UNIT 4 CONCEPT OF GIS

Structure

4.1 INTRODUCTION

You have read in the earlier units about remote sensing, mapping, digital image interpretation and global positioning system (GPS). In this unit, you will be introduced to various aspects of Geographical Information System (GIS). In spite of ever increasing environmental awareness, Earth's environment is still not well understood. GIS has emerged as an all encompassing tool to understand the Earth and its environment. GIS are a special class of information systems that keep track not only of events but also where these events are operating. Due to increasing complexity of the real world situations, more challenges emerge in knowing about the mother Earth and also in planning and decision making processes. Today, GIS is considered as an important tool in planning and decision-making. As a consequence, it has been extensively incorporated in many areas, such as cadastral mapping, land use planning, forestry, wildlife management, infrastructure planning, military surveillance, environmental monitoring, network planning, facility selection including many socio-economic applications, etc. Some of the advanced applications involve air traffic monitoring, road navigation, crime analysis and so on.

Today many of us are using this technology knowingly and unknowingly. The ability of GIS to handle and manage vast geospatial data makes it an important tool for a wide variety of applications. Integration of GIS technology with other known spatial technologies such as remote sensing, GPS and mobile devices has increased its applications particularly in the areas of interactive mapping, site-based services, precision farming and in-vehicle navigation systems. At present, GIS has become the most accepted and standard technology of utilising geospatial data. This technology can be misused or misinterpreted therefore, a proper knowledge of GIS technology and its basic concept is essential before

utilising this technology. In this unit, we will discuss the basic concepts, components and organisation of GIS along with its historical development and current status.

Objectives

After studying this unit, you should be able to:

- define GIS and its components;
- explain the historical development of GIS; and
- discuss the organisational aspects of GIS.

4.2 DEFINITION OF GIS

A *Geographic Information System* (GIS) is defined as a computer system which is used for capturing, storing, managing, querying, analysing and displaying geospatial data (Chang, 2010). GIS helps to evaluate the real world features which are represented as geospatial (geographical) data in terms of their position and in relation to the coordinate system, their attributes and spatial interrelation with each other.

Geospatial data also called as geographically referenced data describes both the locations and the characteristics of spatial features such as rivers, roads, canals, land parcels, vegetation covers, on the surface of the Earth. The huge processing and handling capacity of geospatial data distinguishes GIS technology from other information systems. This capacity also establishes GIS as an important technology for research analysts, environmental managers and natural resource planners.

GIS is defined based on different aspects, such as toolbox-based, database-based and organisation-based (Burrough and McDonnell, 1998). Let us discuss all these definitions one by one.

i) **Toolbox-Based**

It includes powerful set of tools for collecting, storing, retrieving data at will, transforming and displaying spatial data from the real world.

ii) **Database-Based**

This definition involves a database system in which most of the data are spatially indexed and upon which the set of procedures are operated in order to answer queries about spatial entities in the database.

iii) **Organisation-Based**

This definition comprises an automated set of functions that provides professionals with advanced capabilities for storing, retrieving, manipulating and displaying of geospatial data.

4.3 COMPONENTS OF GIS

Now you are familiar that GIS is a computer system of hardware and software used for storage, retrieval, mapping and analysis of geospatial data. The entire GIS is also considered to include the operating personnel and data that go into the system. Spatial features are stored in a coordinate system (e.g., latitude, longitude) which references a particular place on the surface of the Earth. The

descriptive attributes in tabular form are associated with the spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. For the most part, spatial data 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 by using GIS software. The boundaries of spatial features should 'register' or align properly when re-projected into the same coordinate system. Another property of a GIS database is that it has **topology** which defines the spatial relationships between features within the database.

The fundamental components of spatial data in a GIS are points, lines (arcs) and polygons. GIS analyses such as modelling the flow through connecting lines in a network, combining adjacent polygons that have similar characteristics and overlaying geographic features can only be performed when the topological relationships exist between spatial features.

You have already read about basic components of GIS in Unit 1 of MGY-001.

You have already learnt that the working GIS integrates five key components (refer to Fig. 1.8 of Unit 1 of MGY-001).

Let us now discuss the components of GIS one by one.

4.3.1 Computer Hardware Module

Hardware component of GIS includes all core and peripheral equipment such as computer and operating system to run a GIS. The system is used for data input, storage, management, analysis and display of geographic information (Fig. 4.1). Common choice for this system is personal computers which are mainly operating in the windows system. Just as any hardware component of a computer, GIS hardware also has central processing unit (CPU) used for data processing and analysis. CPU is like a heart of GIS hardware architecture, with control over input/output connectivity with data acquisition, storage and display systems. CPU is linked to a disk drive storage unit probably hard disc drive and provides space for storing data and programmes. The digital tape, cassettes, optical CD-ROMs, DVDs and other devices are commonly used as storage devices that can facilitate extra storage of data. In addition, monitor is used for display whereas GPS receivers and mobile devices for fieldwork. Devices like digitiser and scanner are used to convert non-digital data such as maps and documents into digital form, which later can be used in the computer programmes.

A *digitiser* is a flat board used for vectorisation of any map object. A *plotter* is used to present the result of the data processing in the form of hard copy.

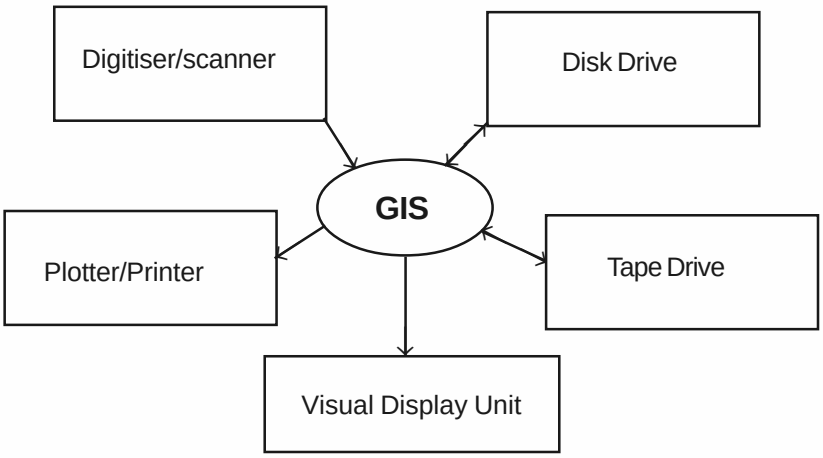

Fig. 4.1: Computer hardware components

Earlier, in order to carry out complex GIS operations, large mainframe computers were used, but today users have wider choices ranging from portable personal computers (PCs) to multi-user supercomputers. Presently, most GIS are implemented in a network platform with client/server interface. This model is based on the concept of distributing the work among different computer systems in a used network. In this type of closed system, server is used to store data and software, and client is the system user to access the server. In client/server environment, the application programmes can be executed either on the server or on the client computer. A server can provide access to many clients whereas client can access multiple servers at the same time.

4.3.2 Computer Software Module

GIS Software which includes programme is required to drive various functions of GIS. They are essential for entry, storage, processing, analysis, manipulation and display of data (both spatial and non-spatial). Like any other software, GIS software is user friendly and cost effective. The main user interfaces in GIS are menus, command lines, scripts and graphical icons. As GIS package has a myriad of functions inherent to them, extensions or add-ons will extend the capabilities of GIS functionalities.

A georelational data model is a geographic data model that represents geographic features as an inter-related set of attribute and spatial data.

Till 1990s the *georelational* data model with its *defacto* standard was implemented. However, the object-relational model replaced the georelational data model. In geographic data model, graphical data components of geospatial data and database management system (DBMS) of non-geospatial data were separately handled and connected by a proprietary interface. In an object-relational data model, both graphical and descriptive data are stored in a single database. The use of new technologies has enhanced the capabilities of GIS and made GIS a smart machine for geographical knowledge.

Initially, GIS software was developed as a turnkey system in which the end user was not allowed to do any modifications. As the technology progressed the priority was given to the total box approach by GIS software vendors. In this technological approach, the users were permitted to customise their application by using a scripting language to make add-on software extensions to meet their specific needs of data processing and analysis. But these approaches had proprietary limitations as the scripting language is a software product of a specific vendor.

GIS software development has taken new turn of moving away from proprietary development environment to open industry standards. Presently, it is possible to integrate GIS functions and application software modules built using programming languages. Examples of such programming languages are visual basic for application (VBA), visual C++ and dot net, etc.

Since 1990s open source GIS softwares (e.g., GRASS, ILWIS) with potentiality of working on all major platforms (Windows, Linux, etc.) which allows GIS user society with low cost and affordability with source code open making human readable. But these softwares have limitations and drawbacks which are required to be addressed for the benefit of users.

4.3.3 Data

Data is an important component of GIS. GIS data comprise various types of inputs. The data inputs are essential for GIS system to produce information. As you have already read in the previous units, large volume of high resolution data are widely available at affordable cost due to the recent developments in remote sensing and GPS technologies. This is also one of the reasons for the increased awareness of availability of data and tremendous development of GIS technology. In order to store and maintain large volumes of data the use of database management is required. The data input, transformation and output in GIS platform is illustrated in Fig. 4.2. Let us now discuss them one by one:

You have read about data and information in Unit 4 of MGY-001

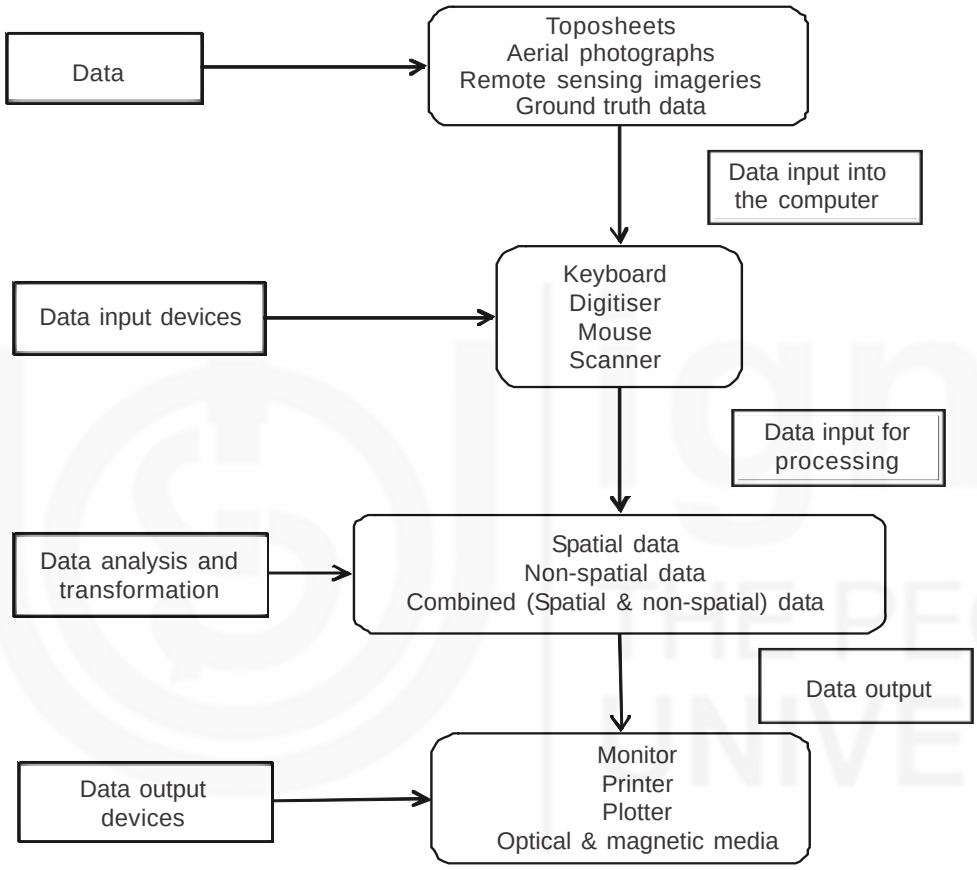

Fig. 4.2: Data input, transformation and output in GIS platform

- **Data Input:** It can be done with the use of many tools such as scanners, mouse, digitiser, word processors and spread sheets. Data input and its verification will be discussed in detail in Unit 7 of MGY-003.
- **Data Storage and Management:** Storage and management of geospatial data is programmed using GIS software. Location, linkages (topology) and attributes of geographic elements are structured and well organised in an attribute database environment.
- **Data Analysis and Transformation:** Data analysis is another important component of GIS applied to data in order to achieve answers to the questions asked to GIS. Basic requirement for data transformation in GIS is to remove errors in data sets and make them ready to match with other data sets.
- **Data Output:** The output and presentation of geographical data is characterised by different output devices. It may be presented as maps, tables and figures by various ways using computer monitors for display,

printers and plotters for hard copy display and magnetic and optical tapes for storage in digital formats.

4.3.4 People

The tremendous growth of GIS technology in the early 1990s has led to the increased attention on the user aspects of human factor in GIS development. Based on the information needs and the way they interact with the system, GIS users are classified as: viewers, general users and GIS specialists (Lo and Yeung, 2009) as shown in Fig. 4.3.

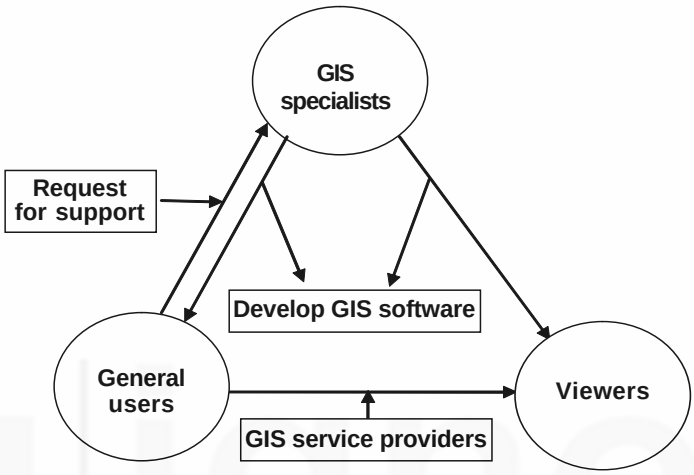

Fig. 4.3: People component of GIS

- **Viewers:** People who browse geographical database for their referential information are called *viewers*. Viewers are the users whose primary requirement is to easily access geographical information using the system. In general, they are not involved in the design and development of GIS. But they influence whether to accept or reject the technology because they are the larger class in people component of GIS.
- **General Users:** People who use GIS for general purpose such as for business, professional services and decision-making processes are called *general users*. The list of general users includes scientists, engineers, lawyers, entrepreneurs, administrators, planners, facility managers, politicians and many others. They use GIS for relatively simple spatial queries to very complicated tempo-spatial modelling depending on their requirements. They are active users and have direct influence on the successful use of GIS in an organisation.
- **GIS Specialists:** They are the people who plan and develop GIS software. This group includes GIS managers, database administrators, GIS application specialists, system analysts and programmers. They develop GIS software according to the needs of the above mentioned two groups of users (viewers and general users) and provide technical support to them. Unlike viewers they play a direct role in successful implementation of GIS technology in an organisation.

4.3.5 Methods

We will study the details of data/models in Units 5 and 6 of MGY-003.

In an organisation, GIS operates successfully according to a well designed implementation of the plans and rules. Basically, plans and rules include the models and operating practices which are unique to each organisation. In many organisations, GIS is not optimally used in spite of costly hardware and sophisticated software packages since the organisational aspects are not

properly looked into. The people working in an organisation are also important because they possess various skills to handle and work with geographic data and run GIS. Even they can be able to design, programme and maintain GIS. They also supply data, do suitable analysis and interpret them and make decision at strategic level as shown in Fig. 4.4.

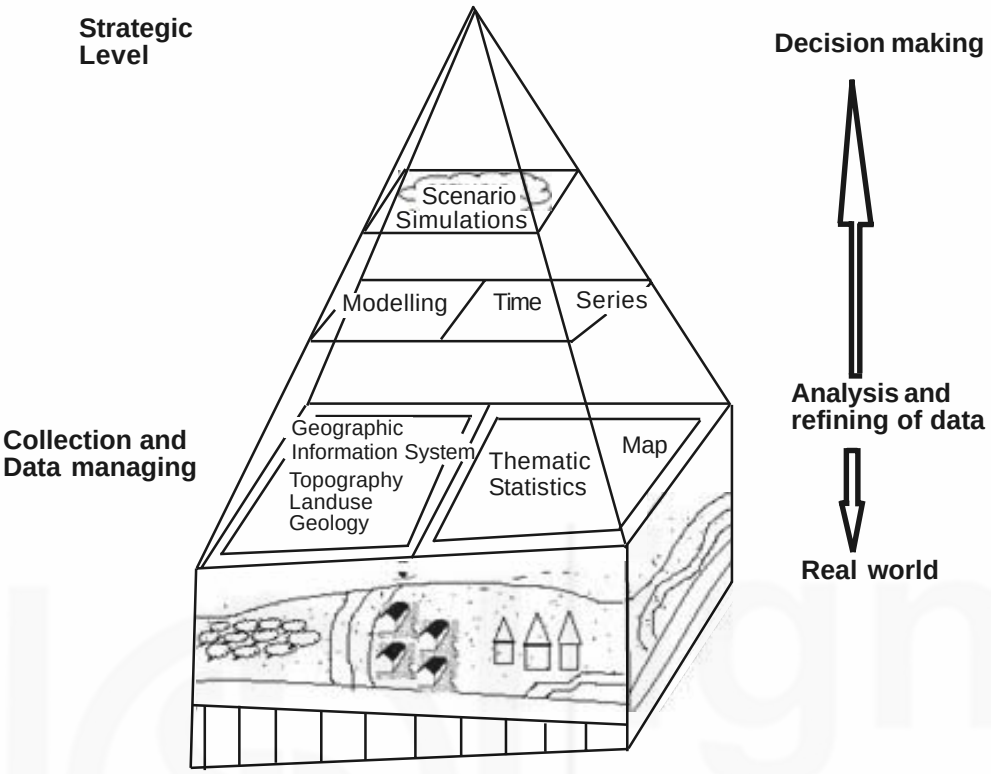

Fig. 4.4: A decision making pyramid

For many years, GIS has been considered to be too difficult, expensive, and proprietary. However, with the advent of graphical user interface (GUI), powerful and affordable hardware and software and public digital data has broadened the range of GIS applications and brought GIS to the mainstream use.

Check Your Progress I

Spend 5 mins

1) What is GIS?

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2) Differentiate between general user and GIS specialist in people component of GIS.

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4.4 HISTORICAL DEVELOPMENT

In the early 1960s, the Canadian Geographic Information Systems (CGIS) was conceptualised and became operational in 1971. It has been reclaimed to be the first ever GIS producer. It was developed to address the requirement of the Federal Government of Canada for land and resource management system. Geographical Information Retrieval and Analysis System (GIRAS) was developed by US Geological Survey in 1973 to analyse the land use and land cover data. There were similar developments in Europe. The best system was developed by the Swedish Land Data Bank (SLDB) in 1970s for automated land and property registration. Local Authority Management Information System (LAMIS) and Joint Information System (JIS) both were used by local government in Britain for land use control and monitoring.

During the late 1960s and 1970s, computer based processing of data was initiated simultaneously in universities of North America and Europe. Notable among them are Laboratory for Computer Graphics at Harvard University, Centre for Urban and Regional Analysis at University of Minnesota, USA, Experimental Cartographic Unit at Royal College of Art, London and Department of Geography, University of Edinburgh (Chrisman, 1988). Hence the 1960s and 1970s can be denoted as the formative years for GIS.

GIS development in the formative years was application driven to meet the needs of an individual organisation rather than spatial analysis. These were generally developed for government agencies and universities for specified research and data management objectives. The first vector-based GIS software was developed by Environmental Systems Research Institute (ESRI), California in 1982, to use georelational data model. In this model, a hybrid approach was followed for geographical data processing. As GIS became more pronounced in the application framework, GIS vendors such as ESRI, MapInfo, Strategic Mapping Inc., started partnering with main business software vendors like Microsoft, Oracle and others to bring GIS products to mainstream business.

Viewing of GIS data over the internet got standardised in the beginning of 21st century. The advent of internet made geospatial data and mapping applications available via World Wide Web (WWW). Recently, a growing number of free and open source GIS software packages such as GRASS (Geographic Resources Analysis Support System) run on a range of operating systems have mushroomed under the umbrella of Open Geospatial Consortium (OGC).

OGC is an international industry consortium with companies, government agencies and universities participating to develop publicly available open source GIS software. It also supports and formulates solutions that "geo-enable" the web, wireless and location-based services to make complex spatial information and services accessible for all kinds of purposes.

During the last decade there has been a tremendous development in the application of GIS technology in India. The Space Applications Centre (SAC) of Indian Space Research Organisation (ISRO) in collaboration with Scanpoint Geomatics, Ahmedabad, has developed the first Indian GIS software named as IGIS (Integrated GIS and Image Processing Software) in 2009. IGIS is indigenous software used for both image processing and GIS. It runs on UNIX and Windows platforms. Indian Institute of Technology (IIT), Mumbai, has developed GIS software which can be used for natural resource management by governmental, private and non-governmental organisations and other allied organisations. The low-cost software is made commercially available and it is marketed by Bhugol GIS Pvt. Ltd., under the society for Innovation and Entrepreneurship of IIT, Mumbai. There are many private organisations in India which have developed and are still developing the proprietary softwares used

for various applications. It may be mentioned that however, the use of GIS technology for resources survey and environmental assessment started at Space Applications Centre and other national agencies in early nineties.

The National Remote Sensing Centre (NRSC), Hyderabad, and Indian Institute of Remote Sensing (IIRS), Dehradun, have also contributed significantly in use of GIS. Both these agencies are playing a major role to disseminate GIS technology at national and international level through education and training programmes. The boom of GIS development escalated during the last decade and has encouraged the commercial organisations to develop GIS projects for wider applications like infrastructure development, natural resources management, facility management and business/market analysis.

4.5 GIS AS A SCIENCE AND TECHNOLOGY

Like all sciences, an essential requirement of geographic information science is a method for discovering new knowledge. This supports the transparency of assumptions and methods, and helps to know how previous knowledge was discovered in addition to the existing knowledge. As you know geography is concerned with the patterns and processes that describe the form and function of the surface of the Earth. By knowing geography and relationship of people to the location, we can make informed decisions about the way we live on our planet Earth. Now we have been doing this by using GIS where we are using it both as a science and technology. As a technology, GIS has been working in following two ways:

Science is concerned with the discovery and organisation of knowledge in which scientific knowledge comes through by employing scientific methods or experiments.

Technology is the application of science or knowledge in the design, production and utilisation of goods and services and in the organisation of human activities.

- involving the use of a particular class of software, associated hardware tools and digital geographic data in order to advance some specific purpose and
- it helps in technology making, involving the advancement of the tool's capability.

On the other hand GIS as science is concerning with the analysis of the fundamental issues raised by the use of GIS. Technically, GIS incorporates spatial data with attribute data (tabular data). This coupled data is used to map, analyse and assess real-world problems.

Geographic information science is problem solving science addressing various issues of human civilisation. One of the most important merits of GIS as a problem solving tool lies in its ability to combine the general with specific problems. The software of a GIS captures and implements general knowledge, while the database of a GIS represents specific information. GIS solves the ancient problem of combining general scientific knowledge with specific information and gives practical value to both. GIS is also a powerful user support tool that allows not only managing attribute data but also to collect, process, integrate, manage and analyse spatial data. It possesses functionalities which are similar to other types of information systems, and it also possesses functionalities which are unique in nature. This uniqueness differentiates it with other information systems. It has a framework of four core functionalities such as spatial imaging, database management, decision modelling and design and planning.

- **Spatial Imaging:** It is the functionality of GIS to represent data and information in a definite coordinate system (e.g., a map).

- **Database Management:** It refers to GIS capability to collect, store, analyse and provide access to data.
- **Decision Modelling:** It is a GIS capability function with analytical and decision-making tool functionalities.
- **Design and Planning:** It is a function in which GIS tools are used for creation, design and planning.

There are several other GIS applications which can be used by applying the core GIS functionalities. Some of these include surveying, automated mapping, facilities management, market analysis, logistics, transportation, strategic decision-making, engineering and design and planning.

Spend 5 mins

Check Your Progress II

1) What is OGC?

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2) List the core functionalities of GIS.

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4.6 ORGANISATIONAL ASPECTS OF GIS

GIS exists in a well organised framework in an institutional context. It requires good organisational support in terms of hardware, software, availability of data and infrastructure for effective implementation of GIS activities. Trained manpower and set of protocols guiding them are the prerequisites to implement GIS in an organisation. A good institutional framework determines the quality of spatial data to be used. It also ensures application and implementation of analysed data using GIS in an organisation. Like any other technology, GIS has this common character and shares a common characteristic of many powerful technologies. For providing potential benefits, GIS requires proper institutional resources in order to not to have wastage of resources.

GIS acts as decision supporting tool where data is input, stored and analysed for making specific decisions. It passes through several interactions and assessment steps before a final decision is reached. The methods of operation and integration of GIS in an organisational structure have to be recognised in the decision making process of an organisation.

GIS is used for analysis of spatial data and results in measuring distances and areas, identifying the vicinity and overlay, and combination of different information. Because of these spatial analytical techniques, GIS has its specific significance than the other software technologies.

The organisational issues to be considered in implementing GIS are as follows (www.cfr.msstate.edu):

i) Create Awareness

People of the organisation should be made aware of the geographical data along with its application and also uniqueness of GIS from other technologies. Basic information of GIS technology is to make available to the people in improving operations and decision-making skills for the betterment of the organisation. Before fulfilling the needs of applying GIS technologies, somebody in the organisation must know the basic concepts and importance of GIS technologies in order to create awareness and initiate the management to implement GIS in the organisation.

ii) Need Analysis Survey

Before any new proposal is taken up by any organisation, a need analysis survey is to be carried out. It starts with a set of concepts that are refined or built in order to justify the proposal. The people who are interested in implementation of GIS in a system must be educated about the important aspects of GIS. For implementing GIS, the proponents of the system must provide enough background information on system performance and stimulate additional inputs to justify implementation. To benefit the organisation and clients, one should demonstrate the efficiencies in use of GIS over present day spatial data analysis. Finally, the need assessment brings life to GIS in an organisation by justifying the system in terms of data, processes and products.

iii) Define System Requirements

The next process after need assessment is to provide a definite system requirement/design which is useful and applicable to the organisation. The period of installation and the start-up of the system should be short in order to minimise the monetary losses to the organisation.

There are two issues to be concentrated on the design specifications of GIS system. These issues are interrelated and cannot be addressed entirely in an independent way. The issues are:

a) ***Technical Issues***

These issues relate to the data base design and hardware/software specifications that are used to develop and manage database. First thing to be considered in developing the database is to select basic type of data (attribute and graphic) to be stored. Then select the data structures for each type to be interrelated and efficiently manipulated and analysed. Based on these parameters, select the software to be implemented and then worry about the hardware. Existing databases of the organisation should be considered in database design and for specification of the software.

After database design and software specifications, hardware specifications are to be considered in the technical environment phase. The hardware specification includes computing environment, networking, etc.

b) ***Institutional Issues***

The toughest things for the management to agree are the changes in personal assignment of the employees. In addition to these, new employees have to be recruited and training has to be imparted as per the requirement.

Onetime installation of system and maintenance of the database in an organisational environment is very much essential in order to be considered by the management for long term support in personnel and organisational perspectives. Further, to have a better institutional support, it is to be made clear that GIS is a resource and when implemented, it will benefit all sections of the organisation.

An organisation should specify people requirement for data entry, programming, system maintenance and for general uses in GIS environment and there should be no negligence in recruiting manpower. GIS personnel department must ensure to relate one department to the other and the needs of the organisation to enhance the capability of applying GIS for organisational benefits. Once all the components of the system including the technical specifications for establishing GIS are accepted, the organisation can solicit proposals for buying GIS software.

iv) Implementation Phase

The debugging of operational system is an important preliminary task before the implementation phase of GIS. During this phase, adjustments are to be made to design and test in a pilot mode before larger GIS software installations are made. Once the pilot mode is successfully implemented, the organisation can go for full installation of GIS software. Appropriate training in GIS is a prerequisite for the employees if the organisation expects immediate results from application of GIS.

The steps to be followed in implementation of GIS considering the technology acceptance throughout the process are:

a) pilot phase of the project

b) design adjustment phase, and

c) full implementation phase.

During full implementation phase important aspects to be considered are stated below:

- management should take responsibilities and security of the system installations
- training should be imparted to the employees before completion of design adjustment
- tools should be developed to the users during application development, and
- throughout the implementation process, one should be aware of quality control.

v) Education, Management and Maintenance

Actual process and planning for education, management and maintenance starts from need assessment and requirement phases of GIS in an organisation.

- **Education:** For new users and system administrators the formal practical and on-the-job training should be specified according to the requirements. Almost all the software/hardware vendors provide training at their facility centers or sometimes on-site. For the people who can devote time can learn from the self-taught modules.

- **Management:** GIS management should be consistent in operations in order to avoid minimum conflicts with users. It should be transparent to the users in sharing data updates, accessibility, etc.
- **Maintenance:** Maintenance is an important task and should be planned to coincide with off hours. The maintenance operations include back up of databases, maintenance and repairs of peripherals and upgradation of software/hardware. The process should be regularly scheduled to avoid system problems and to maintain uninterrupted work plan.

vi) Organisational Considerations

For successful implementation of GIS in an organisation, one should work hard and present justifiable evidence that GIS technology can be cost effective, economically viable and easily incorporated into the operation. To avoid failures and to successfully implement GIS, organisations should plan to address:

a) system acquiring costs

b) data requirements and cost of acquiring it

c) database design and development

d) installation and implementation system costs and

e) life cycle and operational costs of implementation of GIS.

4.7 ACTIVITY

You have learnt about the concept of GIS and its components. Now you visualise the changes which GIS can bring in your oganisation.

4.8 SUMMARY

In the present unit, you have read about the definition, components and elements of GIS. Let us summarise what you have learnt in this unit.

- GIS is a system of hardware and software where both spatial and non-spatial data can be brought together and integrated for mapping and analysis.
- The focus of GIS has changed from earlier system centric approach to service oriented approach.
- GIS as a science and technology addresses various issues of human civilisation giving practical value to both scientific knowledge and specific information.
- For effective implementation of GIS activities, a well organised framework of institutional support is required.

4.9 UNIT END QUESTIONS

Spend 30 mins

1) Explain the key components of GIS.
2) Write in detail the historical development of GIS.
3) GIS as a science and technology. Justify.
4) What are the organisational aspects of GIS?

4.10 REFERENCES

- Burrough, P. A. and McDonnel, R. A., (1998), *Principles of Geographical Information Systems*, Oxford University Press, Oxford.
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- Chrisman, N., (1988), The risks of software innovation: a case study of the Harvard lab, *The American Cartographer* Vol 15, pp. 291-300.
- Lo, C. P. and Yeung, A. K. W., (2009), *Concepts and Techniques of Geographic Information Systems*, PHI Learning Private Ltd. New Delhi
- http://www.cfr.msstate.edu/students/forestrypages/fd/fo4313/topic20.pdf (retrieved on 10 March, 2012).

4.11 FURTHER/SUGGESTED READING

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- Burrough, P. A. and McDonnell, R. A., (1998), *Principles of Geographical Information Systems*, Oxford University Press, Oxford.

4.12 ANSWERS

Check Your Progress I

1) GIS is a user support tool not only to manage attribute data but also for collecting, storing, retrieving, transforming and displaying spatial data.

2) General users are those people who use GIS for general purpose such as business, professional services and for decision making. People who plan and develop GIS software for viewers and general users and also provide technical support to them are called GIS specialists.

Check Your Progress II

1) OGC is the consortium of companies, government agencies and educational institutions to develop open source software. It also helps to make complex spatial information and services accessible for all purposes.

2) The four core functionalities in GIS are: a) spatial imaging, b) database management, c) decision modelling and d) design and planning function.

Unit End Questions

1) Refer section 4.3

2) Refer section 4.4

3) Refer section 4.5

4) Refer section 4.6