Fundamental Concept of Geographical Information System

(Unit:1)

Semester: II

Paper Code: GIS 07

Name of Paper: Geographic Information System

PG Diploma in RS & GIS

Dr. SHYAMA PRASAD MUKHERJEE UNIVERSITY, RANCHI

1.1 Definition of GIS:

Geographic Information System (GIS) is defined as an information system that is used to input, store, retrieve, manipulate, analyse 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.

The key components of GIS are a computer system, geospatial data and users, as shown in Figure 1.1.

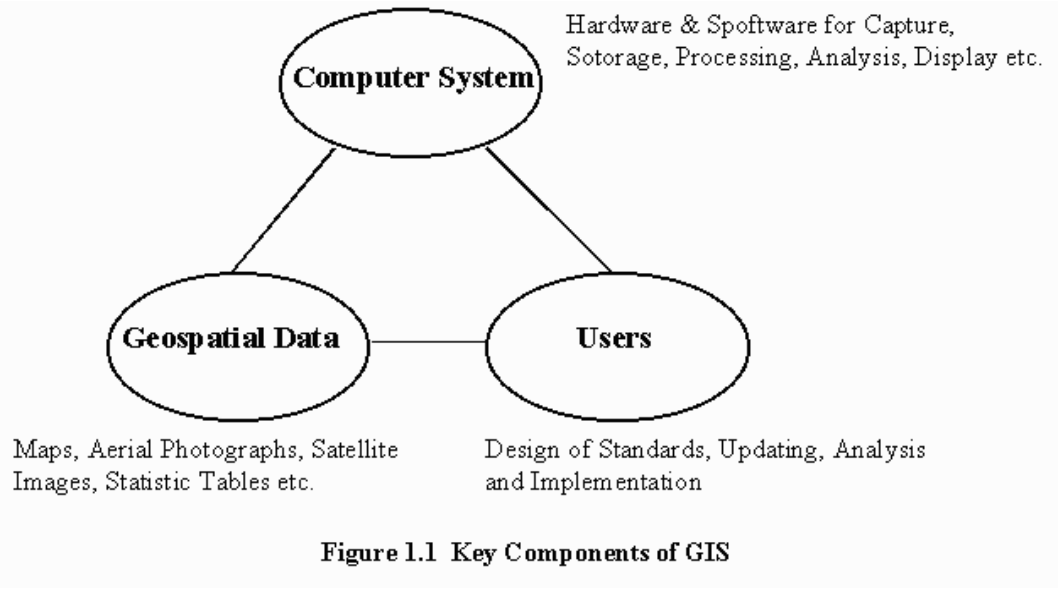

Figure 1.1 Key Components of GIS

A computer system for GIS consists of hardware, software and procedures designed to support the data capture, processing, analysis, modeling and display of geospatial data.

The sources of geospatial data are digitized maps, aerial photographs, satellite images, statistical tables and other related documents.

Geospatial data are classified into graphic data (or called geometric data) and attributes (or called thematic data) as shown in Figure 1.2. Graphic data has three elements; point (or called node), line (or called arc) and area (or called polygon) in either vector or raster form which represent a geometry of topology, size, shape, position and orientation.

The roles of the user are to select pertinent information, to set necessary standards, to design cost-efficient updating schemes, to analyze GIS outputs for relevant purpose and plan the implementation.

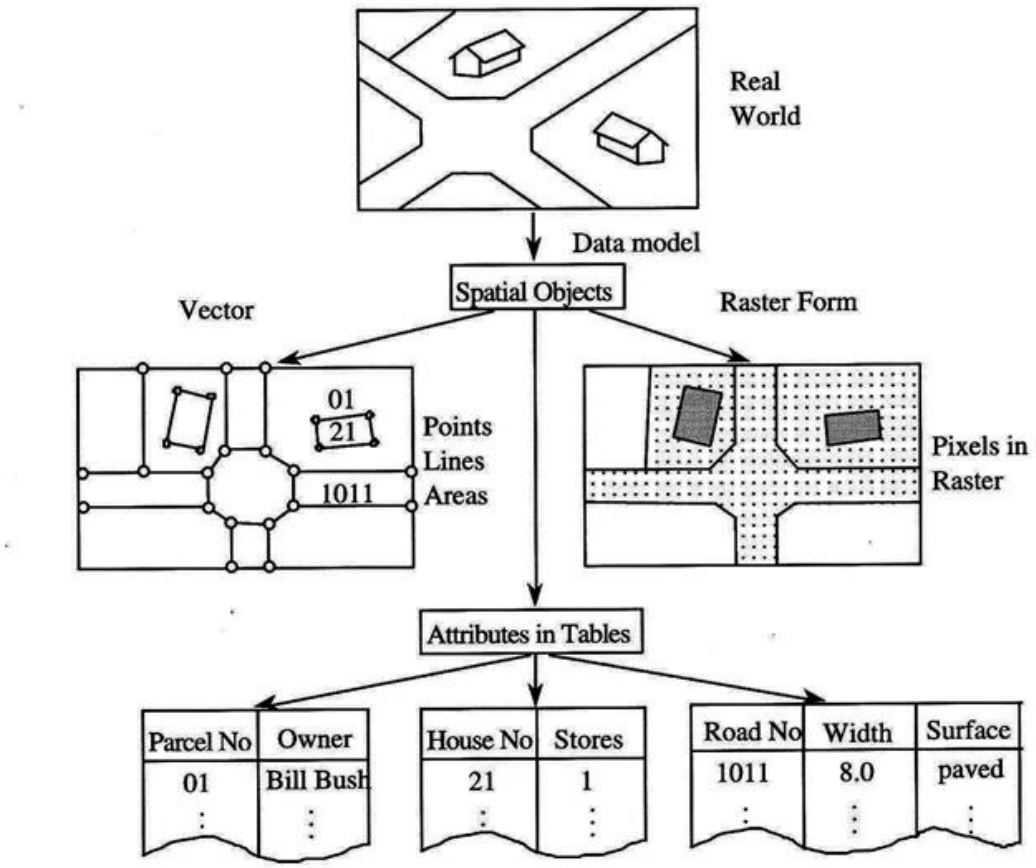

Figure 1.2 Concept of Geospatial data

1.2 Why is a GIS needed?

These are the following reasons why a GIS is needed.

- geospatial data are poorly maintained
- maps and statistics are out of date
- data and information are inaccurate
- there is no data retrieval service
- there is no data sharing

Once a GIS is implemented, the following benefits are expected.

- geospatial data are better maintained in a standard format
- revision and updating are easier
- geospatial data and information are easier to search, analyze and represent
- more value added product
- geospatial data can be shared and exchanged freely
- productivity of the staff is improved and more efficient
- time and money are saved
- better decisions can be made

Table 1.1 shows the advantages of GIS and the disadvantages of conventional manual works without GIS.

Table 1.1 GIS Versus Manual Works

Maps	GIS	Manual Works
Storage	Standardized and Integrated	Different Scales on different Standards
Retrieval	Digital Data Base	Paper Maps, Census, Tables
Updating	Search by Computer	Manual Check
Overlay	Systematically Done	Expensiv eand Time Consuming
Spatial Analysis	Very Fast	Time & Energy Consuming
Display	Easy	Complicated
	Cheap and Fast	Expensive

Figure 1.3 shows a comparison between geospatial information management with and without GIS.

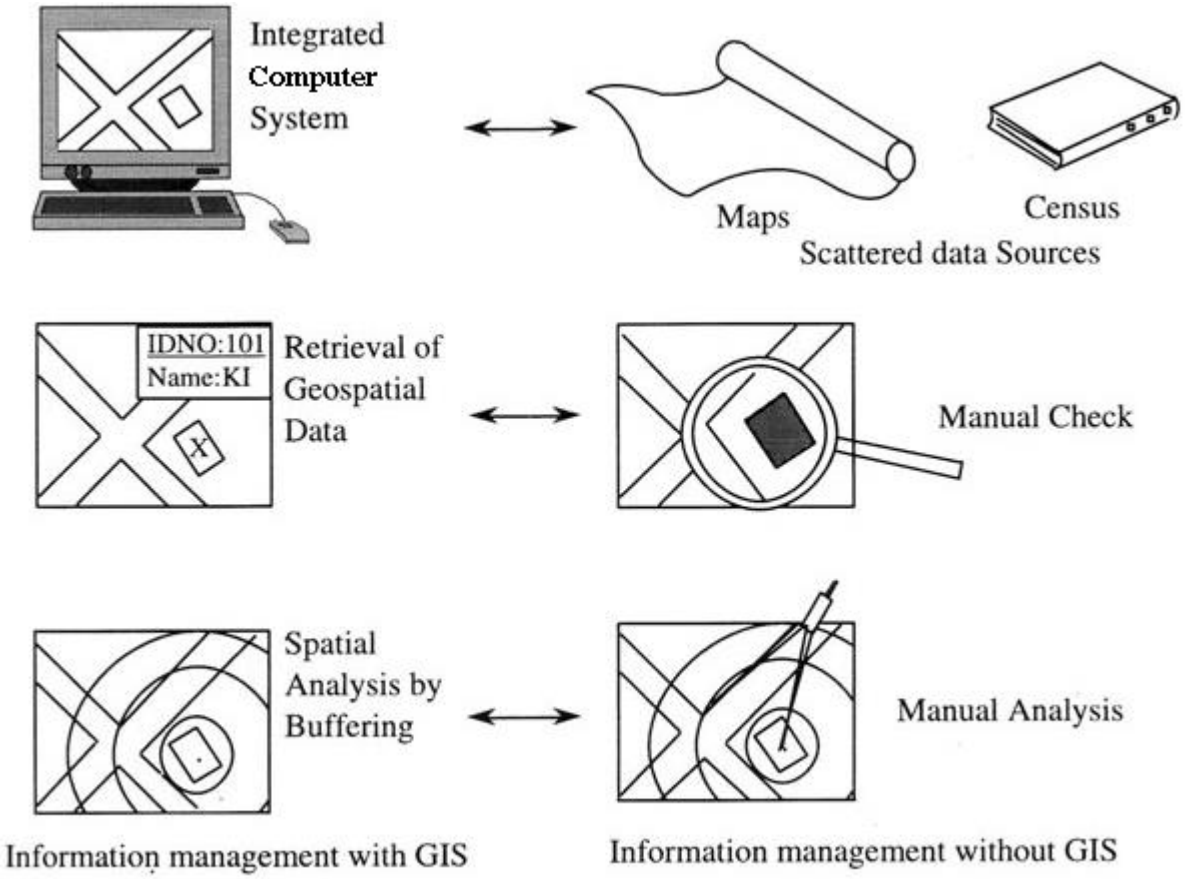

Figure 1.3 Comparision of Geospatial Information Management

1.3 Required Functions for GIS

The questions that a GIS is required to answer are mainly as follows :

- What is at.....? (Locational question ; what exists at a particular location)
- Where is it.....? (Conditional question ; which locations satisfy certain conditions)
- How has it changed.....? (Trendy question ; identifies geographic occurrence or trends that have changed or in the process of changing)
- Which data are related .....? (Relational question : analyses the spatial relationship between objects of geographic features)
- What if.....? (Model based question ; computers and displays an optimum path, a suitable land, risky area against disasters etc. based on model)

Figure 1.4 shows examples of questions to be answered by GIS.

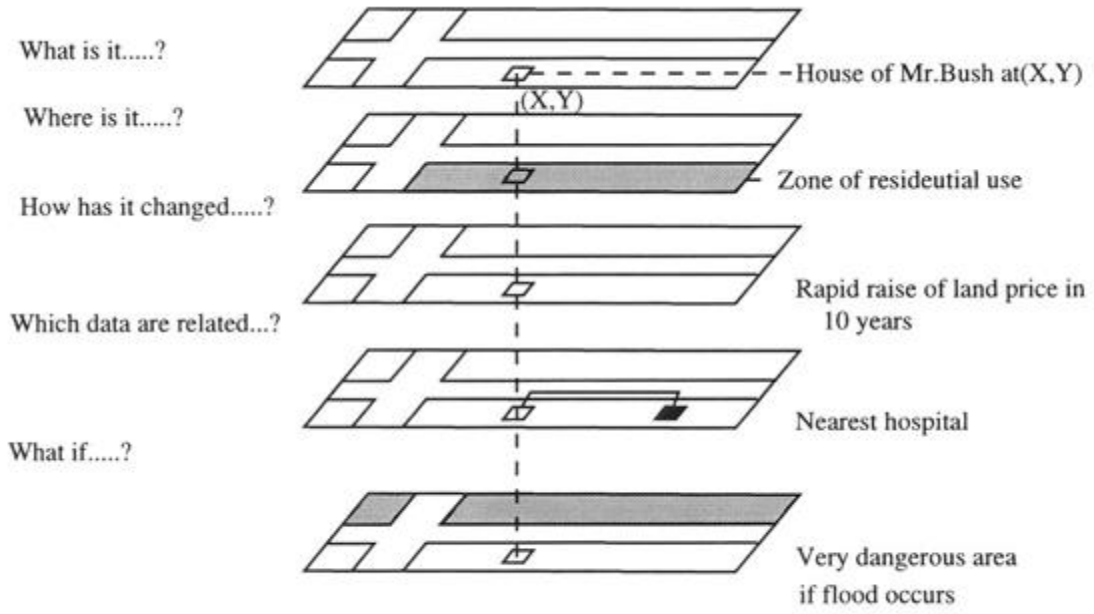

Figure 1.4 Required Functions of GIS

In order to meet the above requirements, the following functions are necessary for GIS (see Table 1.2)

- data acquisition and pre-processing
- data based management and retrieval
- spatial measurement and analysis
- graphic output and visualization

Table 1.2 Basic Functions of GIS

Functions	Sub-functions
Data Aquisition and preprocessing	Digitizing Editing Topology Building Projection Transformation Format Conversion Attribute Assignment etc.
Database Management and Retrieval	Data Archival Hierachical Modeling Network Modeling Relational Modeling Atrribute Querry Object-oriented Database etc.
Spatial Measurement and Analysis	Measurement Operations Buffering Overlay Operations Connectivity Operations etc.
Graphic Output and Visualization	Scale Transformation Generalization Topographic Map Statistical Map 3D Birdís Eye View etc.

1.4 Computer System for GIS

A Computer system is mainly composed of hardware and software.

a. Hardware system

A hardware system is supported by several hardware components.

Central processing unit (CPU)

CPU executes the programs and controls the operation of all components. Usually a personal computer (PC) or a work station is selected for the required CPU or as a server computer.

Memory

Main memory :essential for the operation of the computer because all data and program must be in main memory for fastest access. More than 64 M bytes are at least necessary for PC based GIS.

Auxiliary memory : is used for large permanent or semi-permanent files with slower access. Hard disks, floppy disks, magnetic tapes, or optical compact disks (CD-ROM) are used. At least more than 1 G bytes is required for hard disk in GIS.

Peripherals

Input devices : key board, mouse, digitizers, image scanners, digital cameras, digital photogrammetric workstations etc.

Output devices : colour displays, printers, colour plotters, film recorders etc. Figure 1.5 shows an examples of components of a GIS hardware system.

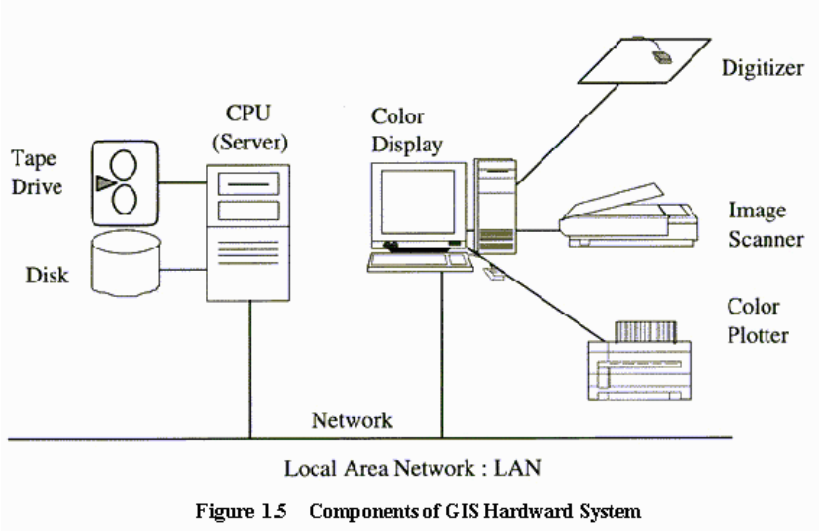

Figure 1.5 Components of GIS Hardward System

b. Software System

A software system is composed of programs including operating system, compilers and application programs.

Operating System (OS) : controls the operation of the programs as well as all input and output.

For Pcs : MS-DOS (IBM PCs) and WINDOWS is the dominant OS.

For Workstations : UNIX and VMS are the dominant OSs.

Compilers : convert a program written in a computer language to machine code so that CPU can execute binary operation. Commonly used languages include C, Pascal and FORTRAN and BASIC etc.

Application Programs : Many vendors are providing GIS software systems as listed in Table 1.3

Table 1.3 Several Vendors of GIS Software

GIS Software	Vendor	CPU		Data Model		Applications		
		PC	WS	Vector	Raster	Analysis	DTM	Network
	ESRI	○	○	○	○	○	○	○
ARC/INFO	Intergraph		○	○	○	○	○	○
MGE	Generation 5	○	○	○		○	○	○
Geo/SQL	Technology	○						
	IBM	○	○	○	○	○		○
GFIS	Clark Univ.	○			○	○		
IDRISI*	GRASS	○	○		○	○		
GRASS*	Information Center							

Remarks : * public domain software

1.5 GIS as Multidisciplinary Science

GIS in an integrated multidisciplinary science consisting of the following traditional disciplines.

Geography	Statistics
Cartography	Operations Research
Remote Sensing	Computer Science
Photogrammetry	Mathematics
Surveying	Civil Engineering
Geodesy	Urban Planning etc.

Table 1.4 **summarizes how the above disciplines make up GIS with respect to the functions. GIS has many alternative names used over the years with respect to the range of applications and emphasis as listed below.**

- Land Information System (LIS)
- AM/FM-Automated Mapping and Facilities Management
- Environmental Information System (EIS)
- Resources Information System
- Planning Information System
- Spatial Data Handling System

GIS is now becoming an indepedent discipline in the name of "Geomatic", "Geoinformatics"; or "Geospatial Information Science" that is used in many departments of government and university.

Table 1.4 Relations of Traditional Disciplines with GIS

Discipline	Functions of GIS								
	Data Acquisition	Mapping	Pre-processing	Data Structure	Data Base	Spatial Analysis	Modeling	Display	Application
Geography		○				○			○
Cartography	○	○						○	○
Remote Sensing	○	○						○	○
Photogrammetry	○	○						○	○
Surveying	○	○							
Geodesy		○							
Statistics			○		○	○			
Operations Research						○	○		
Computer Science			○	○	○	○	○	○	
Mathematics				○		○	○		
Civil Engineering						○	○		
Urban Planning						○	○		○

1.6 Area of GIS Applications

Major areas of GIS application can be grouped into five categories as follows.

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.

Table 1.5 summarizes the major areas of GIS applications

Table 1.5 Major Areas of GIS Applications

Area	GIS Applications
Facilities Management	locating underground pipes & cables planning facility maintenance telecommunication network services energy use tracking & planning
Environment and Natural Resources Management	suitable study for agricultual cropping management of forests, agricultual lands, water resources, wetlands etc. environmental impact analysis disaster management and mitigation waste facility site location
Street Network	car navigation (routing & scheduling) locating houses and streets site selection ambulance services transportation planning
Planning and Engineering	urban planning regional planning route location of highways development of public facilities
Land Information System	cadastre administration taxation zoning of land use land acquisition

1.7 GIS as an Information Infrastructure

Information has become a key issue in the age of computer, space technology and multimedia, because the information infrastructure contributes to the quality of life as in the following's infrastructure.

Social infrastructure...better society
Environmental infrastructure....better management
Urban infrastructure.....better life
Economic infrastructure.....better business
Educational infrastructure.....better knowledge

Figure1.6 shows major components of GIS information infrastructure. In order to achieve the GIS information infrastructure, the following issues should be solved and promoted (see Figure 1.7).

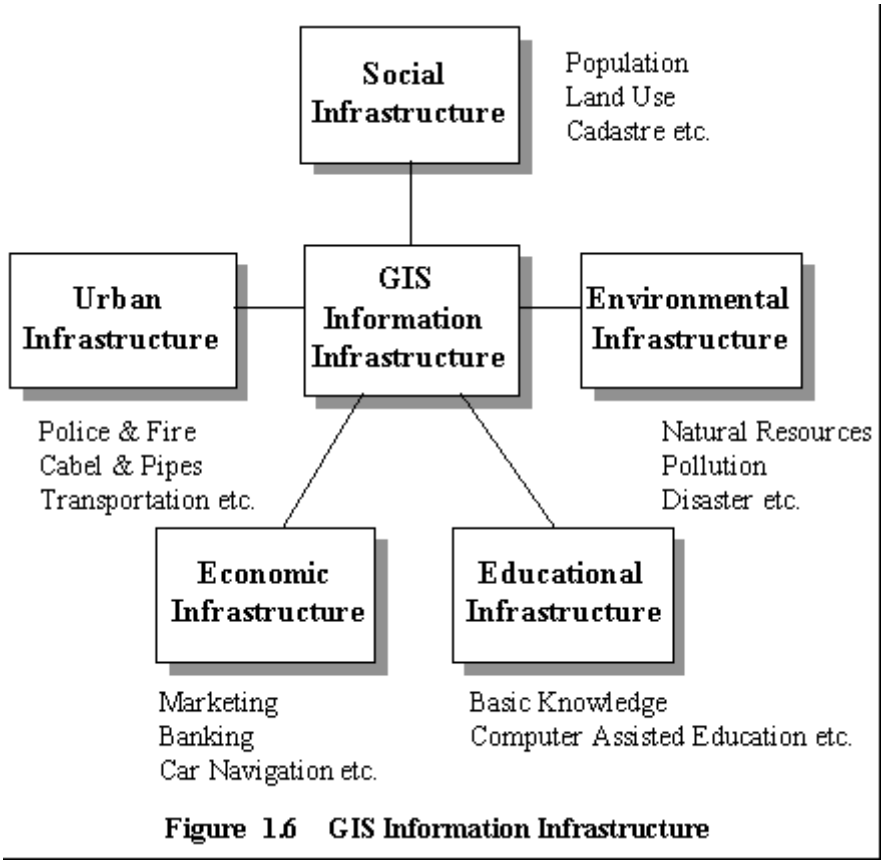

Figure 1.6 GIS Information Infrastructure

Open data policy

GIS data and information should be accessible by any user, freely or at inexpensive costs and without restriction.

Standardization

Standards for data format and structure should be developed to enable transfer and exchange of geospatial data.

Data/Information sharing

In order to save cost and time for digitization, data sharing should be promoted. In order to foster operational use of geospatial data, information and experience should be shared among users.

Networking

Distributed computer systems as well as databases should be linked to each other to a network for better access as well as better service.

Multi-disciplinary approach

Because GIS is a multi-disciplinary science, scientists, engineers, technicians and administrators of different fields of study should cooperate with each other to achieve the common goals.

Interoperable procedures

GIS should be interwoven with other procedure's such as CAD, computer graphics, image processing, DEM etc.

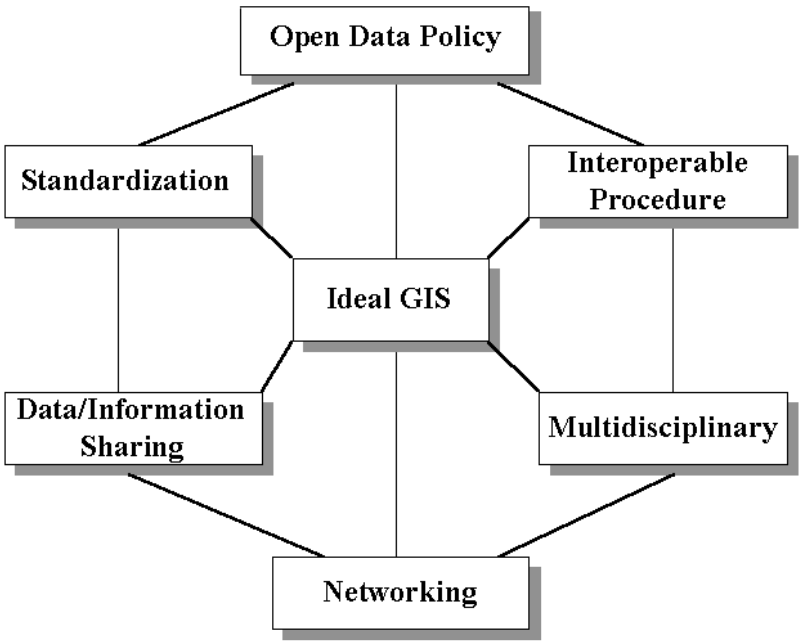

Figure 1.7 Ideal GIS

1.8 GIS for Decision Support

GIS can be a very important tool in decision making for sustainable development, because GIS can provide decision makers with useful information by means of analysis and assessment of spatial database as shown in Figure 1.8.

Decision making including policy making, planning and management can be interactively implemented taking into consideration human driving forces through public consensus. Driving forces include population growth, health and wealth, technology, politics, economics etc. by which human society will set up targets and goals on how to improve the quality of life.

Thus human driving forces, the key elements of human dimensions, will give impacts on the environment such as development of natural resources, urbanization, industrializations, construction, energy consumption etc. These human impacts will accordingly induce environmental changes such as land use change, change of life style, land degradation, pollution, climate change etc. Such environmental change should be timely monitored to increase public awareness. Remote sensing can be very useful for better understanding of relationship between human impacts and the environmental change as well as for building databases.

Physical dimensions monitored by remote sensing can be fed back to human dimensions through analysis and assessment by GIS in order to support better decision. In this sense, remote sensing should be integrated with GIS.

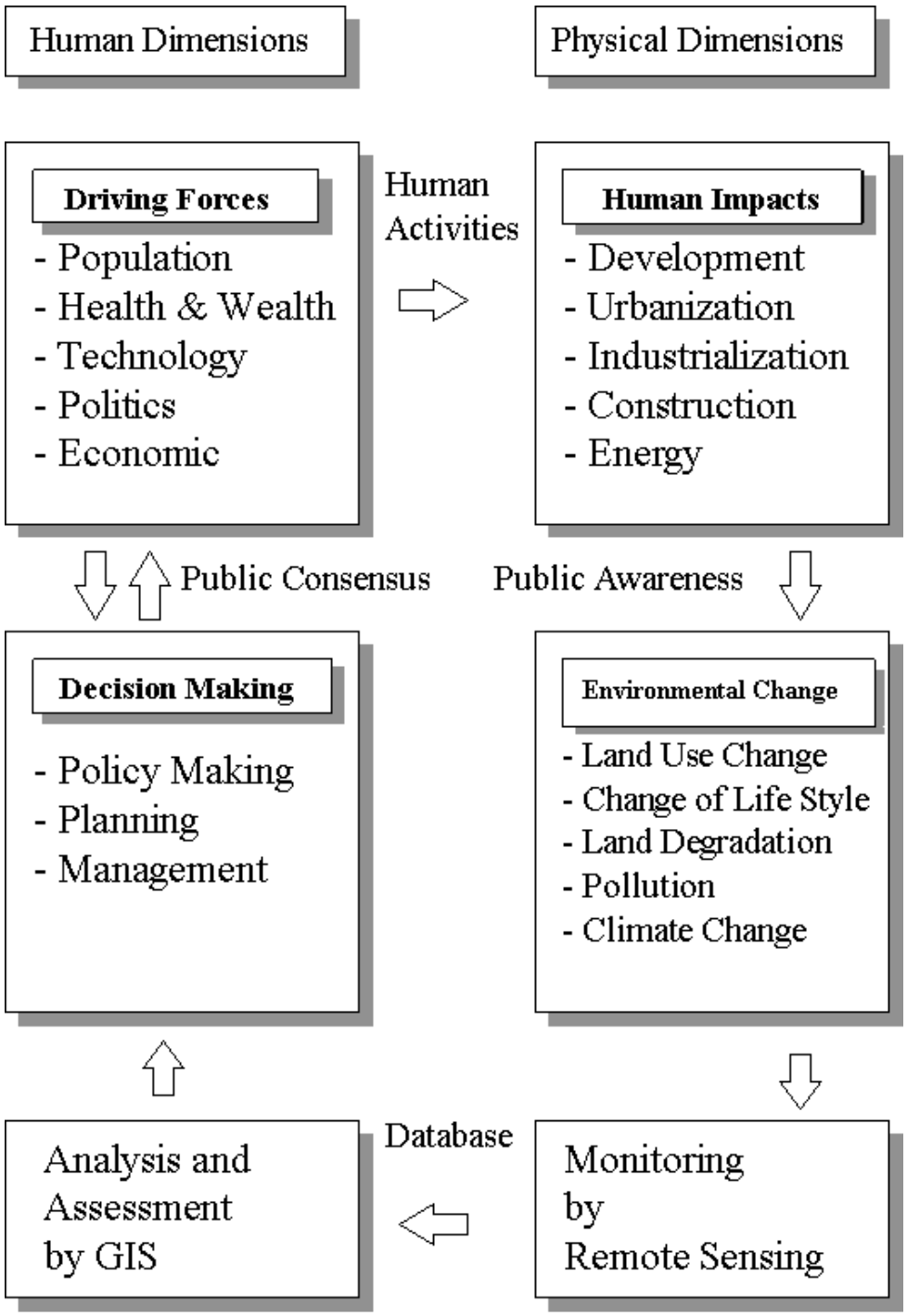

Figure 1.8 GIS for Decision Suport

References

1. NCGIA (National Center for Geographic Information and Analysis),
   University of California, Santa Barbara
   Core Curriculum; "Introduction to GIS" "Technical Issues in GIS", 1990
2. Konecny, Gottfried
   Basic Considerations for the Implementation of Spatially Based Information Systems,
   Proceeding of Third International Colloquium of LIESMARS, WTUSM, Wuhan,
   1994
3. Korte, George B.
   The GIS Book, Third Edition
   Onward Press, 1993
4. Japan Association of Remote Sensing
   Remote Sensing Note, Edited by Shunji Murai
   Japan Association of Surveyors, 1993
5. Meijerink, Allard M.J. et al
   Introduction to the Use of Geographic Information Systems for Practical Hydrology,
   International Institute for Aerospace Survey and Earth Sciences (ITC), ITC
   Publication Number 23, Enschede, 1994
6. SIAGE-ALITEC
   Geocube, SIAGE, France, 1994
7. Bertin, Jacques
   Semiologie Graphique
   Mouton, 1967
8. Imhof, Eduard
   Kartographische Gelaende-Darstellung
   Walter de Gruyter & Co., 1965
9. Harvard University
   Mapping Software and Cartographic Data Bases, 1979
10. Murai, Shunji
    How to see, take and produce stereoscopic photographs (Japanese version)
    Gihodo Publishing Co., Ltd, 1988