types and density and land use analysis in Calangute tourist site. Suitability analysis for urban development. Rural population estimation.
Saharanpur, Uttar Pradesh	1991	Land use/land cover mapping. Land use change detection. Analysis of urban amenities and facilities. Residential service level and accessibility to facilities and services. Study of potential areas for residential development. Housing density and urban population estimation.
Saharanpur, Uttar Pradesh	1993	Identification of slums. Efficacy of remote sensing in census operations. Morphology of city. Suitability analysis of vacant lands for urban development
Dwarka, Delhi	1993	Inventory of built-up environment
Bangalore, Karnataka	1994	Quality of residential environment. Appraisal of development plan. Land use change detection.

		Study of open spaces.
Jammu, Jammu & Kashmir	1995	Land use/land cover mapping. Growth profile of city. Identification of slums and squatter settlements. Selection of new sites for residential development. Inventory of vacant lands. Urban land use change detection. Qualitative assessment and zonation of natural hazards
Mizapur, Uttar Pradesh	1997	Mapping properties for tax assessment.

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