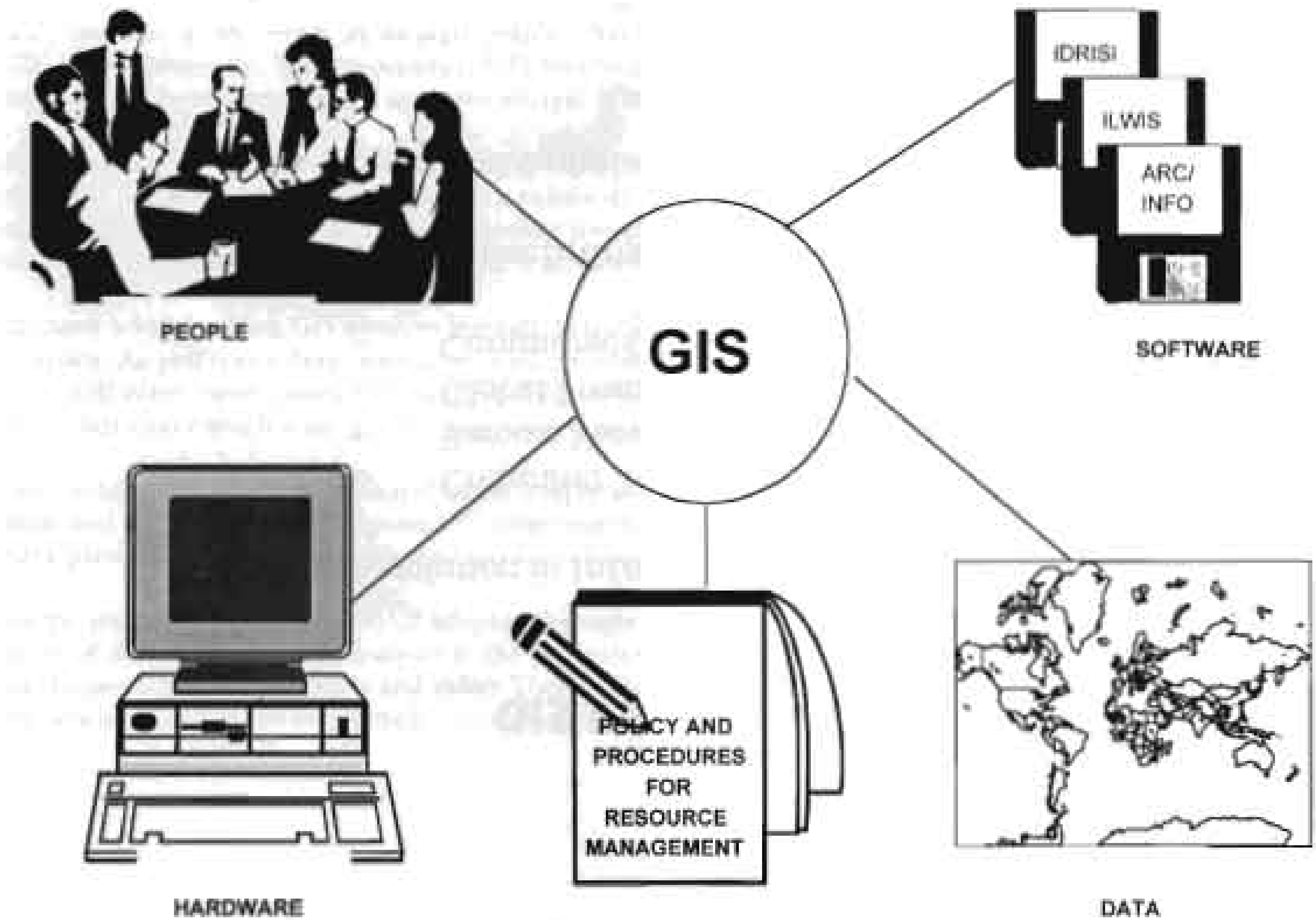
Chapter 2

Overview of GIS

Geographic Information Systems



GIS Evolution

- revolution in **information technology**
  - Computer Technology
  - Remote Sensing
  - Global Positioning System (GPS)
  - Communication Technology
- rapidly **declining cost** of computer hardware
- enhanced **functionality** of software

The Philosophy of GIS

GIS has had an enormous impact on virtually every field that manages and analyses spatially distributed data. For those who are unfamiliar with the technology, it is easy to see it as a magic box. The speed, consistency, and precision with which it operates is truly impressive. Moreover, its strongly graphic character is hard to resist. However, the experienced analyst see the philosophy of GIS quite differently. With experience, GIS becomes simply an extension of one's own analytical thinking. The system has no inherent answers, these depend upon the analyst. It is a tool, just like statistics is a tool. It is a tool for thought.

Investing in GIS requires more than an investment in hardware and software. Indeed, in many instances this is the least of concerns. Most would also recognise that a substantial investment needs to be made in the development of the database. However, one of the least recognised and most important investments is in the analysts who will use the system. The system and the analyst cannot be separated – to put it simply, one is an extension of the other.

In many ways, learning GIS involves learning to think – learning to think about patterns, about space, and about processes that act in space. As you learn about specific procedures, they will often be encountered in the context of specific examples. In addition, they will often have names that suggest their typical application. But resist the temptation to categorise these routines. Most procedures have much more general applications and can be used in many novel and innovative ways (Idrisi Student Manual).

The proliferation of GIS is explained by its unique ability to assimilate data from widely divergent sources, to analyse trends over time, and to spatially evaluate potential environmental impacts caused by development. Such advances in information technology have provided governments with the means to address the requirements of spatial data management in developing countries.

As the technology becomes widely adopted throughout the world, there are signs that its functions are gradually changing from those of data collection and analysis to the promotion of visualisation, incorporating a variety of existing data sources and new techniques such as multimedia and video. These techniques will ensure that the data, and in particular geo-reference information, become more accessible to non-technical audiences.

Why GIS?

- 70% of the information includes some geographical facts in the decision-making process
- Ability to assimilate divergent sources of data both spatial and non-spatial (attribute data)
- Visualisation impact
- Sharing of information
- Analytical capability in a spatial context

Why GIS ?

Many professionals, such as foresters, urban planners, and geologists, have recognised the importance of spatial dimensions in organising and analysing information. Whether a discipline is concerned with the very practical aspects of business, or whether a discipline is concerned with purely academic research, geographic information systems can introduce a perspective which can provide valuable insights.

GIS are a means to an end, not an end in themselves. The value of GIS lies not just in the immediate efficiency with which the technology is implemented. Rather, it lies in how the technology helps us to think differently about the way we organise, understand, and use spatial information. New appreciation of the importance of spatial location or geography in real world analysis has emerged from the application of GIS technology. Predictions suggest that billions of dollars will be spent on GIS technology and its applications. The basic factors affecting the diffusion of GIS are due to reasons described below.

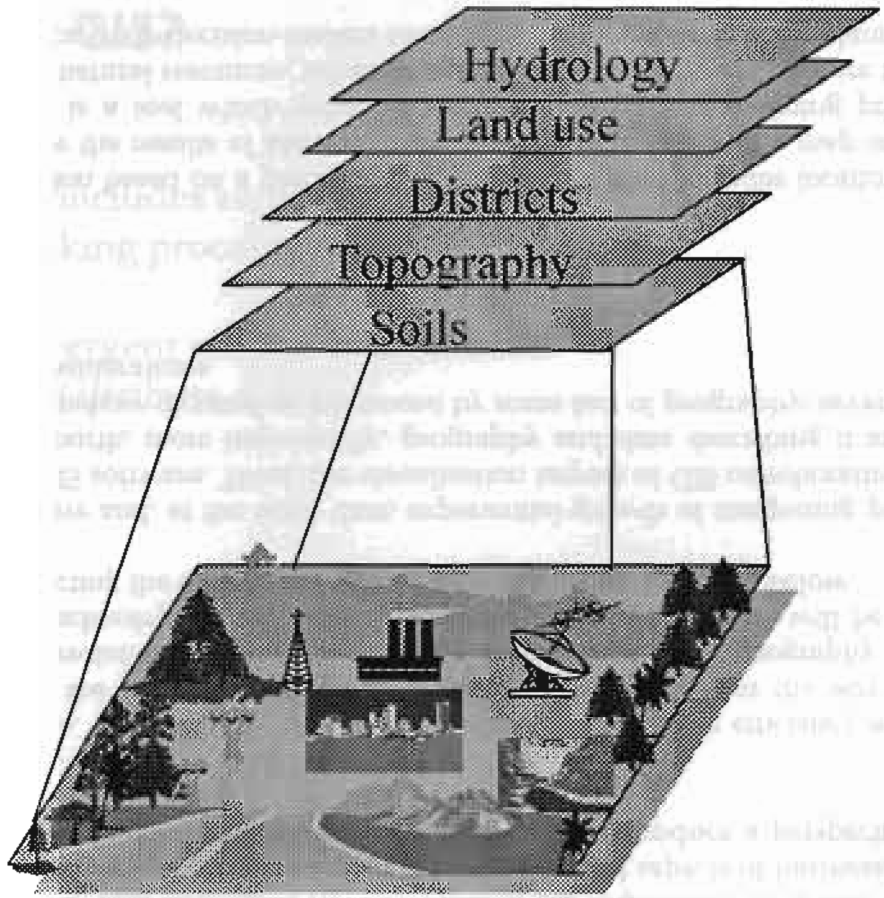
First, the rapidly declining cost of computer hardware and, at the same time, exponential growth of computing power. Second, user-friendly software and increasing functions of GIS software. Third, the visualisation impact of GIS corroborating the Chinese proverb "a picture is worth a thousand words." Fourth, more importantly, geography and data describing it are part of our everyday lives; almost every decision we make is somehow dictated or influenced by some fact of geography; seventy per cent of the decisions, we make are based on geographical considerations.

Thinking Spatially

Thinking spatially is a method of assessing a situation based on a perception of information that includes location. Part of this method would typically include the ability to review the results of assessment or analysis in the form of a map or some sort of report which identifies a geographic location. GIS is a tool which enhances decision-making and planning processes. Most planning applications, be they environmental or for natural resources, urban or agricultural development, require this approach. The three-dimensional spatial analysis ability of GIS can help decision-makers to address the mountain-specific planning processes in a more realistic way.

GIS

A computer-based system, capable of holding and using data describing places on the earth's surface.



The real world consists of many geographies which can be represented as a number of related data layers.

GIS Definition

Geographic data have traditionally been presented in the form of a map. Large-scale development of computer hardware and software is increasing the use of maps dramatically. Many organisations now spend a large amount of money on Geographic Information Systems (GIS) and on geographic databases. The costs of computer hardware and software are decreasing rapidly, and programmes are becoming more user-friendly, making GIS accessible to a large number of people.

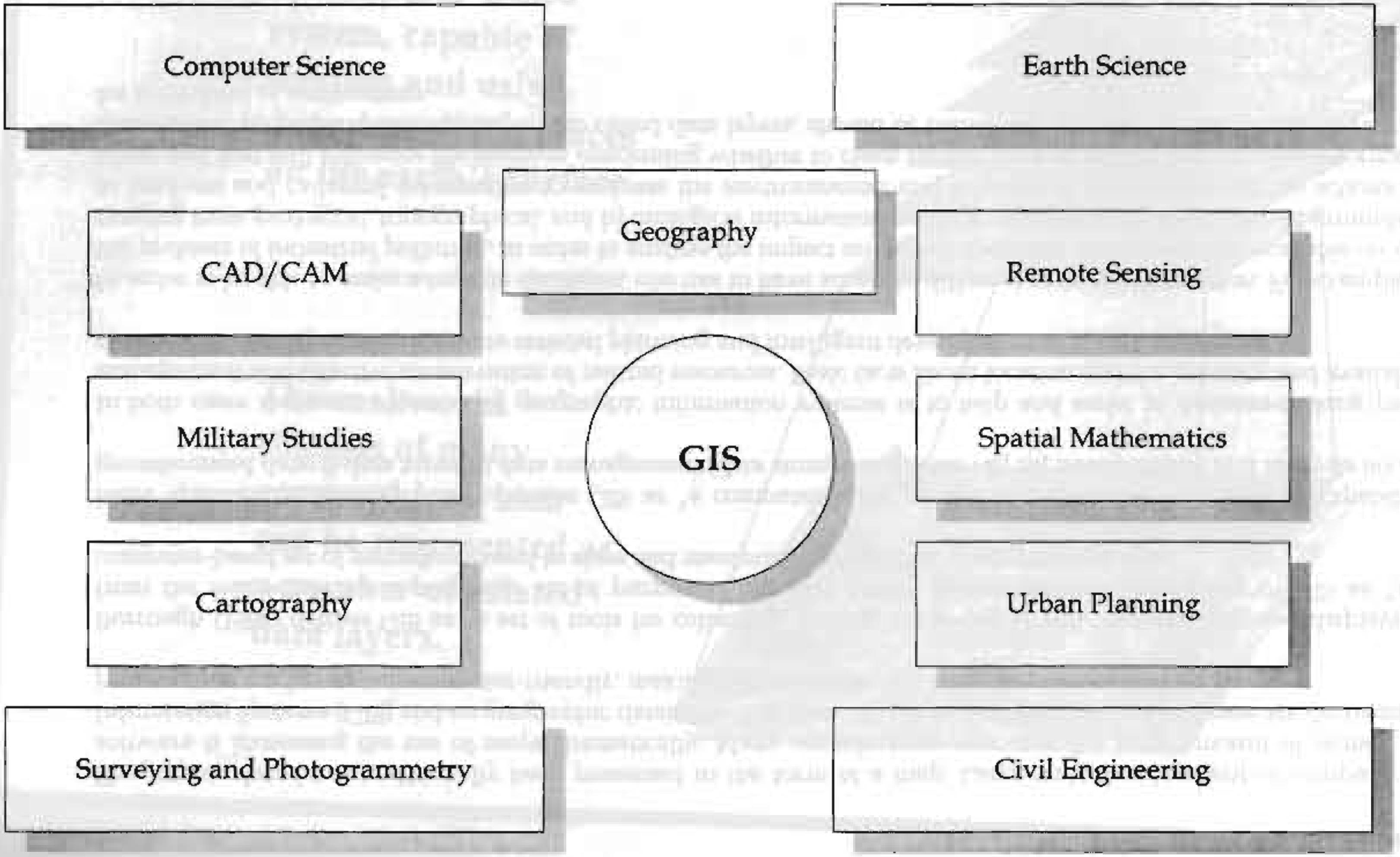
Burrough (1986) defines GIS as "a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes." Aronoff (1989) gives a general description of GIS as "any manual or computer-based set of procedures used to store and manipulate geographically-referenced data."

More specifically, Aronoff (1989) defines GIS as "a computer-based system that provides four sets of capabilities to handle georeferenced data: i) data input ii) data management (data storage and retrieval) iii) manipulation and analysis iv) data output."

In both cases the main objective of geographic information systems is to help and assist in decision-making processes for the management and effective conservation of natural resources. Basic facts about location and the quantity and availability of natural resources are indispensable for more rational planning and intelligent development of natural resources.

In order to be able to make adequate decisions, one has to have access to different sorts of information. For example, in the case of the problem of industrial pollution, in order to analyse the impact on the environment, data should be available on various aspects, ranging from geological, topographical, and hydrological information used for modelling the dispersion of groundwater pollution to land-use and cadastral information to evaluate the environmental and economical implications of the actions that should be taken and that will influence the decision concerning whether to clean up the mess or not. In this process, information of various dimensions, present in different maps, also called data layers, should be combined. In other words, GIS are a very important tool for these kind of applications.

GIS Historical Development



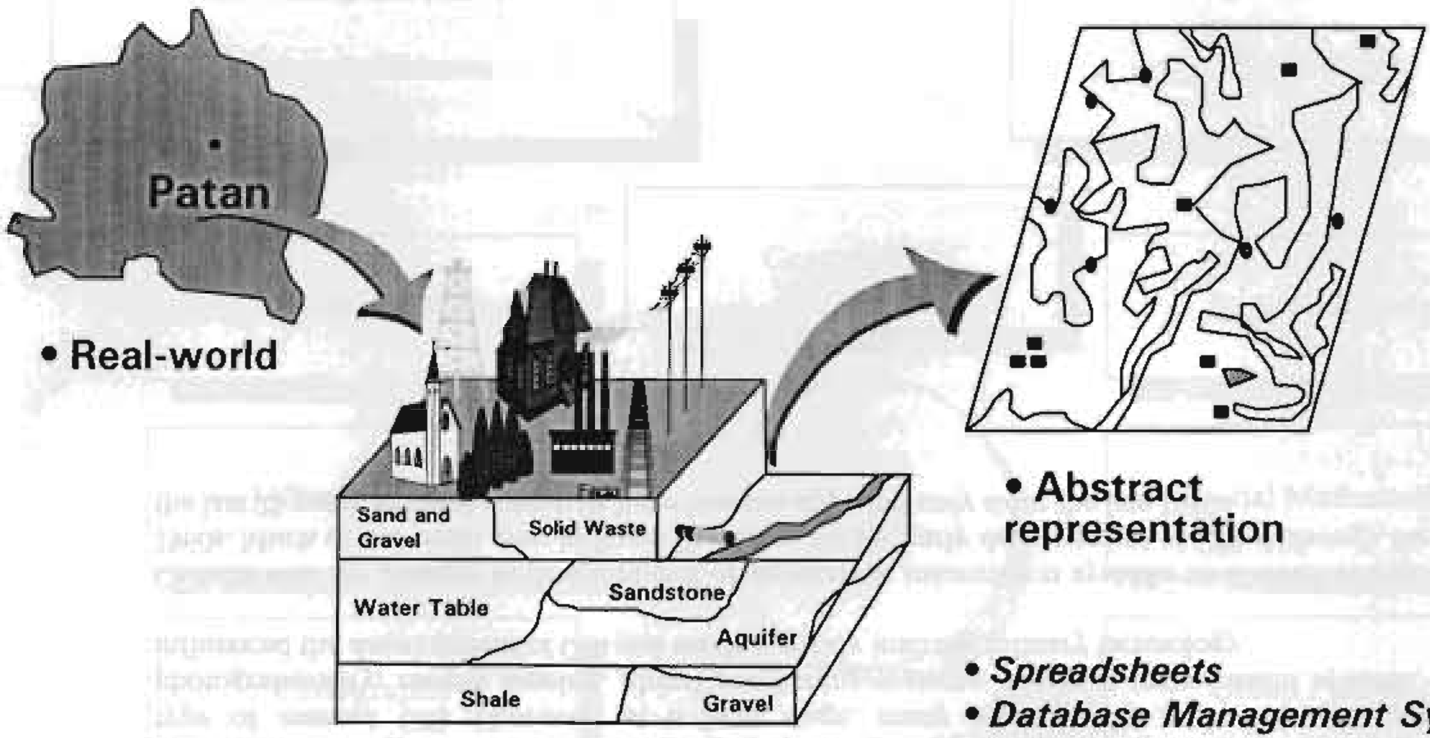
History of GIS

GIS, and the beginnings of simple spatial analysis, would not exist without geography and cartography. The contributions made by information and systems' development, in conjunction with the advancement in computer technology, have made GIS a powerful analytical tool.

The GIS technology has evolved from geography and geo-type disciplines. Cartographic map production can be taken as the first type of manual GIS. However, at a later stage, many other fields, such as civil engineering, computer cartography, photogrammetry, remote sensing, global positioning systems, database management systems, earth sciences, and so on have influenced the development of GIS and made it a truly interdisciplinary technology.

Canada was the pioneer in development of geographic information systems as a result of innovations dating back to the early 1960s. Much of the credit goes to Roger Tomilson for the early development of GIS. Although the field of GIS has been around for the last 25 years, the real potentials have become apparent only since the late 1980s.

Handling Geographic Information



- Real-world
- Geographic features
- Abstract representation

- *Spreadsheets*
- *Database Management Systems (DBMS)*
- *Computer Aided Design (CAD)*
- *Cartographic Packages*
- *Photogrammetrical Software*
- *Image Processing Software*

Spatial Operations

Many computer programmes can handle geographic data such as those described below.

Spreadsheets (e.g., Lotus 1-2-3, QuatroPro). A spreadsheet can be thought of as a large imaginary piece of electronic paper that can contain information in rows and columns, which is used for all sorts of (mathematical) operations for producing graphs. Spreadsheets are often used in combination with GIS.

Database Management Systems (e.g., Oracle, dBase). A Database Management System (DBMS) is a set of programmes which is a collection of information about things and their relationships to each other and which maintain and manipulate data in a database. A DBMS only handles "attribute data" and cannot handle maps. It generally forms an integrated part of GIS.

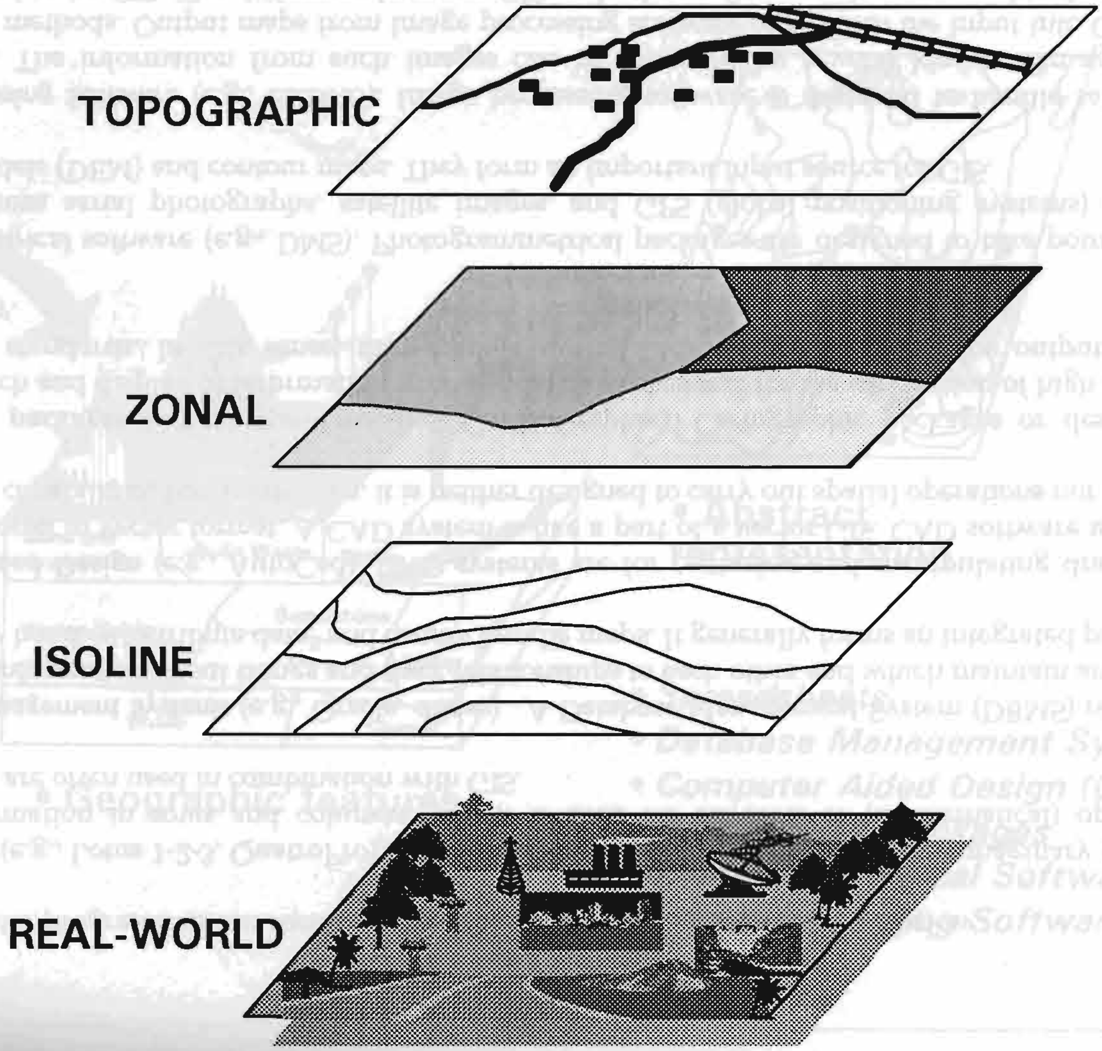
Computer Aided Design (e.g., AutoCad). CAD systems are for capturing and manipulating drawings. Point, line, and polygon objects are stored in vector format. A CAD system is like a part of a vector GIS. CAD software is highly developed and has very good display capabilities, but, on its own, it is neither designed to carry out spatial operations nor use raster data types.

Cartographic packages (e.g., Aldus Freehand, CarthoGraphix). Cartographic packages or desktop mapping systems are for selective search and display of information from spatial databases and for the production of high quality output maps which meet cartographic standards. In this sense, they form a useful addition to GIS, since the output facilities of most GIS are still unsatisfactory.

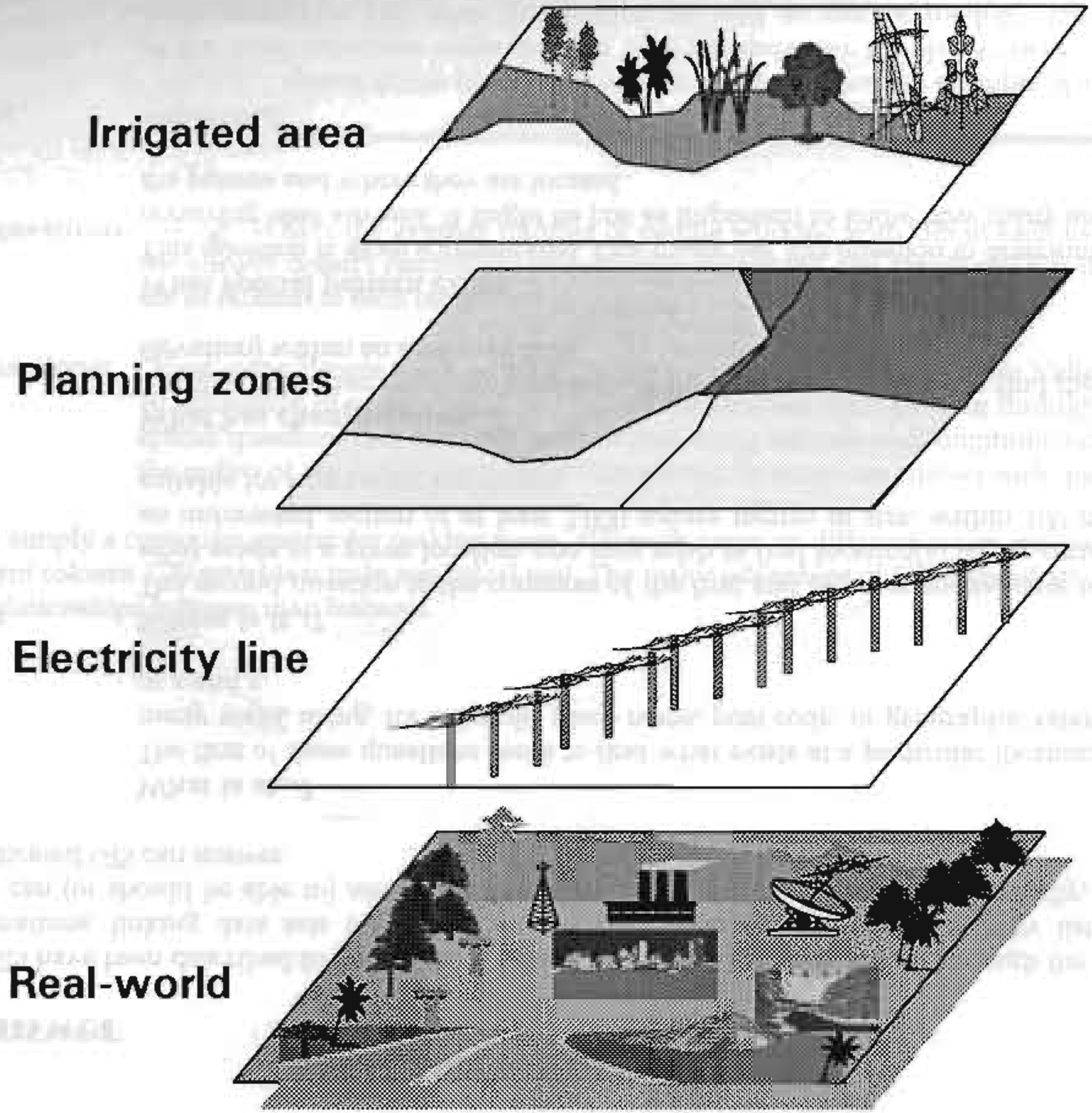
Photogrammetrical software (e.g., DMS). Photogrammetrical packages are designed to take point sample data (mostly of terrain elevations) from aerial photographs, satellite images, and GPS (global positioning systems) data, and then produce digital elevation models (DEM) and contour maps. They form an important input source for GIS.

Image Processing Software (e.g., ERDAS). Image processing software is designed to handle satellite images, or scanned aerial photographs. The information from such images can be extracted by several kinds of image enhancement techniques and classification methods. Output maps from image processing software often form the input into GIS. These software packages are not considered to be GIS. The difference between GIS and other software using geographic data is that only GIS permit spatial operations on the data.

Maps and Spatial data



What can GIS do?



Questions GIS can answer

Thus far, GIS have been described in two ways: i) through formal definitions, and ii) through the technology's ability to carry out spatial operations, linking data sets together. One can also, however, distinguish GIS by listing the types of questions the technology can (or should be able to) answer. If one considers a particular application carefully, there are five types of question that sophisticated GIS can answer.

Location — **What is at...?**
The first of these questions seeks to find what exists at a particular location. A location can be described in many ways, using, for example, place name, post code, or geographic reference such as longitude/latitude or x and y.

Condition — **Where is it...?**
The second question is the converse of the first and requires spatial data to answer. Instead of identifying what exists at a given location, one may wish to find location(s) where certain conditions are satisfied (e.g., an unforested section of at least 2,000 square metres in size, within 100 metres of a road, and with soils suitable for supporting buildings).

Trends — **What has changed since...?**
The third question might involve both of the first two and seeks to find the differences (e.g., in land use or elevation) within an area over time.

Patterns — **What spatial pattern exists...?**
This question is more sophisticated. One might ask this question to determine whether landslides are mostly occurring near streams. It might be just as important to know how many anomalies there are that do not fit the pattern and where they are located.

Modelling — **What if...?**
"What if.." questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local groundwater supply. Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operation. For example:

Name	Latitude	Longitude	Population
Kathmandu	27°42′ N	85°20′ E	421258
Lalitpur	27°41′ N	85°18′ E	115865
Bhaktapur	27°40′ N	85°26′ E	61405

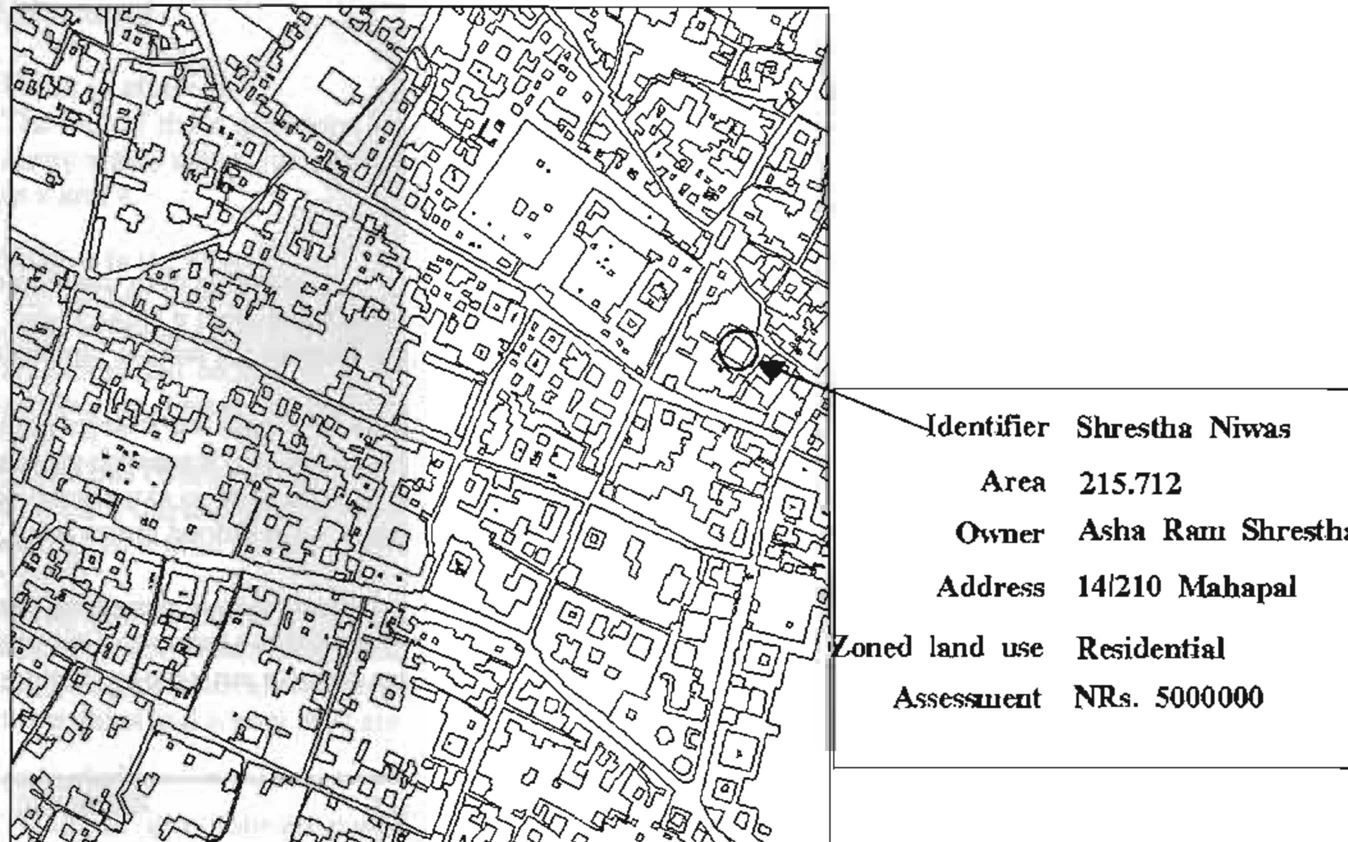
Aspatial questions: Asking "What's the average number of people working with GIS in each location?" is an aspatial question - the answer doesn't require the stored value of latitude and longitude; nor does it describe where the places are in relation to each other.

Spatial questions: "How many people work with GIS in the major centres of Kathmandu Valley", or "Which centres lie within 10 kilometres of each other?", or "What's the shortest route passing through all of these centres?" These are spatial questions that can only be answered using latitude and longitude data and other information such as the radius of the earth. Geographic Information Systems can answer such questions.

GIS are not simply a computer system for making maps, although maps on different scales are created in different projections and with different colours. GIS provide a truly analytical tool. The major advantage of GIS technology is that it facilitates identification of spatial relationships between map features.

GIS Questions - Locations - What is at ... ?

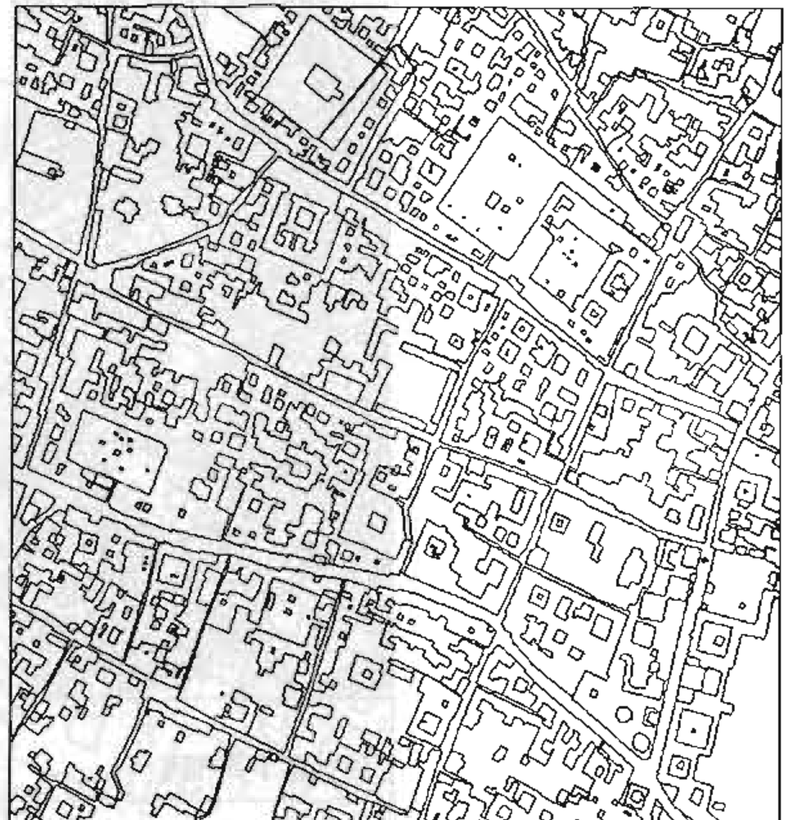
Mangal Bazar, Lalitpur District



Who owns the land at Mangal Bazar, and what is an assessment?

GIS Questions - Conditions - Where is it ... ?

Mangal Bazar, Lalitpur District



Residential Land use

Assessed at less than Rs. 500000

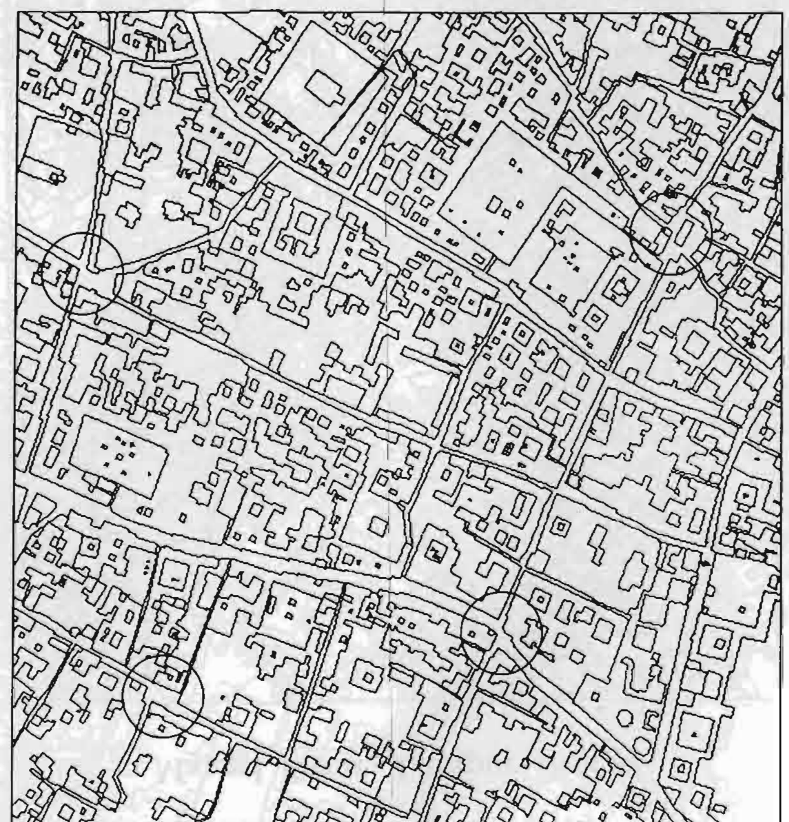
4 bedrooms

Made of local bricks

Where are houses that you might consider buying located?

GIS Questions - Patterns - What data are related ... ?

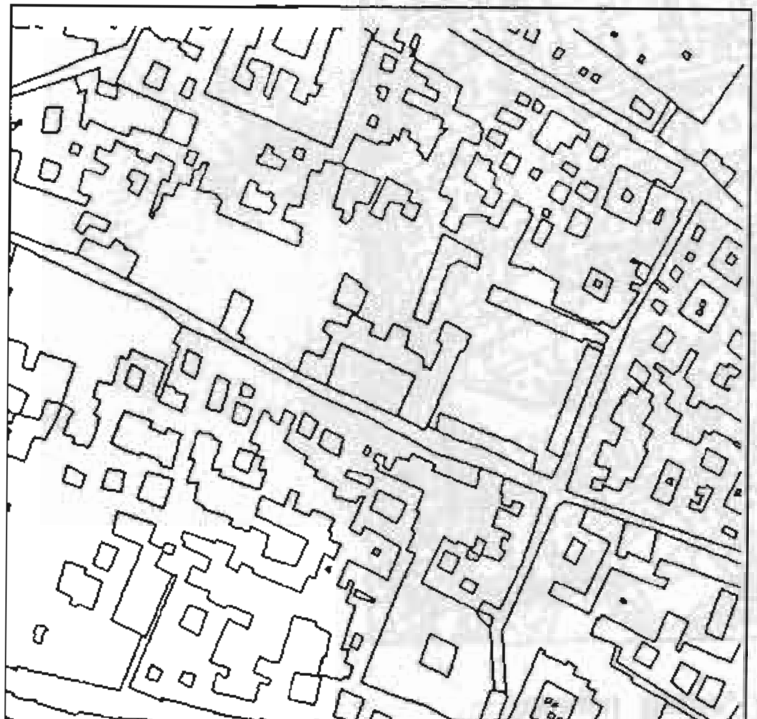
Mangal Bazar, Lalitpur District



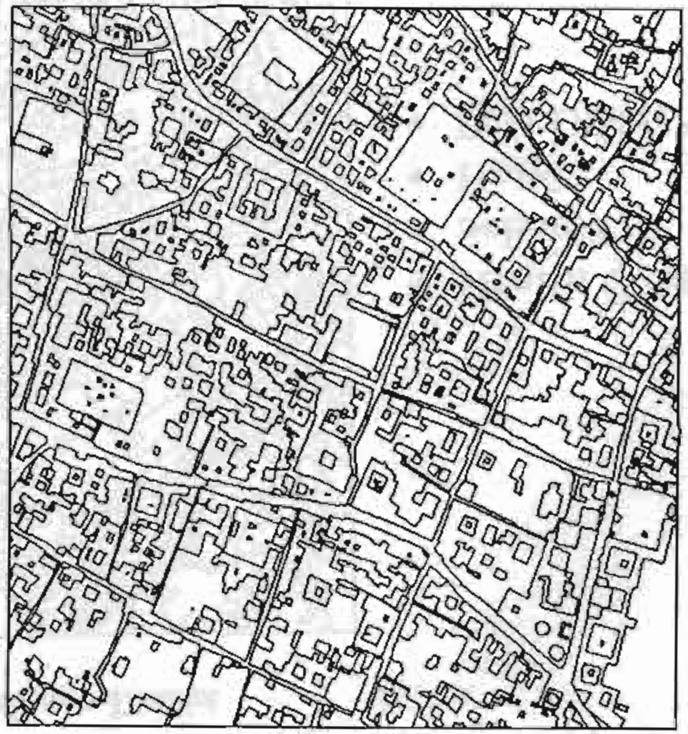
What kind of patterns exist that provide potentials for vehicular accidents?

GIS Questions - Trends - What has changed since ... ?

Mangal Bazar, Lalitpur District



1970

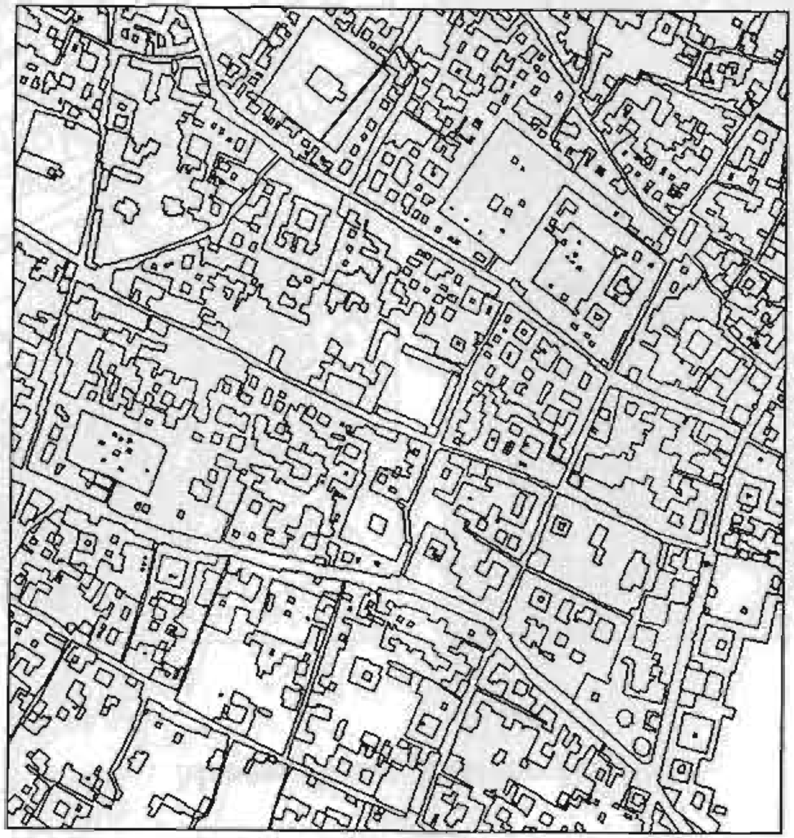


1990

How much land has been used for residential construction since 1970?

GIS Questions - Models - What if ... ?

Mangal Bazar, Lalitpur District



- Health Centre?
- School?
- Hotel?
- Post Office?

Where would you want to open a new service centre?

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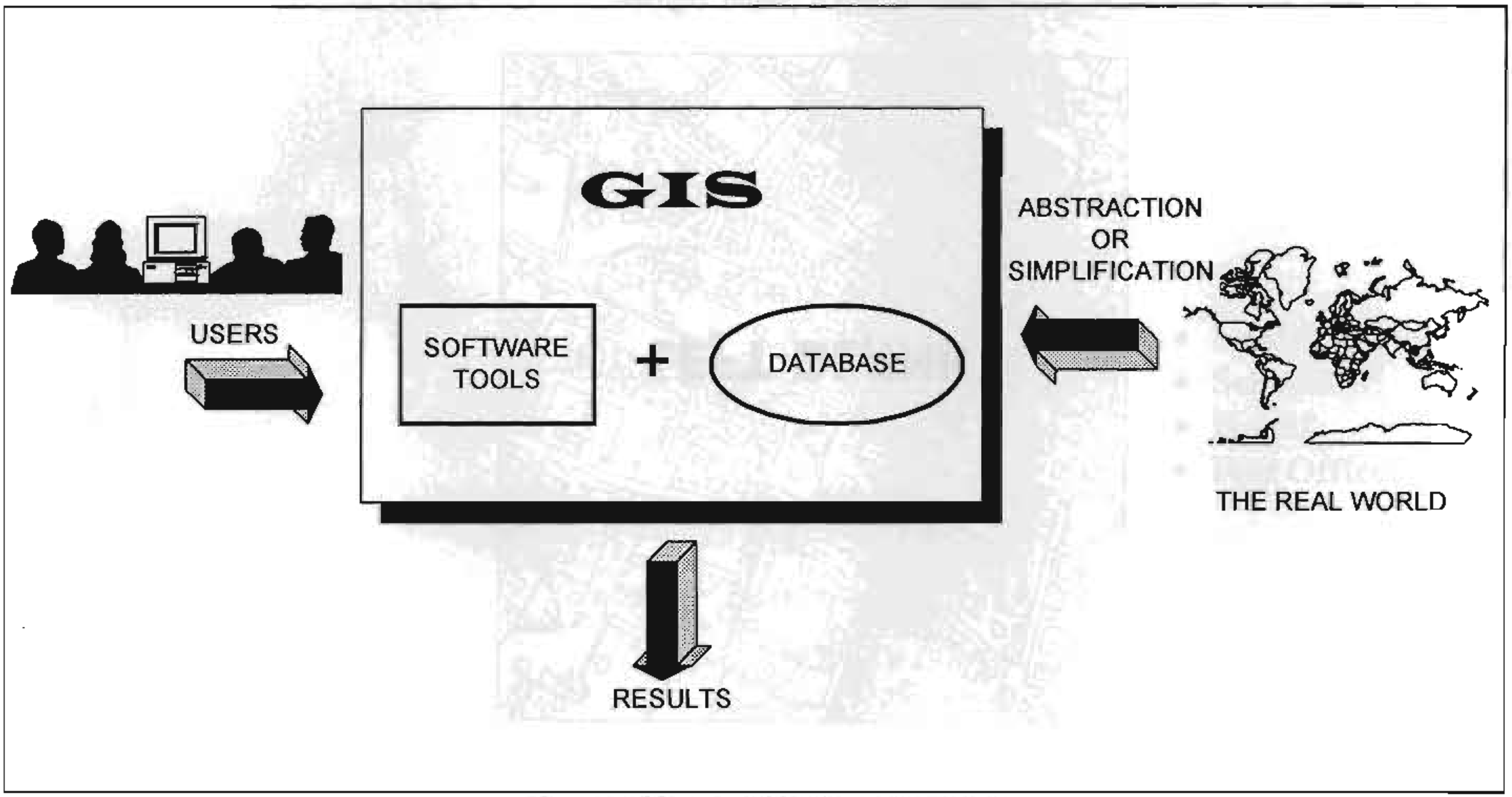
Components of GIS



Components of GIS

Several components are involved in GIS technology.

Hardware

A computer and the associated peripherals are essential for handling spatial data in GIS. These devices are collectively known as hardware.

Software

Software refers to the programmes that run on computers; these include programmes to manage the computer and to perform specific functions. For example, Lotus, dBase, WordPerfect, and ARC/INFO are specialised software programmes designed to perform certain tasks.

Database

A central theme to GIS is the database. A GIS database deals with spatial data. GIS facilitate integration of spatial and attribute data and this makes GIS unique in contrast to other database systems. The beauty of GIS technology lies in the ability to assimilate disparate sources of data and analyse them.

Human Input

People who work with GIS form the most important component. GIS constitute truly a interdisciplinary field and require varied backgrounds of expertise, depending upon the applications. In addition, for technical management, a Hardware Specialist, System Administrator, and Database Manager are required for a corporate GIS set-up.

Policy and Procedures

A methodology is a must to derive the results users need. Basically, this includes spatial analysis for the particular appli-cation. By and large, this depends upon the institutional framework and its interest in exploiting GIS technology for decision-making.

Applications of GIS

- Natural Resources' Applications
- Environmental Applications
- Socioeconomic Applications
- Management Applications

GIS Applications

Computerised mapping and spatial analysis have been developed simultaneously in several related fields. The present status would not have been achieved without close interaction between various fields such as utility networks, cadastral mapping, topographic mapping, thematic cartography, surveying and photogrammetry remote sensing, image processing, computer science, rural and urban planning, earth science, and geography.

The GIS technology is rapidly becoming a standard tool for management of natural resources. The effective use of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system to transform this data into usable information.

The GIS technology is used to assist decision-makers by indicating various alternatives in development and conservation planning and by modelling the potential outcomes of a series of scenarios. It should be noted that any task begins and ends with the real world. Data are collected about the real world. Of necessity, the product is an abstraction; it is not possible (and not desired) to handle every last detail. After the data are analysed, information is compiled for decision-makers. Based on this information, actions are taken and plans implemented in the real world.

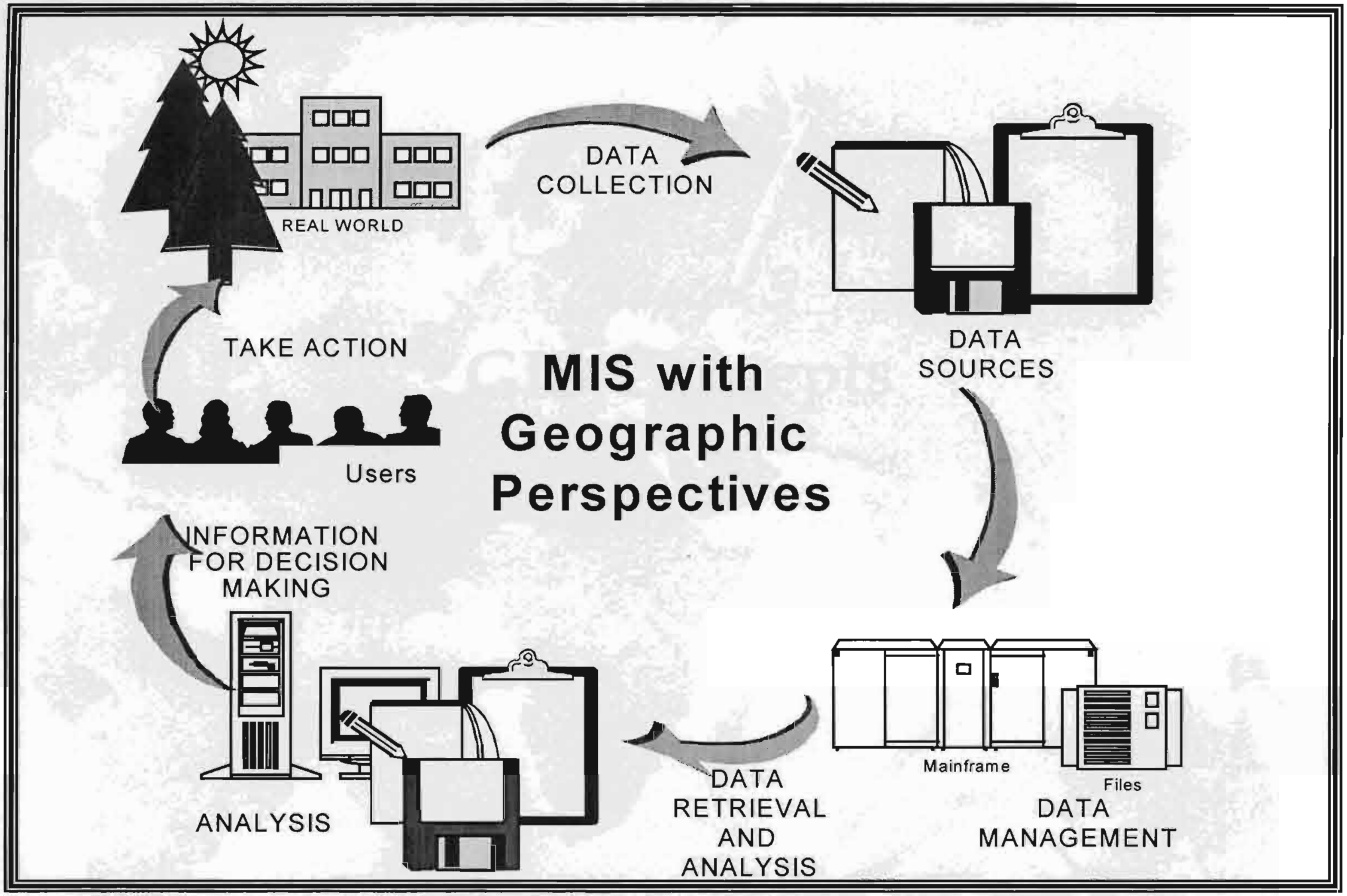
Some typical examples of GIS applications within natural resource planning are:

- land-use planning and management
- mineral exploration
- environmental impact studies
- management of natural resources
- management of water resources
- natural hazard mapping
- forestry and wildlife management
- soil degradation studies
- monitoring desertification
- agricultural development

Sample GIS Applications

- Land-use planning and management
- Mineral exploration
- Environmental impact studies
- Management of natural resources
- Natural Hazard Mapping
- Forestry and wildlife management
- Soil degradation studies
- Monitoring desertification

The Planning Process



- Land use planning and management
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- Envi[illegible]
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- Monitoring desertification