



## **GIS based Utility Mapping**

May 2015

**Supported under**

**Comprehensive Capacity Building Programme (CCBP)**

**Ministry of Urban Development**

**Government of India**



## **Prepared by: Module Preparation Team:**

1. K. Sudhakar, Team Leader, State Reforms Performance Management

2. Editorial Advise, Guidance and Review

- Mr. Shabbir Shike, Urban Planner.
- Mr. Vijay Bhaskar, CGG

3. Content Contributions:

- Mr.Ravi Rohan, UMC, Senior Research Associate, UMC
- Mr.Vijay Bhaskar, Senior Research Associate, UMC
- Mr. Raghu Ram, Team Leader, RPMC, Mahabubnagar

## Outline of the Module

<b>COMPONENT</b>	<b>DESCRIPTION</b>
<b>BACKGROUND</b>	Utilities management throughout all the ULB in India are facing unprecedented change, Municipal utility services are using new strategies for better manage and improve utility services. Geographic information system (GIS) technology offers utility organizations a method of quickly accessing and producing maps, leveraging database information, and automating work processes. Improved hardware, software, and networking technology have created opportunities for the utility industry to build and benefit from more comprehensive and sophisticated GIS.
<b>INTENDED AUDIENCE(S)</b>	Municipal Commissioners, Municipal Engineer, City Planner, Sanitary Inspector, Municipal Health Officer, Revenue Inspectors etc.
<b>LEARNING OBJECTIVES</b>	<ul style="list-style-type: none"> <li>• Equip the municipal staff with the knowledge of GIS mapping.</li> <li>• Understand the application of GIS in Municipal functions</li> <li>• Provide orientation of GIS application and its advantages</li> <li>• To provide understanding on applications of GIS in Municipal administration.</li> <li>• Equip the Municipal staff on base map preparation.</li> <li>• Furnish various utility mapping attributes/components using GIS.</li> <li>• To equip the municipal staff for delivering services using GIS based services.</li> </ul>
<b>MODULE OVERVIEW</b>	<b>STRUCTURE/ CONTENTS</b>
<b>MODULE DEIVERY OUTLINE</b>	<b>(TOPICS UNDER EACH HEADING)</b> <ul style="list-style-type: none"> <li>✓ <b>Awareness on various services that can be rendered using GIS</b></li> <li>✓ <b>Knowledge on GIS based utility mapping and validation of services.</b></li> <li>✓ <b>Improving the Skills of the staff in GIS mapping.</b></li> </ul>
<b>MODULE ACTIVITIES</b>	<b>(METHODS OF TEACHING)</b>
<b>SUPPORTING MATERIALS</b>	Reading Material on Introduction to GIS and GIS based Utility Mapping.
<b>MODULE FEEDBACK</b>	
<b>MODULE DEVELOPER</b>	<b>SRPMC.</b>

## **Contents of the Enclosed Compact Disc (CD)**

**1. Soft Copy of the Module in PDF Format**

**2. Power Point presentation of the Module**

**3. Reference Material for all Sub Modules**

**i. Fundamentals of GIS**

**ii. GIS tools**

**iii. Municipal Utility Mapping.**

**4. Other Related Documents**

# Table of Contents

<b>Table of Contents.....</b>	<b>6</b>
<b>1 Introduction to GIS based Utility Mapping.....</b>	<b>7</b>
1.1 Evolution of GIS In The Utilities .....	11
1.2 Advantages of GIS in Municipal Mapping.....	11
<b>2 Application areas of GIS.....</b>	<b>12</b>
2.1 GIS applications in day to day functions of ULB.....	12
2.2 Guidelines for the preparation of Geo-referenced city base maps.....	13
<b>3 Major GIS based Utility Mapping Components .....</b>	<b>13</b>
3.1 GIS based property tax assessment .....	15
3.2 GIS based utility Mapping- sustainability.....	17

# 1 Introduction to GIS based Utility Mapping

Municipalities at large are taking up e-Governance and technology based service delivery initiatives to improve efficiency, transparency and accountability in their functioning while enhancing the quality of citizen services they offer. Utilities management throughout all the ULB's in India are facing unprecedented change. Meager service delivery of government-owned utilities has added new elements of risk to the management of utilities today. Municipal utility services and cooperatives are using new business strategies to better manage and improve utility services. Geographic information system (GIS) technology offers utility organizations a method of quickly accessing and producing maps, leveraging database information, and automating work processes. Improved hardware, software, and networking technology have created opportunities for the utility industry to build and benefit from more comprehensive and sophisticated GIS.

Geographic Information System (GIS) is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, and other administrative records.

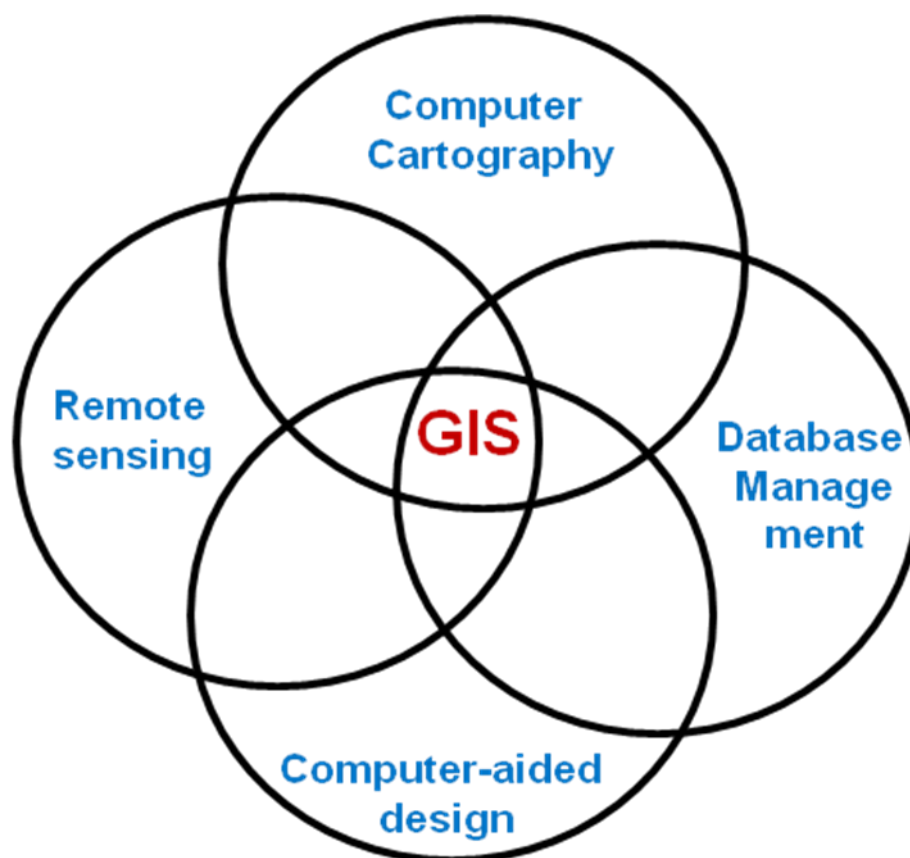
Spatial features are stored in a coordinate system (latitude/longitude, state plane, UTM, etc.), which references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis.

## **Three views of GIS:**

1. **Data base view:** Unique database of the world- a geographic database.
2. **Map view:** Focuses on cartographic aspects of GIS. See GIS as map processing (each dataset is represented as map called layer/theme/ coverage) and display system.
3. **Model view:** Emphasizes spatial analysis. Focuses on analysis and modeling in which GIS is seen more as a spatial information science than a technology.

## **GIS differs from CAD and other graphical computer applications:**

All spatial data is geographically referenced to a map projection in an earth coordinate system and can be "re-projected" from one coordinate system into another, thus data from various sources can be brought together into a common database and integrated using GIS software. Boundaries of spatial features should "register" or align properly when re-projected into the same coordinate system. GIS database has "*topology*," which defines the spatial relationships between features. The fundamental components of spatial data in a GIS are points, lines (arcs), and polygons. When topological relationships exist, we can perform analyses, such as modeling the flow through connecting lines in a network, combining adjacent polygons that have similar characteristics, and overlaying geographic features.



#### 1-1 Understanding GIS...

- **Computer Cartography** focuses on data retrieval, classification and automatic symbolization
- **Remote sensing** focuses on to collect, store, manipulate & display raster data typically derived from scanners mounted on aircraft or satellite platforms
- **Database Management** are the well developed software system optimized for storing and retrieving non-graphic attribute data



- **Computer-aided design** focuses on designing and drafting new objects.

### Data representation

GIS data represents real world objects (roads, land use, elevation) with digital data. Real world objects can be divided into two abstractions: Discrete objects (a house) and continuous fields (rain fall amount or elevation). Two broad methods “Raster and Vector” used to store data in a GIS and represents a geometry of topology, size, shape, position and orientation.

### Area of GIS Applications

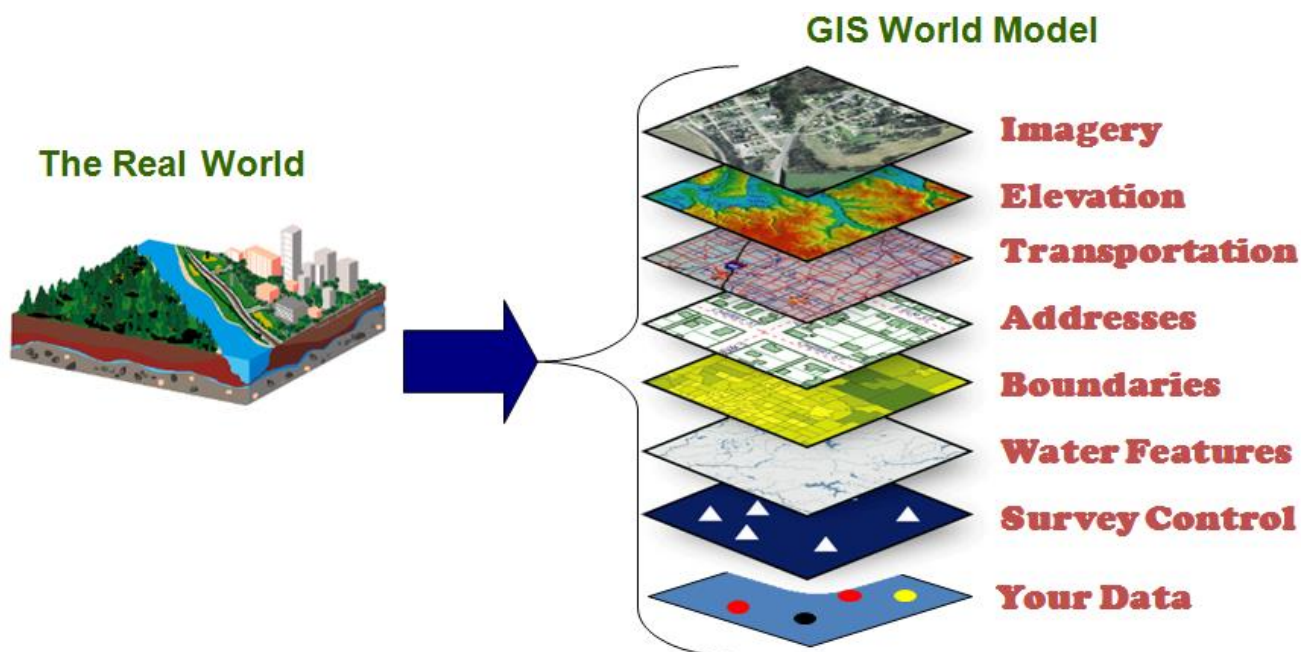
**Facilities Management:** Large scale and precise maps and network analysis are used mainly for utility management. AM/FM is frequently used in this area.

**Environment and Natural Resources Management:** Medium or small scale maps and overlay techniques in combination with aerial photographs and satellite images are used for management of natural resources and environmental impact analysis.

**Street Network:** Large or medium scale maps and spatial analysis are used for vehicle routing, locating house and streets etc.

**Planning and Engineering:** Large or medium scale maps and engineering models are used mainly in civil engineering.

**Land Information System:** Large scale cadastre maps or land parcel maps and spatial analysis are used for cadastre administration, taxation etc.



### 1-2 GIS Image and Real world interpretation

**Attributes:** Maps convey descriptive information through map symbols, colors, and labels.

Here are some typical examples:

- Roads are displayed based on their road class (for example, line symbols representing divided highways, main streets, residential streets, unpaved roads, and trails).
- Streams and water bodies are drawn in blue to indicate water.
- City streets are labeled with their name and often some address range information.
- Special point and line symbols denote specific features such as rail lines, airports, schools, hospitals, and special facilities.

In a GIS, descriptive attributes are managed in tables, which are based on a series of simple, essential relational database concepts. A relational database provides a simple, universal data model for storing and working with attribute information. DBMSs are inherently open because their simplicity and flexibility enables support for a broad range of applications.

**Table 1-1 Representation of Data in GIS database**

<b>How the four elements are represented in GIS Map Layer Types</b>	<b>GIS Datasets</b>
Features—points, lines, and polygons	Feature classes
Attributes	Tables
Imagery	Raster datasets
Surfaces	Both features and rasters can be used to provide a number of alternative surface representations:
	Feature classes (such as contours)

### 1-3 Attribute wise layer representation in GIS

Common GIS representations Theme	Geographic representation
Hydrography	Lines
Road centerlines	Lines
Vegetation	Polygons
Urban areas	Polygons
Administrative boundaries	Polygons
Elevation contours	Lines
Well locations	Points
Orthophotography	Raster
Satellite imagery	Raster
Land parcels	Polygons
Parcel tax records	Tables

#### 1.1 Evolution of GIS In The Utilities

The primary goal of any utility is to plan and manage the use of facilities to deliver a commodity such as water, natural gas, or electricity to its customers. The ULBs in India has always relied on hardcopy maps to manage facilities. The earliest efforts were made using Computer Aided Design/Drafting (CAD) software as the basis for systems which came to be called Automated Mapping/Facilities Management (AM/FM). A number of approaches geared to map reproduction were taken, based around the CAD technology, BUT Auto CAD mapping is partly successful, failed to act as a decision making tool. A comprehensive tool which can map the utilities based on the attribute data analysis would be GIS.

#### 1.2 Advantages of GIS in Municipal Mapping

- Improved service delivery and management efficiencies
- Efficient design and management of facilities
- Data sharing that supports decision making
- Collaborative efforts
- Decreased redundancy

- Visualization of data to create new information
- Support for daily work flows throughout the utility

## **2 Application areas of GIS**

GIS can be helpful for the documentation of spatial plans and in the approval process for the development, building and installation permits. GIS applied to a wide range of land management and land use planning issues including the interpretation and formulation of land use policy. Land-use policy can be interpreted within GIS using a modelling approach. Output in the form of maps showing areas in which land-use changes are more likely to occur, and statistics, graphs and tables summarizing this information according to a variety of specified spatial units. Such output allows land-use implications to be discussed. The predicted land-use changes can also form input for GIS-based impact assessment.

- Municipal Applications like Water pipelines, sewer lines, drainage lines, storm water lines etc.
- Mapping various social infrastructure features like Graveyards, Parks, Playgrounds, Temples, Mosques, ponds etc.
- Facility Management (Power, Gas, Water, Sewage and Telecom)
- Location based services (industries, education, health etc.)
- Corridor mapping for infrastructure like transporting connectivity studies, road alignment, power line, pipelining alignment.
- Disaster management (floods, landslides, earthquake)
- Agricultural lands, Forestry lands vacant land, Government lands etc.
- Land use/ Land cover mapping
- Geologic and soil mapping
- Environmental assessment, monitoring and management

### **2.1 GIS applications in day to day functions of ULB.**

- i. Mapping the cleaning of streets, drains, removal of rubbish, scavenging and solid waste management
- ii. Mapping the areas supplied with protected water
- iii. Identification of new roads, bridges, cause ways and culverts
- iv. Mapping the road width and major road junctions.
- v. Mapping the city into various illumination zones of public street lighting

- vi. Mapping various Town planning – Zones and Building Regulations
- vii. Manage the construction and maintenance of buildings, Property tax assessment etc.
- viii. Health mapping the city like hospitals, maternity and child welfare centers, dispensaries
- ix. Mapping the slaughter houses, markets parks, play grounds, burial grounds and urban forestry
- x. Mapping the Slum and other encroachments

## 2.2 Guidelines for the preparation of Geo-referenced city base maps

Base map is required to mark pedestal information of the city, a base map displays the fundamental data set (key physical features such as, roads, railway network, rivers, neighbourhood/slum boundaries, schools, other landmarks etc.) that is used to render sector data more meaningful. A good base map should easily answer the question “Where?” a particular attribute is on the map. The roads, landmarks and other places that are included in the map should be spatially related and correspond to the ground position. Displaying or analyzing the base data with the sector data assists the user in making effective and well-informed decisions.

- Preparation of base maps at coarser levels using SOI maps (1:50,000) and finer scale (1: 2000 or 1:5,000 and 1:500) respectively.
- Procurement of appropriate high resolution satellite images of towns from NRSC/other reliable sources. The images (5.8 mt Resolution) available in Bhuvan (Web Geoportal for Earth Observation Data developed by ISRO) can also be used for preparation of Base Map
- Digitization, image rectification, ground truthing and preparation of city base map.

## 3 Major GIS based Utility Mapping Components

Utility mapping includes Roads, water pipelines, sewerage, storm water electric lines, traffic management, health center, fire stations telecommunications Miscellaneous services etc.

Sl.No	Feature	Components for feature class mapping
1	Road	· Major, minor road network
		· Road intersections
		· Carriage way

Sl.No	Feature	Components for feature class mapping
		· Footpath
		· New roads
2	Water Pipelines	· Pipeline Distribution network
		· Pumping stations
		· Overhead tanks
		· Water treatment plant
		· Reservoir overhead/underground
		· Balancing tanks
		· Bore holes
		· Water supply office locations
		· Location of valves
		· Fire hydrant locations
		· Consumer indexing with property no
		· Public taps
3	Sewer pipeline	· Sewer pipe network
		· Pipe segments
		· Joints
		· Manholes
4	Storm water drain	· Storm water drain network
		· Width of drain
5	Electric lines	· Electric feeders
		· Electric sub stations
		· Electric poles
		· Transformers
		· Low tension lines
		· Jurisdiction of SDO
		· Consumer indexing
		· Street lighting network and spacing of streetlights
· Location of street light pole		

Sl.No	Feature	Components for feature class mapping
6	Traffic management	· Traffic control room
		· Traffic light network
		· Traffic signal post
		· Public parking
		· Bus stop
		· Traffic congestion areas
		· Petrol pump
7	Health care	· Hospital location
		· Dispensaries
		· PHCs
		· Chemist shop location
8	Fire services	· Fire station location
		· Area jurisdiction for each fire station
		· Fire prone areas
9	Telecommunication network	· Telephone exchange
		· Telephone pole
		· Telephone cables along road
		· Distribution point
10	Miscellaneous services	· Government lands
		· Vacant lands
		· Parks & playgrounds
		· Graveyards etc.

### 3.1 GIS based property tax assessment

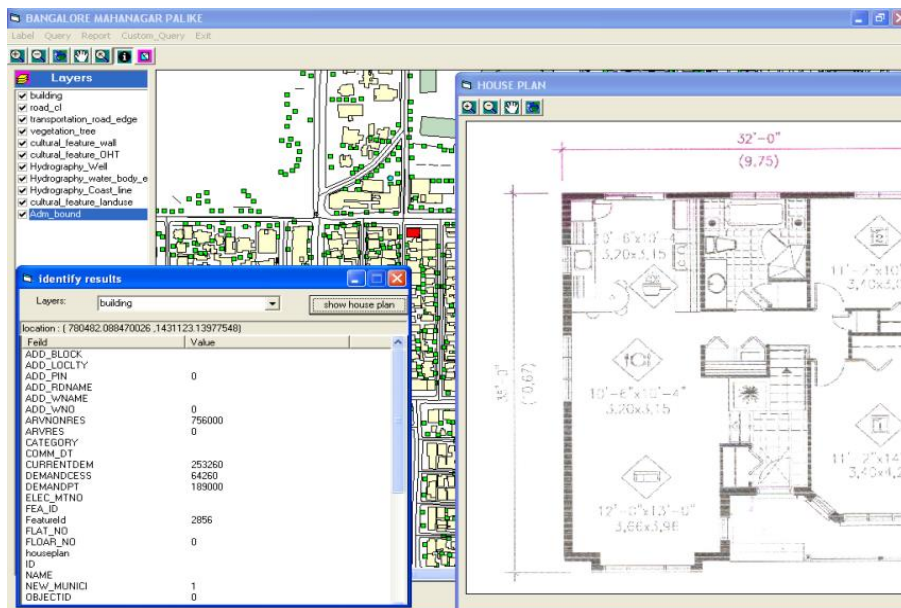
Key challenges faced by ULB in property tax assessment

- Lack of proper mechanism to check property tax collection and track tax evaders
- Migrate from existing annual rental value tax system to a Unit Value System (UVS)
- Lack of transparency resulting in delays in addressing public

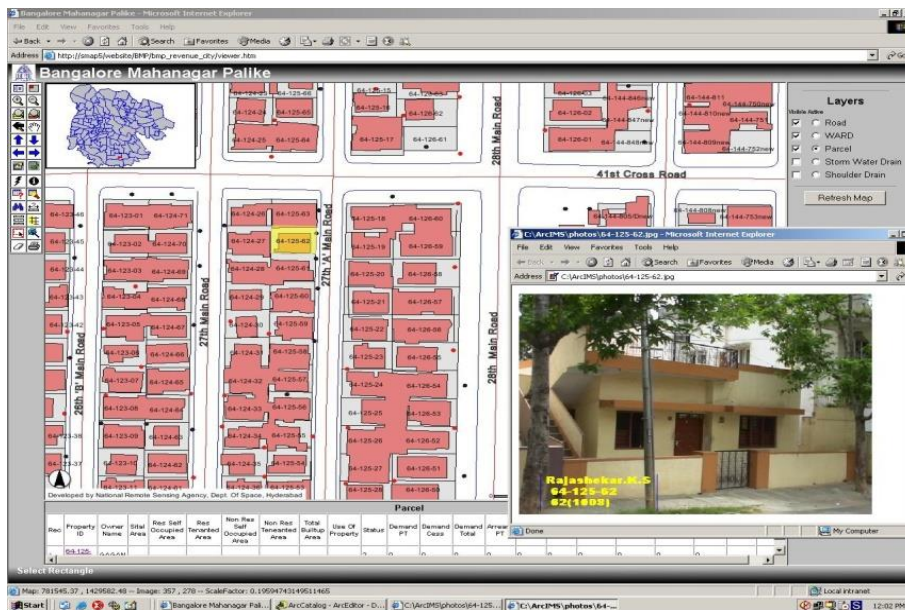
GIS based solutions for property tax management including spatial content generation, assessment data preparation, desktop application and web interface.

- Creation of a GIS-based spatial property database using high resolution satellite imagery geo-referenced control points taken by dual-band GPS (DGPS) survey, and updated by ground truthing (validation). The property boundary layer is then migrated on top of this GIS base map to create homogenous GIS data layers.
- Assessment data preparation using existing property details and door-to-door contact surveys.
- Re-number of properties in the ULB jurisdiction to assign a unique identifier to each property and fixing of house numbers
- Development of desktop application for property database repository management and tax assessment
- Development of informative and interactive web-GIS system for online property tax calculation and payment

In GIS based property tax assessment each house is identified with the House number, owner name, contact no etc. The accurate area of the plot is calculated with the help of the GIS.







**3-1 GIS Based Utility mapping- Overview of Building marking (Above); Sample Property Tax Collection**

### 3.2 GIS based utility Mapping- sustainability

It is increasingly becoming an important component in the planning support system. Recent advances in the integration of GIS with planning models, visualisation, and the Internet will make GIS more useful to urban planning. Today, the main constraints on the use of GIS in urban planning are not technical issues, but the availability of data, organisational change, and staffing.

The lack of available data remains one of the major hindrances in the use of GIS. As a type of information system, GIS needs graphic and textual data in order to function. There is no life in GIS without applications and there can be no application if there are no data. In short, data are vital to GIS. In the developed countries, a reasonable amount of geographical data is available thus making the establishment of a GIS relatively easy if sometimes expensive, unfortunately, data are not so readily available in the developing countries. The most readily available data are those from remote sensing which means that they are restricted largely to land cover information from which a very limited amount of information about land use can be extracted. Because of this it is not surprising to find that data contained in GIS in developing countries are primarily concerned with the physical environment and land cover. Socioeconomic data, which are vital to urban and regional planning, are generally lacking and often limited only to population census data.

The state-of-the-art in planning in the developing countries has not advanced much in comparison to GIS. The skills of planners and the planning systems may not be ready to utilise the data and functions provided by GIS. Planners could employ GIS in conjunction with new planning techniques so that they are better able to diagnose potential problems and assess the desirability of alternative plans. In spite of this, most planners in the developing countries are not yet aware of the benefits and potential applications of GIS. Furthermore, even though much effort has been spent on data collection, comparatively little has been spent on transforming data into information for making planning decisions.

## **Summary of the Module**

Geographic Information System (GIS) is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, and other administrative records.

Spatial features are stored in a coordinate system (latitude/longitude, state plane, UTM, etc.), which references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. GIS can be helpful for the documentation of spatial plans and in the approval process for the development, building and installation permits. GIS applied to a wide range of land management and land use planning issues including the interpretation and formulation of land use policy. Land-use policy can be interpreted within GIS using a modelling approach. Output in the form of maps showing areas in which land-use changes are more likely to occur, and statistics, graphs and tables summarizing this information according to a variety of specified spatial units. Such output allows land-use implications to be discussed. The predicted land-use changes can also form input for GIS-based impact assessment.

### **GIS applications in day to day functions of ULB.**

- xi. Mapping the cleaning of streets, drains, removal of rubbish, scavenging and solid waste management
- xii. Mapping the areas supplied with protected water
- xiii. Identification of new roads, bridges, cause ways and culverts
- xiv. Mapping the road width and major road junctions.
- xv. Mapping the city into various illumination zones of public street lighting
- xvi. Mapping various Town planning – Zones and Building Regulations
- xvii. Manage the construction and maintenance of buildings, Property tax assessment etc.
- xviii. Health mapping the city like hospitals, maternity and child welfare centers, dispensaries

xix. Mapping the slaughter houses, markets parks, play grounds, burial grounds and urban forestry

xx. Mapping the Slum and other encroachments

Utility mapping includes Roads, water pipelines, sewerage, storm water electric lines, traffic management, health center, fire stations telecommunications Miscellaneous services etc.