



**AN APPRECIATION OF GEOGRAPHIC INFORMATION
SYSTEMS IN URBAN PLANNING**

by

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ABSTRACT

Urban planning is a multi-disciplinary process, which demands input from various decision makers. An efficient and realistic plan can only emerge if the different parties involved coordinate their efforts to find solutions now. This can be achieved more than ever before using Urban Information Systems (UIS), be it within an organisation or between organisations.

This dissertation defines the Geographic Information System (GIS) as a planning tool and describes the functions of its different components. It also examines other types of urban information systems and their role in urban planning, such as Data Base Management Systems (DBMS), Decision Support Systems (DSS) and Expert Systems (ES). The work touches on coupling the GIS with other sophisticated UIS, in an attempt to incorporate modelling techniques and expert knowledge into its functionalities. The report further addresses the importance of networking GIS to achieve a better data sharing in planning environment, and the recent technologies involved. In addition, the work describes several GIS applications in urban planning and explains the use of neural networks in this field. Also issues which relate to successful implementation of a GIS and the problems involved are discussed.

The dissertation concludes that a GIS technology can be used to its fullest potential if firstly it is integrated with other information systems, to create an intelligent GIS and secondly, it is used as a data sharing tool which requires resolving problems related to communications and organisational matters.

Finally, the work outlines recommendations which are considered essential for implementing and maintaining a successful GIS, both on technological and organisational levels.

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LIST OF ABBREVIATIONS

AM/FM	Automated Mapping/Facilities Management
B-ISDN	Broad Band Integrated Services Digital Network
CAD	Computer Aided Design
DBMS	Data Base Management System
DQDB	Distributed Queue Dual Bus
DSS	Decision Support System
ES	Expert System
FDDI	Fiber Distributed Data Interface
GIS	Geographic Information System
GPS	Global Positioning System
LAN	Local Area Network
MAN	Metropolitan Area Network
UIS	Urban Information System

CHAPTER ONE

1. INTRODUCTION

1.1 History

Since the earliest civilisations on this planet, mankind has tried to use maps for recording information. The earliest discovered map is imprinted on a clay tablet by the ancient Egyptians, dated back to about 2500 BC. Other means, like pebbles, sticks etc. were probably used to relate geographical (spatial) relationships of objects, forming the basic idea of geographic information systems [1].

The first reliable and accurate base maps were produced by mid-eighteenth century in Europe. This was when the Governments recognised the importance of map making (cartography) as a tool for recording and planning purposes. By the twentieth century, already science and technology were developing very rapidly demanding for a greater volume of data. In parallel, the advance of aerial photography and satellite remote sensing produced huge amounts of geographic data, which was not possible to handle and analyse in a simple map form [2].

In response to the information explosion, several universities investigated the possibility of using computer-based systems as an aid. In the 1960s Harvard University started the first steps by developing a number of automated mapping and analysis programs. Also the University of Washington, at Seattle, made remarkable contributions in the fields of transportation analysis and urban planning and renewal. By 1968 thirty five urban and regional planning agencies were implementing computer-based systems in the United States [1].

It was only in the 1970s that geographic information systems were developed to handle large volumes of geographical data. Canada was the first country to implement a geographic information system in the area of Rehabilitation and Development of Canada's Agricultural Lands [1, 2]. At that time GIS was simply a central computer with storage disks, memory and such devices. By the 1980s the central mainframe was extended and linked with terminals (personal computers), which increased the popularity of GIS. But one of the most important advances was the connection of the personal computers and the workstations into a network [3].

1.2 Background

1.2.1 What is a Geographic Information System (GIS)

In order to understand and explain the phrase Geographic Information System, it must be divided into two parts: geography and information systems. Geography comprises of Geo, which means earth and graphy is the process of writing. Therefore, the word Geography means writing about the earth [1]. Any point on the earth has a spatial relationship with other points or objects.

The other part of the phrase, information system, is the process in which the collected data is stored and analysed in order to produce useful information to improve the decision-making process [1, 4].

A geographic information system is an information system which can process spatial (point, line, polygon) and attribute data (length, height, depth) [4].

1.2.2 Spatial Data Storage in a GIS

Spatial data can be stored in a GIS in three forms: raster, vector and quadtree (Figure 1.1) [3].

- (i) *RASTER*: A regular grid covers an area say for example 500 by 500 m². Each cell has a specified attribute data.
- (ii) *VECTOR*: This type gives a good representation of the reality. Points, lines and areas are stored in a precise x and y coordinates.
- (iii) *QUADTREE*: This type is between the first two. The data are stored in various grid sizes. In areas of similar characteristics the grids are large and become smaller towards the edges of an area for more precise lines.

1.2.3 Components of a GIS

A GIS mainly comprises of four components: data input, data management, data manipulation and analysis and data output [2]. In addition to the four components a skilled user is required when it comes to complicated spacial data analysis, who must be well aware of the stored data and the system [5].

Figure 1.2 shows very schematically the four different components of a GIS. The software tools represent the database management system and the data manipulation and analysis system. These components will be discussed in more detail further in this report.

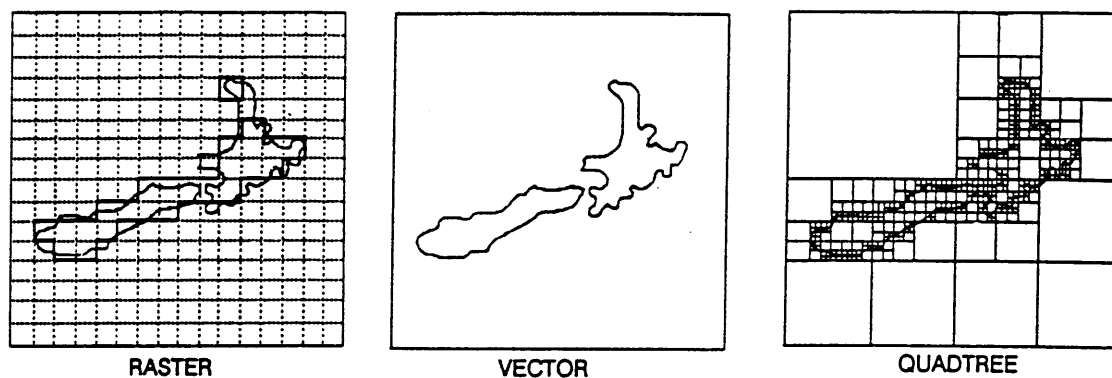


Figure 1.1 Types of Spatial Data Storage in GIS

Source: Scholten, H.J.; Stillwell, J.C.H. (eds) (1990): Geographical Information Systems for Urban and Regional Planning. Kluwer Academic Publishers, Netherlands, pp 6.

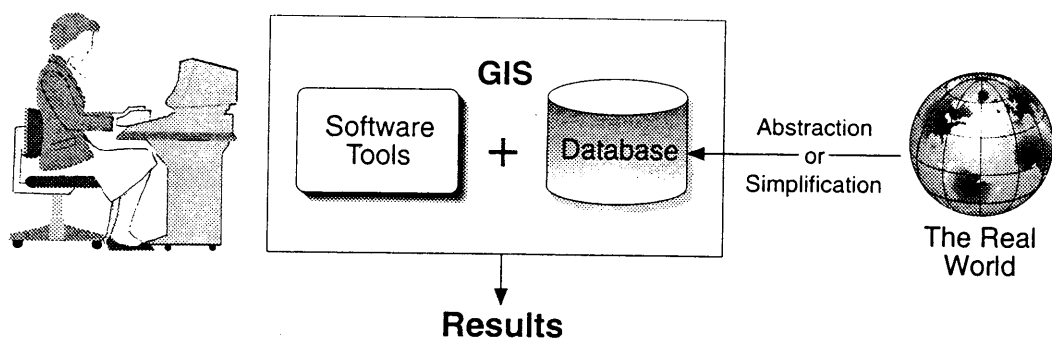


Figure 1.2 Components of a GIS

Source: Environmental Research Institute (1993): Understanding GIS, The ARC/Info Method. John Wiley and Sons Inc, New York, USA.

1.3 Objectives

The main aim of this dissertation is to give the reader an appreciation of using urban information systems in general and geographic information systems (GIS) in particular in the field of urban planning. The study explores the principles, functions, uses and applications of GIS and its relation to other systems in urban planning by reviewing and going through recent published literature. In addition the study considers the areas of deficiency and progress of GIS towards more efficient systems in the future.

This report is not an expert study in the field of GIS, but gives an overall understanding of the system's uses in urban planning and highlights its present limits and future trends. The study could serve as background reading for researchers or new users of the system who have interest in the subject.

1.4 Scope of the Report

The use of computers in urban planning as an analysis tool has lagged behind and the strides have been slower than other disciplines such as engineering and medicine, due to the subjective nature of the information the planners deal with. It was only recently, and to a limited extent, that planners have started using computers as mapping and analytical tools due to the emergence of geographic information systems.

The report emphasises the importance of GIS use in urban planning. First, by using its available functions, second, by integrating the system with other powerful systems, such as decision support systems and expert systems, to increase the limited analytical strength of a GIS. Part of the report is dedicated to a number of GIS applications in urban planning as a stand alone and as an integrated system with other applications.

The study also covers the recent technologies in networking and the importance of data sharing in a GIS environment.

Further in the report issues related to implementation of successful GIS and the problems and difficulties involved are discussed.

1.5 Structure of the Report

Based on the objectives and scope of work this dissertation is structured as follows:

CHAPTER TWO addresses the various issues which relate to information systems on the one hand and urban planning on the other hand in an attempt to bridge the two fields. Also, it discusses the planning process and the most appropriate environment for the planning practice.

CHAPTER THREE describes the different types of information systems used in urban planning, including data base management systems (DMBS), geographic information systems (GIS), decision support systems (DSS) and expert systems (ES). This chapter also outlines the components of these systems and touches on their capabilities in planning.

Chapters two and three provide the reader with a wide perspective in order to compare geographical information systems with other urban information systems and relate it to the planning discipline. The next chapters concentrate on the use of GIS in urban planning.

CHAPTER FOUR defines geographic information systems and describes in detail the function of its components. This chapter also highlights the use of GIS in the remote sensing field. A considerable part is dedicated to integration of GIS with other urban information systems (DSS and ES) in an effort to reinforce the analytical capabilities of GIS. In addition, related technologies to GIS which have been recently used to capture data are described.

CHAPTER FIVE emphasises the importance of networking information systems and the role of communication technology in creating the required standards of planning environments for more effective coordination. A brief description of the different types of networks are given. Also some of the important issues of data sharing and administration are addressed. In addition this chapter touches on concurrent engineering, which has lately emerged in the engineering and business environment and the possibility of its application in urban planning.

CHAPTER SIX describes several applications of GIS in urban planning as a stand alone system and as coupled with other systems such as DSS, ES and artificial neural networks.

CHAPTER SEVEN discusses the successful implementation of GIS and the difficulties involved, mainly in terms of organisation context.

CHAPTER EIGHT draws conclusions and recommendations.

And finally is the list of references.

CHAPTER TWO

2. INFORMATION SYSTEMS AND URBAN PLANNING IN GENERAL

2.1 Information Systems in General

2.1.1 What is an Information System?

An information system is generally defined as a computerised system which can store large amounts of data and is able to retrieve and transform the data into useful information [4]. Nijkamp [6] defines information systems in a different manner but based on similar ideas. He believes that an information system is any type of system which can solve, organise and rationalise complex choices and can act as a decision support system for planners and policy makers.

Han and Kim [7] define urban information systems as computer-based systems which have the ability to integrate information from different sources to form adequate and useful information to aid planners in the urban planning process.

Star and Estes [1] consider an information system as a 'Chain of operations that takes us from planning the observation and collection of data, to storage and analysis of the data, to the use of the derived information in some decision making process'.

Therefore, the function of an information system is not just storage of data, but it must have the capabilities to retrieve and manipulate data to produce suitable information for a particular situation or problem, to improve decision making.

2.1.2 Value of Information in Urban Planning

Good evaluation in planning is only possible if reliable information is available. As time passes, societies grow more complex, and as a result, planners are required to look into continuously increasing information than ever before. Nowadays collection of relevant information is considered as power and an indispensable tool in organisations concerned with public affairs and agencies dealing with competitive environments. Inadequate information could lead to ineffective planning, misinterpretation of socio-economic processes, inconsistent or incoherent decisions and bad communication. When information leads to a bad decision, it is called 'mis-information' [6].

The reason for gathering, organising and processing data is to produce reliable information in order to gain a wider understanding of the environment and to plan for a better society. Planners have different views on information and interpret it in various ways. For example, some planners emphasise that urban planning starts with data and information, from which goals of a society are derived. Others see that planning is an information producing process, which leads to a reduction of uncertainties in a decision-making process [7].

Useful information is derived as a result of aggregation, manipulation and statistical, mathematics or algorithmic changes of data, in order to acquire necessary knowledge and to solve a problem or to indicate the correct direction of movement [7].

Ward, Griffiths and Whitmore [8] argue that the importance of information will grow as more organisations will accept its new role in the future. They support the view that the organisations of the 21st Century will be information based. The number of people in an organisation will be reduced to accommodate only knowledge specialists working in harmony as one team, forming an organisation with a unified view.

The above situation could be thought of as an ideal situation, and very hard to reach, but certainly it reflects the importance and power of information in the opinion of the specialists.

To cope with the continuous increase in data, it is essential to computerise information for several reasons. First, to increase the efficiency of workers in an organisation. Second, to prevent conflicts between departments or parties by having access to a centralised computerised information system. The system must be flexible to allow for changes which result from the dynamic state of the society and the environment. It should also be able to provide critical information to the policy makers as their needs change daily [4].

In many countries and especially the developing ones, the problem is not mainly due to scarcity of data, but it is due to dispersed data among the different authorities. The only way to make use and obtain reliable data is to collect, store and organise those data in a rational coherent manner. This can only be achieved by using information systems [9].

2.1.3 Types of Information in Urban Planning

The uses of computers in urban planning have been less significant than in other fields. This is mainly due to the subjective nature of information the planners deal with. Unlike other disciplines (business, engineering, etc.) urban planning involves data related to public goods and services which require inseparable quantitative and qualitative appraisal. Planning is a multi-disciplinary activity, where many parties are involved in a decision-making process [7]. In this process different types of information from different sources are integrated together to analyse a problem and reach a solution.

Han and Kim [7] emphasise that to understand the role of information in urban planning there is a need to distinguish between two different types of information, formal and informal. Formal informations are formalised by the society, such as regulations and legal requirements, planning procedures etc. Informal information, on the other hand, includes personal judgements, intuition and experiences and non-formalised procedures. In their article they further explain that informal informations supplement formal informations in urban planning. But due to the subjective nature of informal information and the technical limitations of urban information systems, they have not been used until recently.

As the tasks of planners become more complex, they should have a greater motivation and drive, more than ever before, to encourage development of a more intelligent computer information system, which will be able to reason, learn and respond to urban planning needs.

2.2 Urban Planning in General

Before starting discussions on urban information systems, it is necessary to highlight and explain what and who is involved in the planning process.

2.2.1 The Planning Process

Planners for almost 50 years have followed the pattern: survey → analysis → plan process. This system of thought has been slowly abandoned to a more comprehensive and logical approach, using decision theory and systems approach [10]. Singh [11] defines the systems approach as 'a multi-disciplinary approach which yields a whole that is different from and at the same time greater than the sum of its parts'. He further elaborates that 'in order to optimise a system the process of decision-making

must be based on clear objectives and rational analysis'. This system calls for lateral thinking to come up with a domain of best options, instead of coming up with a single answer or product. Planning is a continuous (cyclical) process which has no beginning or end. Planners try to incorporate the problems as they arise into this cycle [10].

The planning process deals with spatial problems and plans to develop policies and actions based on spatial information. To benefit from Information Systems in urban planning, the planning process must be rational and systematic, with clear objectives and regulations. Also it should be flexible, so that it can be updated and used over a long period of time.

Polydorides [12] in his paper *A Planner's View* describes a rational planning process in 12 steps as shown in Figure 2.1.

- Steps 1-5: are considered the main spine of a planning process. They include information collection and analysis. Coordinated efforts between the parties involved in the process is essential.
- Steps 6-8: are the stages of development and evaluation of alternatives.
- Step 9: is the point of decision making and selection of the best alternative, through political arguments and evaluation.
- Steps 10-12: the implementation of the selected alternative.

If the planning process is not rational and organised as such, then there is no need for sophisticated and expensive information systems, instead they could impede the intuitive, haphazard planning process.

2.2.2 Who are Involved in Planning?

As mentioned earlier, planning involves various types of activities and many people are involved. Planning is a complex operation and requires different areas of skills. It is difficult to list the whole range of various types of people involved in planning activities. However, an over-simplified classification is listed below [13]:

- *the surveyors*: they are responsible for data acquisition of an area.
- *the engineers*: they play an important role, especially in physical planning where they carry out site investigation, identify problems and prepare feasibility studies.
- *the architects*: they study the plan from a wider point of view, which could include assessment of infrastructure and communication, distribution of buildings and people, land use and proposed development plans.

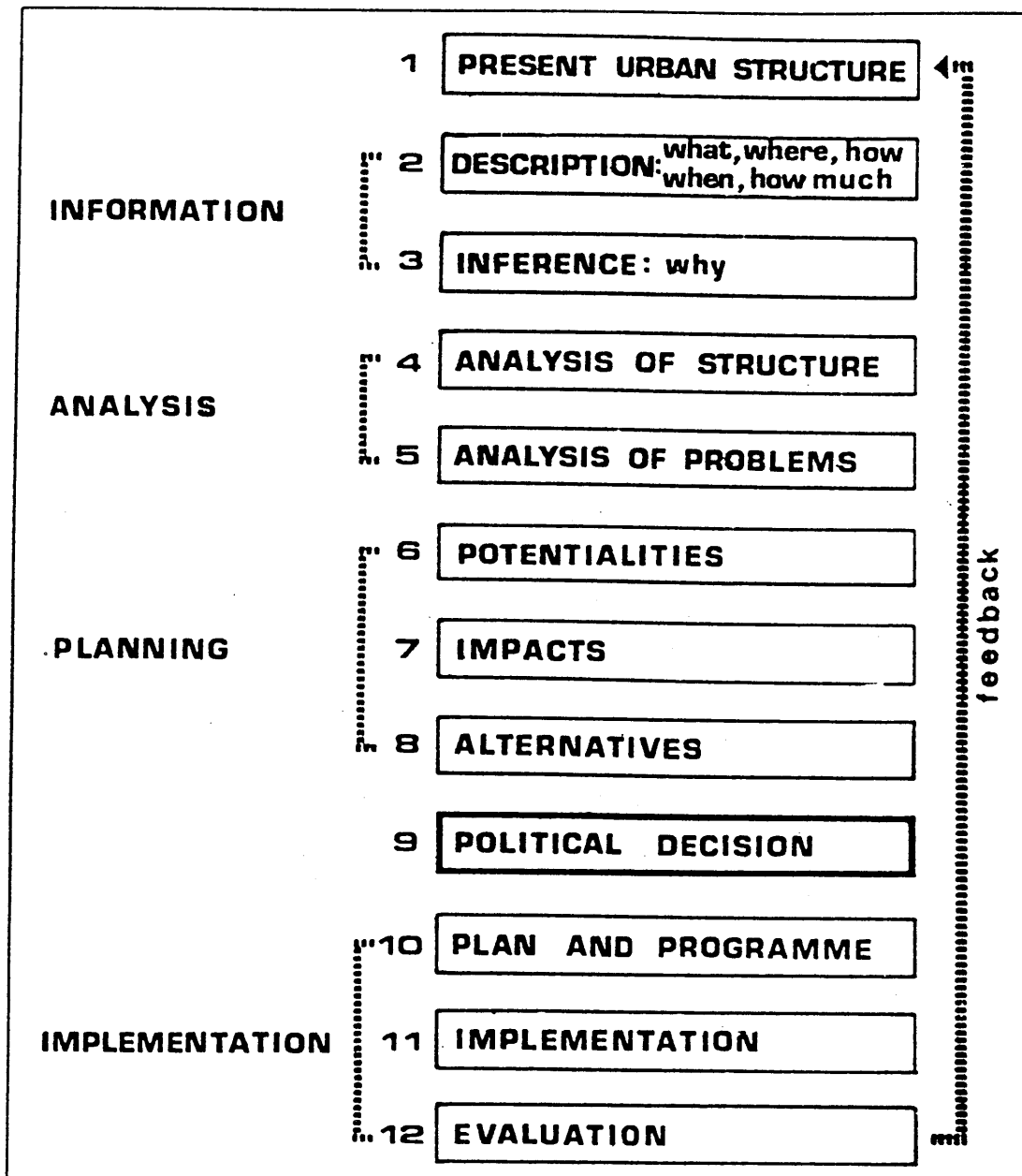


Figure 2.1 The Planning Process

Source: Polydorides, N.D. (1991): GIS and Research, A Planner's View. Second European Conference on Geographic Information Systems, Belgium, Vol 2, pp 897.

- *the economists:* they are responsible for evaluation of the cost benefit analysis and the economy of a planning policy.
- *the environmentalists:* their role is to assess the impact of a planning policy and how it will affect or be affected by the surrounding nature. This will greatly influence the selection of an alternative.
- *the sociologists:* they identify desires, demands, priorities and problems of people as individuals or groups in a community, in order to achieve and come up with the most suitable planning policy, which will reflect the desired goals and objectives of a society.

2.3 Information Systems and Planning

The planning field encompasses many sources of uncertainties. First, planners face external uncertainties such as economic growth, financial, technological development and consumption patterns. Second, planners face uncertainties related to the planning activity such as housing, transportation etc.; third, they face subjective and large numbers of conflicting evaluation criteria. The function of information systems is to overcome some of these uncertainties [6].

Planning has multi-disciplinary characteristics and handles many types of information and a wide range of map types, produced by many different sources. Maps are used to describe, for instance, soils, vegetation, socio-economic data and demography, economic features etc. A map is considered as a kind of information system, because it contains stored, analysed data and information. The first step in a planning project is to collect all such information and standardise them, to support the planning process [14].

Nijkamp and Scholten [15] point out the importance of and value of information systems and communication in planning.

'It is believed increasingly that advanced infrastructures for information exchange and services will be as dominant in the last decade of the twentieth century as waterways, rail and road transport infrastructures were important in previous centuries'.

In the planning process many agencies contribute to the decision making before a final decision is reached. Therefore, it is crucial to create more efficient communications between parties involved, to eliminate any misconception or conflict.

Urban information systems are designed to work with spatial (geographic) information related, for example, to roads, rivers, administrative boundaries of an area, or any information in regard to any point on this hemisphere.

An information system in urban planning can either be manual or automated as described by Star and Estes [1].

- *Manual:* this type comprises of several data elements which include maps, sheets or transparent material used as overlays, aerial photographs, statistical reports and field survey reports. These data are put together and then analysed by using different sorts of instruments such as stereo viewers, mechanical and electronic planimeters etc.
- *Automated:* this system is based on computer aided techniques. Basically, the process used in the manual system occurs in an automated system, but with a greater efficiency and accuracy.

To achieve a better understanding of this planet, mankind has invented microscopes to observe things which are too small to see. On the other hand, satellites are invented to detect and observe things which are too large to see, like the image of the entire planet. Urban information systems can integrate spatial data obtained at different scales, times and formats [1].

Urban planners, like other scientists working with geographic information, observe and monitor the environment, develop maps to indicate earth characteristics and develop model alternatives of action. These activities can be improved greatly by information system technologies.

Therefore efficient urban information systems must be capable of storing data input, analysing data, processing information quickly, developing and generating scenarios and output, and should include cartographical (graphical) representation of goals and proposals.

2.4 Integration of Planning Authorities

A successful planning process can only be accomplished if the process is properly coordinated among all authorities concerned. For instance, the Dutch planning organisation separate sector planning from facet planning. The sector planning deals

with only one specific topic which is handled by one authority, such as housing, traffic etc. Facet planning deals with spatially integrated sector plans, combined into one overall master plan for the whole region. Refer to Figure 2.2.

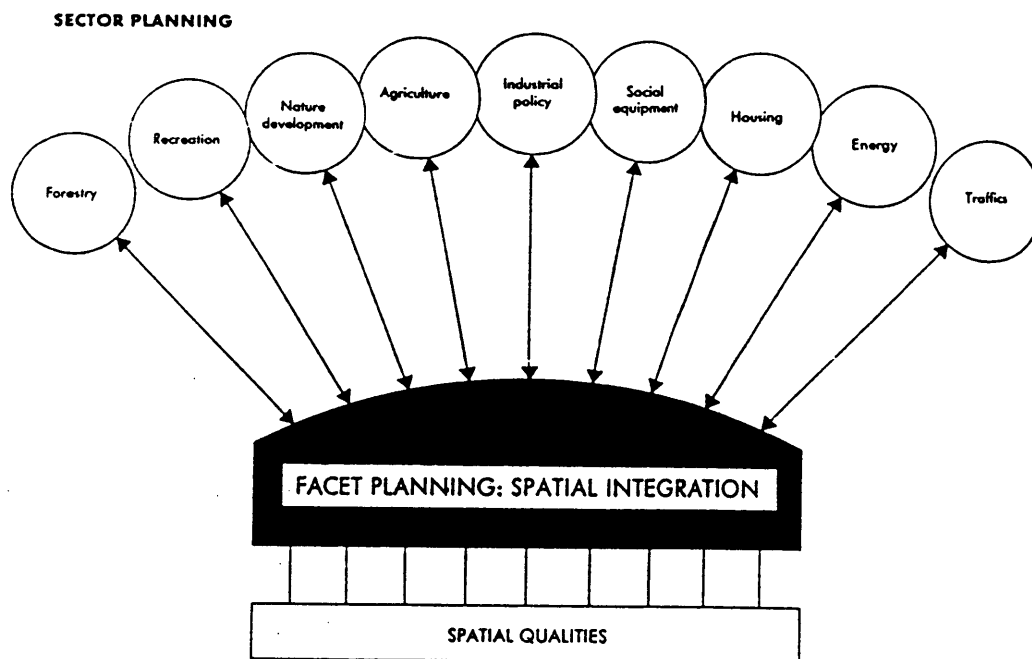


Figure 2.2 Sector and Facet Planning

Source: Janssens, P. (1991): Land Related Information Systems for Research and Planning. Second European Conference on Geographical Information Systems, April 2-5, Belgium, Vol 1, pp 498.

CHAPTER THREE

3. URBAN INFORMATION SYSTEMS

Information systems in urban planning come under a variety of names, depending on the subject that each handles. For instance, there are 'Land Information Systems', 'Geographic Information Systems', 'Environmental Information Systems' etc. These are all computer systems which are covered by a more general name 'Urban Information Systems (UIS)'. UIS are systems that have the capabilities to integrate data from various sources to provide quality information so as to improve decision making in urban planning [7].

Researchers and professionals classify UIS in different ways. Cartwright [16] explains that there are various ways in which computer based information systems are used in planning. He classifies them simply into three categories:

- traditional databases for storing, sorting, retrieving records and simple arithmetic operations.
- interactive systems with manipulation and display capabilities combined with data base management operations such as spread sheets, graphics and mapping.
- expert systems.

Han and Kim [7] classify UIS in a more detailed manner and in accordance to their functions and technologies: Data base management systems (DBMS), geographic information systems (GIS), decision support systems (DSS) and expert systems (ES).

To achieve a better understanding of UIS an attempt is made to describe the various systems in more detail.

3.1 Data Base Management Systems (DBMS)

A data base comprises of collected data from various sources. The data base represents the stored information, and the data base management system acts as the system which manages the data base. The main objective of the data base and collection of information, is to relate phenomena and elements which were separate in the past. A DBMS consists of a set of programs which have the ability to manipulate and maintain data in a data base. It is an intermediate supervisory unit between the data base and the application programs which the user sees (Figure 3.1). This system maintains good quality information and allows for further sharing of data without losing the integrity of the data base [2].

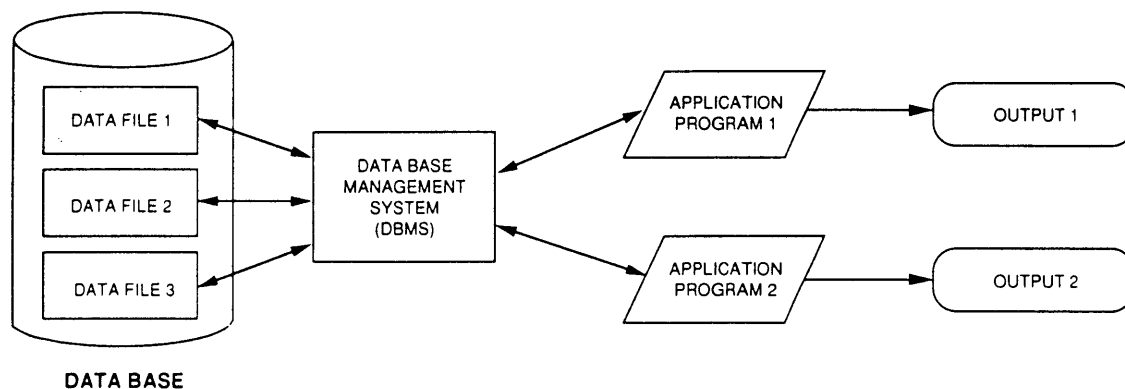


Figure 3.1 Data Base Management Systems

Source: Arnof, S.(1989). Geographic Information Systems: A Management Perspective. WDL Publications, Canada, pp 152.

Planners define DBMS as 'a computer-based system capable of storing, updating, organising and reporting data to the user in a timely, consistent and efficient manner' [7]. In planning DBMS serves as a stand alone or as a part of other types of systems such as geographic information systems and decision support systems [7].

3.1.1 Advantages of DBMS [2]

- Provides a centralised control to ensure data quality standards, security, and maintains integrity of data.
- Allows the information in the data base to be shared in an efficient and controlled manner.
- Reduces the data redundancy in a system.
- Data stored are independent of application programs, which allows easier access to the data base in the case of several users.
- Provides convenient user interfaces, which can even be used by non-programmers.

3.1.2 Disadvantages of DBMS [2]

- Incurs high cost to acquire hardware and software; also the maintenance of such systems is expensive.
- It is more complex compared with a normal simple data processor.
- Centralisation of data and reduction of data redundancy could lead to greater risks of losing and corruption of data. These problems can be reduced by backup and recovery procedures.

The cost effectiveness of a DBMS is dependent on its use and whether or not it will pay back its costs in the long run.

3.2 Geographic Information Systems (GIS)

A GIS is defined as 'an organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information' [5].

Star and Estes [1] define GIS in a more simple form, 'the complete sequence of components for acquiring, processing, storing and managing spatial data'.

Linden [3] describes a GIS 'as a system for capturing, storing checking, integrating, manipulating, analysing and displaying data which are spatially referenced to earth'.

There are numerous definitions of GIS, but they all share a common ground when it comes to the type of information the GIS deals with and that is spatial data. Spatial data may be collected from field surveys, aerial photographs, maps, remote sensing etc.

Spatial data play an important role in urban planning and many other activities related to the economy and management of a country. For example it is used in activities like land use planning, environmental analysis, agriculture and forestry, market research, design and utility line documentation etc. [3].

The main core of a GIS is the data base. This feature distinguishes it from computer mapping systems which produce only graphics. All geographic information systems embody some sort of a data base management system [5].

3.2.1 What a GIS is not

A GIS is not just a geographical package which produces maps, although it can produce high quality maps at different scales in colours etc. A GIS must be used as an analytical tool. It has an advantage over other systems because it can relate between different spatial features of a map [5].

3.3 Decision Support Systems (DSS)

A DSS is a computer based system that helps the user to take decisions on semi-structured or unstructured problems. Problems which are subjective and have uncertainty elements and there is no objective way of solving them [15].

The DSS is an improved version of DBMS. The output of a DBMS serves as an input to DSS, but they are different in the sense that DBMS deal with structured problems. A DSS is supported with a data base and decision models such as operation research models, simulation or optimisation models and projection models [7].

Planners at the present time are faced with huge amounts of data. This makes it very difficult to extract the necessary information for decision making. A DSS provides the decision maker with this facility to support the decision making process [17].

3.3.1 Components of a DSS

The major components of a DSS, as illustrated in Figure 3.2, are as follows [7].

- *The Data Base:* contains raw and processed data
- *The Model Base:* carries out data analysis, operations research etc. to output optimal values and difficult decisions
- *The User Interface:* allows interaction between the user and the system.

3.3.2 Spatial Decision Support Systems

There are two types of systems which have been developed in parallel to support decision making. The first is decision support systems relating to management science, and the second is spatial decision support systems which relate to geography. The latter evolved from geographic information systems [18], and have the same components as the DSS. Willer [18] argues that most GIS's have map overlay capabilities but do not support analytical and statistical modelling which are essential for decision making in urban planning.

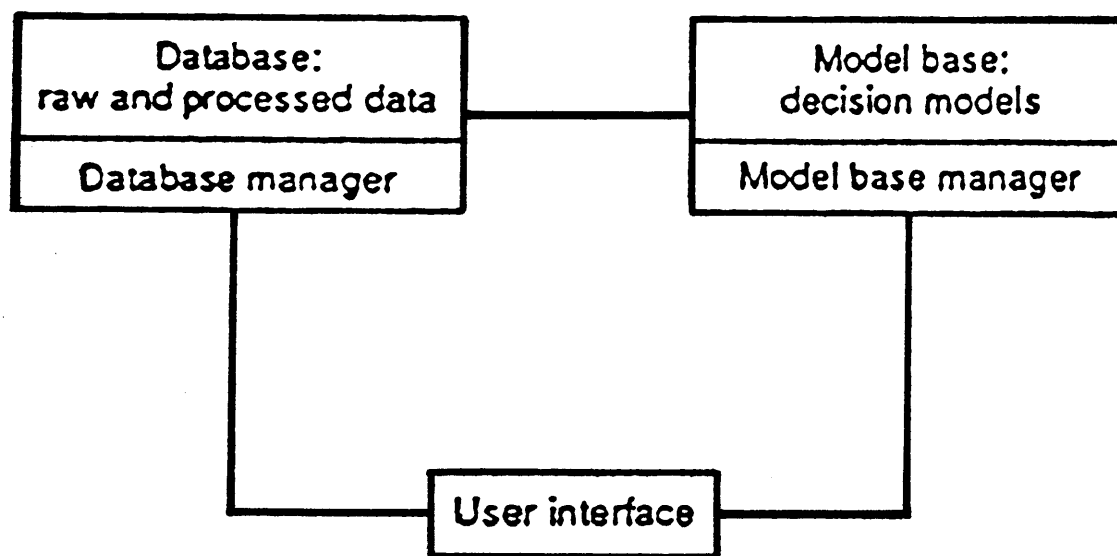


Figure 3.2 Major Components of a DSS
Source: Han, S.Y.; Kim, T.J. (1989). 'Can Expert Systems help with Planning?'
Journal of the American Planning Association, Summer, Vol 55, No 3, pp 298.

3.4 Expert Systems (ES)

Expert systems are considered the most recent and least developed computer systems, compared to the other types of systems in urban planning. Nijkamp and Scholten [15] define an ES as a 'computerised system which utilises knowledge about a particular application area to help decision-makers solve ill-structured problems'. Sharpe, Marksjö and Chen [19] describe an ES as the 'name given to computer software which encapsulates the knowledge of an expert (or set of experts) in a given field, most commonly in the form of if ... then ... rules'.

The components of an ES (Figure 3.3) comprise of a knowledge base which contains facts and rules, an inference engine, which derives solutions by taking the knowledge base through a kind of reasoning process, and a user interface [7, 16].

The knowledge base as per the definitions above, usually stores information obtained from expertise, experience and knowledge. This was called earlier in the report informal information (judgement, experience, human intuition etc.), which has been incorporated into expert systems recently.

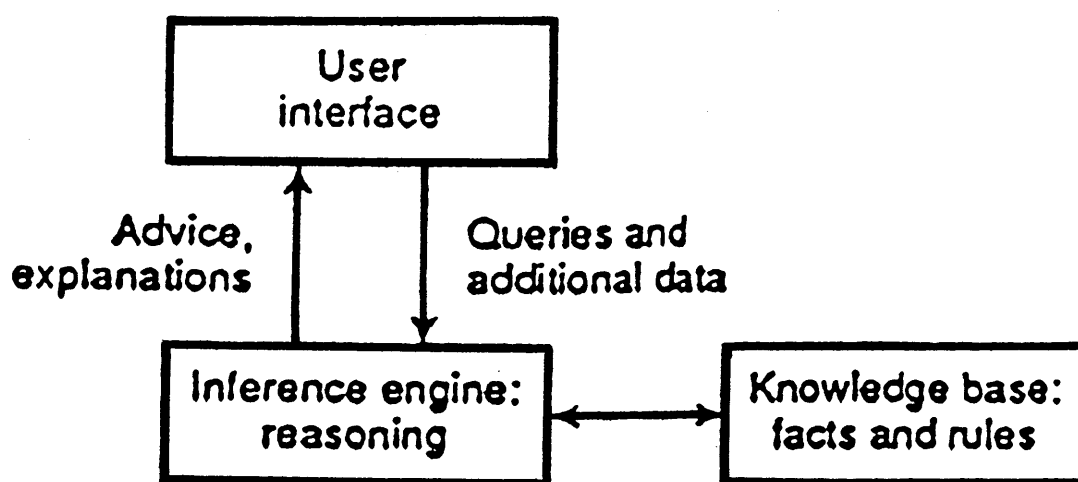


Figure 3.3 Components of an Expert Systems

Source: Han, S.Y.; Kim, T.J. (1989). 'Can Expert Systems help with Planning'. Journal of the American Planning Association, Vol 55, No 3, pp 299.

3.4.1 Advantages of an ES [19]

- *Accessibility:* the users can access the system 24 hours a day, while experts could be available for limited times.
- *Costs and Quality Improvements:* if ES's are properly designed they could lead to many benefits.
- *Knowledge Presentation:* expert knowledge can be preserved and improved if necessary in future.
- *Release of Experts:* Experts can be released to concentrate on more important domains.
- *Knowledge Retention:* Organisations will be able to retain knowledge and expertise, after the experts leave.
- *Training:* ES are used to spread expertise among the staff with less efforts from experts.
- *Multiple Knowledge Sourcing:* ES can provide accumulated knowledge from more than one expert, which increases the effectiveness of the system.

3.4.2 Problems in Developing an ES [19]

- Very expensive to develop and still requires skilled resources to operate.
- Requires long development periods.
- Rapid changes in ES technology.
- Expert systems are at a very early stage. Users must not be misguided by the technology. The results must be checked manually wherever possible, especially at the development stage.
- Maintenance of expert systems is still complex and requires expert knowledge.

3.5 GIS and Integrated Systems

Comparing the different types of information systems in urban planning in the previous sections, it is clear that the most important tool is the GIS as a planning tool. But, for a GIS to become a more powerful and efficient tool it must be integrated with other systems such as DSS and ES.

CHAPTER FOUR

4. GEOGRAPHIC INFORMATION SYSTEMS AND URBAN PLANNING

The use and investment in GIS is spreading among different planning agencies, especially in local governments, because they are the sole bodies who are responsible for urban planning. This technology is considered a great asset for planners because it can 'store, inter-relate, analyse and display an enormous range of spatially referenced information' [20].

The wide spread of GIS is also due to the rapid decline in the cost of computer hardware and the awareness of the importance of geography in the every day life of this world. A great deal of advancement has been made in this field, but still organisational and communication difficulties continue to be the main obstacles even today [5, 20].

Also, another important reason for using GIS in planning is its ability to store data in a digital format. This allows for storage of large amounts of data, which is essential in planning. Also it can retrieve data in greater speeds. In addition GIS has data handling and mapping capabilities unlike computer aided design, (CAD), which produces maps only [2, 16].

4.1 Functions of GIS Components

As introduced earlier a GIS comprises of four components: data input, data management, data manipulation and analysis and data output [2].

4.1.1 Data Input

The data input of GIS consists of two types of data: spatial and attribute data. Spatial data consists of points (oil wells, trees etc.), lines (roads, footpaths, etc.) and polygons, which mean areas (land parcels or any enclosed area). These are called geometric data. Attribute data are non-spatial data and could include, for instance, depth, date of drilling and ownership of a well [1, 7].

Data input is the most difficult and costly phase in starting a GIS. It can take months or years before collecting and digitising the data into the system, so the cost and time required to put GIS in full operation must be accounted for as part of the total cost [2].

There are five means of data entry systems used in a GIS [2]:

- *Keyboard entry*: entering attribute data manually.
- *Coordinate geometry*: use the keyboard to enter the coordinates of points, lines and areas in (x, y) form.
- *Manual digitising*: digitise the spatial features of a map by using a cursor and a digitising table.
- *Scanning*: scan maps automatically into a GIS.
- *Input of digital files*: files which are in digital format can be directly entered into a GIS.

The data input in a GIS are organised in layers as shown in Figure 4.1. These layers can be combined by a GIS to depict the real world.

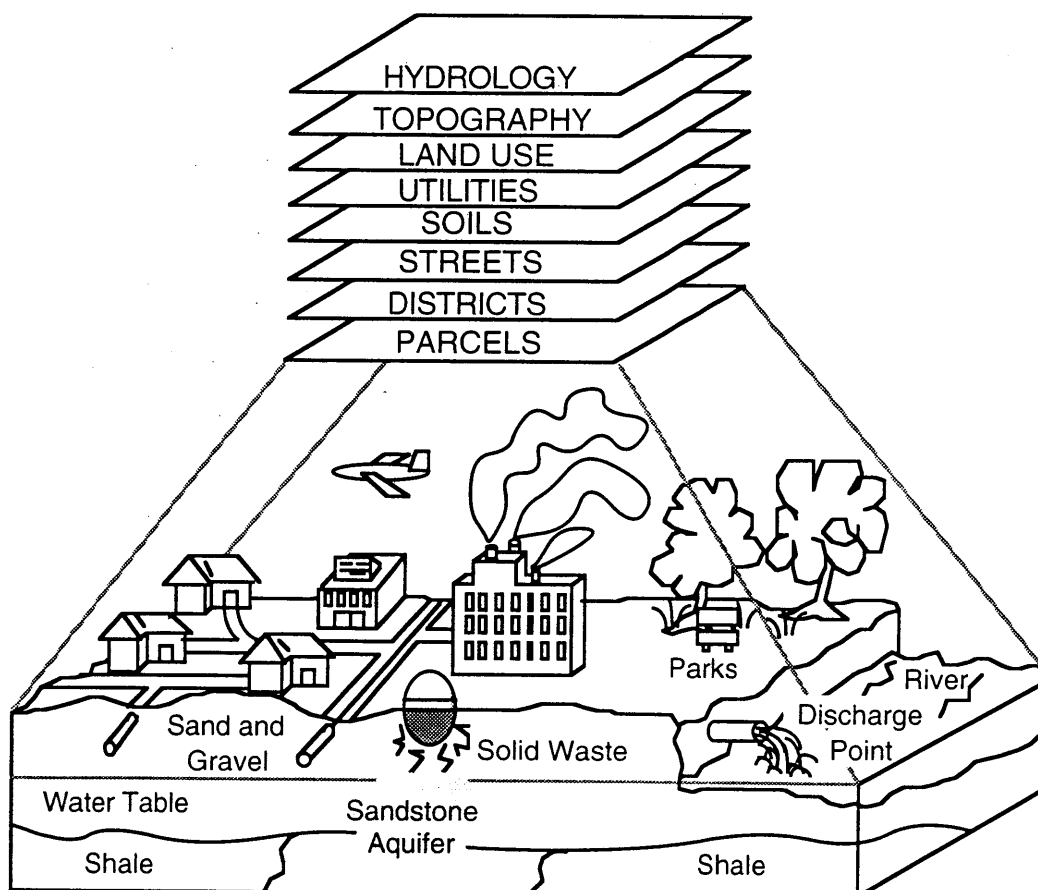


Figure 4.1 Data Input of a GIS and the Real World

Source: Environmental Systems Research Institute (1993): 'Understanding GIS', The ARC/Info Method. John Wiley and Sons, Inc, New York, USA.

4.1.2 Data Management

A DBMS is a major part of a GIS; it includes functions like storing and retrieving data from the data base. DBMS was discussed earlier in some detail in section 3.1. In other fields, such as business, the DBMS can be a stand alone system, but in planning it is part of a larger system and deals with spatial data [7].

A DBMS facilitates for more than one user to work with the system. It also permits to define the data base, store new data, remove old data, modify and enquire about the data base contents. Furthermore, it maintains the security of the data base, so it cannot be changed without authority. It preserves the integrity of the system by checking the data entered to satisfy the internal data constraints. It keeps the data stored in the hardware independently, so when it is changed the user does not notice. Finally it reduces data repetition [1].

4.1.3 Data Manipulation and Analysis

This part of a GIS works in conjunction with the data base contents to obtain new information. For example, if the average slope of an area is required, it can be obtained from the contours which are stored in the GIS data base. GIS can be linked to other systems to allow for more advanced manipulation and analysis in future as technology develops [1].

The GIS data base can mimic existing conditions in this world. To achieve this, the GIS data base model must represent and relate real things in this world. A model may be represented in words, in mathematical equations, or a set of spatial relations displayed as a map or stored in the computer hardware and software of a GIS [2]. Models are valuable in planning because they can be tested and manipulated more quickly and at a lesser cost than actually working with the real situation they represent.

One of the most important functions of a GIS is its capability to predict results of proposed actions. For instance it can predict the effect of closure of a main road on the traffic flow of a city. This ability provides the planner a reasonable opportunity to select the best alternative [2].

To select an alternative is not an easy task. A GIS can provide help partially through its spatial analysis functions, but it cannot give solutions to the part which requires human judgement. This ability can be introduced in a GIS by coupling it with other

systems such as spatial decision support systems and expert systems, as will be discussed further in this report.

4.1.4 Data Output

A GIS can output separate or overlayed (superimposed) maps, which relate various stored information (roads, street lighting, trees, houses etc.). Also it provides a graphical display of spatial data and produces statistical reports [7]. GIS has the capability to link data from different files (layers). This functionality allows for mapping each data layer separately or alternatively producing a combined map of several layers [5]. But, the most important aspect of a GIS is its capability of analytical process and the ability to store back information in the data base for future use [1].

A GIS produces data in three ways [2]:

- *Hard copy*: maps and tables printed on paper, film etc.
- *Soft copy*: graphical and data displays on computer screen.
- *Electronic*: used to transfer data to other computer systems.

4.2 GIS and Remote Sensing

Most information used in a modern urban planning GIS is supplied by remote sensing. The purpose of including remote sensing in this chapter is due to the importance of the technology in enhancing the quality and quantity of data required in the urban planning field.

Remote sensing 'may be defined as the process of deriving information by means of systems that are not in direct contact with the objects or phenomena of interest' [1]. This definition could cover aerial photography taken by aeroplanes to photos and data obtained by satellites orbiting the earth.

Although remote sensing and GIS are both used for planning purposes, they were developed separately. This could have been due to the different technologies involved in each of them. For example, a remote sensing expert deals with sensor systems and image processing methods. While a GIS expert is more interested in map information, spatial analysis and design of data bases. Both systems work to collect and analyse information obtained on earth resources and provide capabilities which complement each other. On the one hand GIS improves the analysis of the data collected by remote

sensing, on the other hand, remote sensing generates high standard information which is essential to GIS [2].

4.3 Types of GIS

GIS technology is applied to many and a vast number of fields. According to a recent article *The Presentation and Analysis of a Spatial Data Using the Computer* in the Newsletter published by the University of Leeds Computing Service [21], the GIS has been classified and ranked by the level of its analytical capabilities:

- *Computer aided design (CAD) systems*: these systems can carry out manipulation of drawings and produce high quality maps in a professional format.
- *Decision support systems*: these are CAD systems which have capabilities to demonstrate the outcome of complicated spatial modelling.
- *Land information systems*: these are used for land and ownership data management and contribute mainly to administrative and legal applications.
- *Automated mapping (AM)/Facilities management (FM) systems*: these were first developed as computer graphics but later developed to handle spatial data [15] in management of utilities (gas, water, electricity, etc.).
- *Global positioning and navigation systems*: these systems are capable of identifying the geographic coordinates of any object on the earth to very high accuracy, by using more than one satellite.
- *General geographic information systems*: these are designed for spatial analysis and data manipulation and they include the majority of functionalities of systems mentioned above.

In urban planning a GIS can only be a useful tool if the last type is used, due to the need for spatial analysis and data manipulation in planning. The above classification does not include expert systems, which are considered one of the most recent technologies and have great promises in urban planning in future. This level of sophistication is required due to the complexity and subjective nature of the decisions involved in urban planning.

4.4 Integrated Geographic Information Systems

As emphasised earlier GIS becomes a powerful and an important tool only when it is integrated with other supportive systems. In the next few sections the intention is to

highlight, in more detail, the research efforts to integrate GIS with spatial decision support and expert systems towards improving the analytical capabilities of GIS.

4.4.1 GIS and Spatial Decision Support Systems

The main function of a spatial decision support system is to aid planners in the decision making process. The system has data and modelling functions and should act as an information specialist. Planners must be capable of applying the system on different planning aspects, such as planning of housing areas, zoning, planning of industrial or shopping centres etc. The system should provide information and must have the capability to model and produce alternatives and finally evaluate the alternatives and display the results. GIS has most of these techniques, but still it does not have the required spatial analysis standards to cope with the planning demands [17].

Vlugt [17] explains that a GIS toolbox contains many functions and facilities which require long periods of training and experience before they are handled properly by planners. A spatial decision support system must be fast, interactive and user friendly in order to be effective. In that sense, it would be much more efficient if it is integrated with only some modules of a GIS and not the entire toolbox.

Clarke [22] gives several reasons for the development of the spatial decision support system and its emergence from the research to the operational stage:

- the advance in GIS technology and capabilities
- the increase in PC popularity, universality and power
- the increase in the amount of spatially referenced data, as a result of advanced data capturing technologies (satellites)
- the emergence of sophisticated technologies and the increasing experience in model applications.

Clarke further argues that GIS applications are currently led by their software technology, and are offered as general purpose tools to users. He stresses that in the spatial decision support systems area, it is important to focus on the 'organisational context of GIS applications and specific user needs' [22]. This, in his opinion, will satisfy and improve the long term analytical applications of GIS.

A spatial decision support system is distinct from other systems in the sense that they are model based systems. When planners want to solve ill or semi-ill structured

problems, they select the appropriate models from the model base to evaluate the data from the data base, and use the output as a basis for their decision making [7].

Spatial decision support systems as stand alone systems are under development or available in a very narrow sense in some fields, like shipping and routing [23]. As an example, if the system is given several routes, the operator interacts with the system, using his experience, until a final route is selected. These systems are built for special purpose applications which makes their development very limited. General purpose GIS cannot perform these tasks. But by integrating spatial decision support systems with larger systems such as GIS, more sophisticated and more complex spatial analysis problems can be solved [23].

4.4.2 GIS and Expert Systems (ES)

To understand and reinforce the idea of integrating expert systems and GIS in urban planning, it is essential to explain the type of knowledge required in the knowledge base of an expert system. Webster, Ho and Wislocki [24] identify the following types of knowledge:

- *Empirical knowledge:* includes statistical, textural and graphical data. Empirical knowledge is divided into three areas:
 - Actual such as survey data and topographic maps
 - Hypothetical such as projections and forecasts
 - Normative goals, preferences and plans.
- *Modelling knowledge:* such as mathematical and statistical analytical techniques, operations research techniques and rule based heuristics.
- *Derived knowledge:* obtained from processing modelling knowledge such as socio-economic indicators.
- *Meta knowledge:* includes formal rules such as selection of the best curve fit for a set of data, and informal rules such as selection of the best control principles for a development scheme.
- *Linguistic and presentational:* this knowledge relates to the user interface of the system.

It is clear that GIS technology is well advanced in handling some of the knowledge above (empirical), but is lacking in regards to the rest. A GIS can gain these capabilities if it is linked to an expert system.

Integration of GIS and expert systems will be a necessity in future. For example, a GIS can identify a suitable site for a particular land use by data overlay manipulations. However, the user must be knowledgeable and expert in his field to establish what is and what is not desirable and must determine the selection criteria. This knowledge can be stored in a knowledge base of an expert system to assist non expert users. Coupling of the two systems will provide more intelligent interface for the user, and will be able to reason and resolve any inconsistent or contradictory information on the part of the GIS [7].

Unlike other fields (medicine, engineering etc.) in urban planning, it is difficult for planners to agree on a solution produced by an expert system. Planners judgements are subjective and differ greatly from one expert to another [7]. This should not discourage planners from looking into developing intelligent information systems. On the contrary, they should be motivated to explore integrating more systems to resolve complex problems in urban planning.

4.4.3 Integration of GIS with DSS and ES

Nijkamp and Scholten [15] in a recently published paper emphasise that one of the conditions which will make information systems effective tools in planning is 'Integration of recent software advances, notably in the geographical information systems (GIS), with modern tools for evaluating urban and regional development projects or programs'.

Before commenting on integration of systems, it must be pointed out that some authors are confused and consider expert systems and decision support systems as being one. On the other hand, there are many authors who distinguish between expert systems and decision support systems. A decision support system provides the user with the necessary information and it is up to him to apply his knowledge and experience to find a solution. An expert system provides the user with expert knowledge and reasoning rules to manipulate and evaluate the data and information provided by the system [17, 25]. Also some ES's recommend courses of action and predict consequences.

Decision support systems incorporate operational research which primarily uses quantitative reasoning, while an expert system in addition involves qualitative reasoning (intuition and rules of thumb). In urban planning, both quantitative and qualitative knowledge and reasoning are required [25].

Considering the above arguments it is evident that a GIS can be an effective tool in urban planning if ultimately coupled with expert and decision support systems.

The integration of GIS with decision support and expert systems is a new technology and is under continuous research and development. There are many techniques for combining these systems but they are beyond the scope of this dissertation.

4.5 GIS and Related Technologies

Vendors of computer based technologies have been trying lately to improve and enhance their systems so that they can be integrated with GIS systems; some of these technologies are (Figure 4.2) [26]:

- *Scanner systems*: these systems can capture data from maps in raster or vector mode and can be input directly into a GIS. Data capture in a GIS has become much more economical than ever before due to this technology.
- *CD Rom/Optical disk subsystem*: major computer hardware vendors offer this system, due to its capability for storing large amounts of data. The optical disk technology is efficient, fast, relatively inexpensive and could be used to store the increasing size of data of a GIS.
- *Raster editing systems*: these systems provide the ability to edit raster images captured by scanning methods. Integrating this technology with the GIS systems will provide the capability to work on vector and raster images on the same work station.
- *Relational data base management systems*: these systems have been used by GIS in the past, but now these systems have extended their function, in order to take advantage of distributed computing environments which have recently become popular. A GIS user can use these capabilities to link his/her data base directly to any or all the relational data bases of the network.
- *Video technologies*: this technology provides for video data capture and display capabilities to be integrated within work stations. The images taken by a video can be stored on a CD Rom or a video disk before linking it to a GIS.
- *Global positioning system (GPS) data capture technology*: this system was covered earlier in the report. It provides high accuracy data from satellites to be entered directly into the GIS.

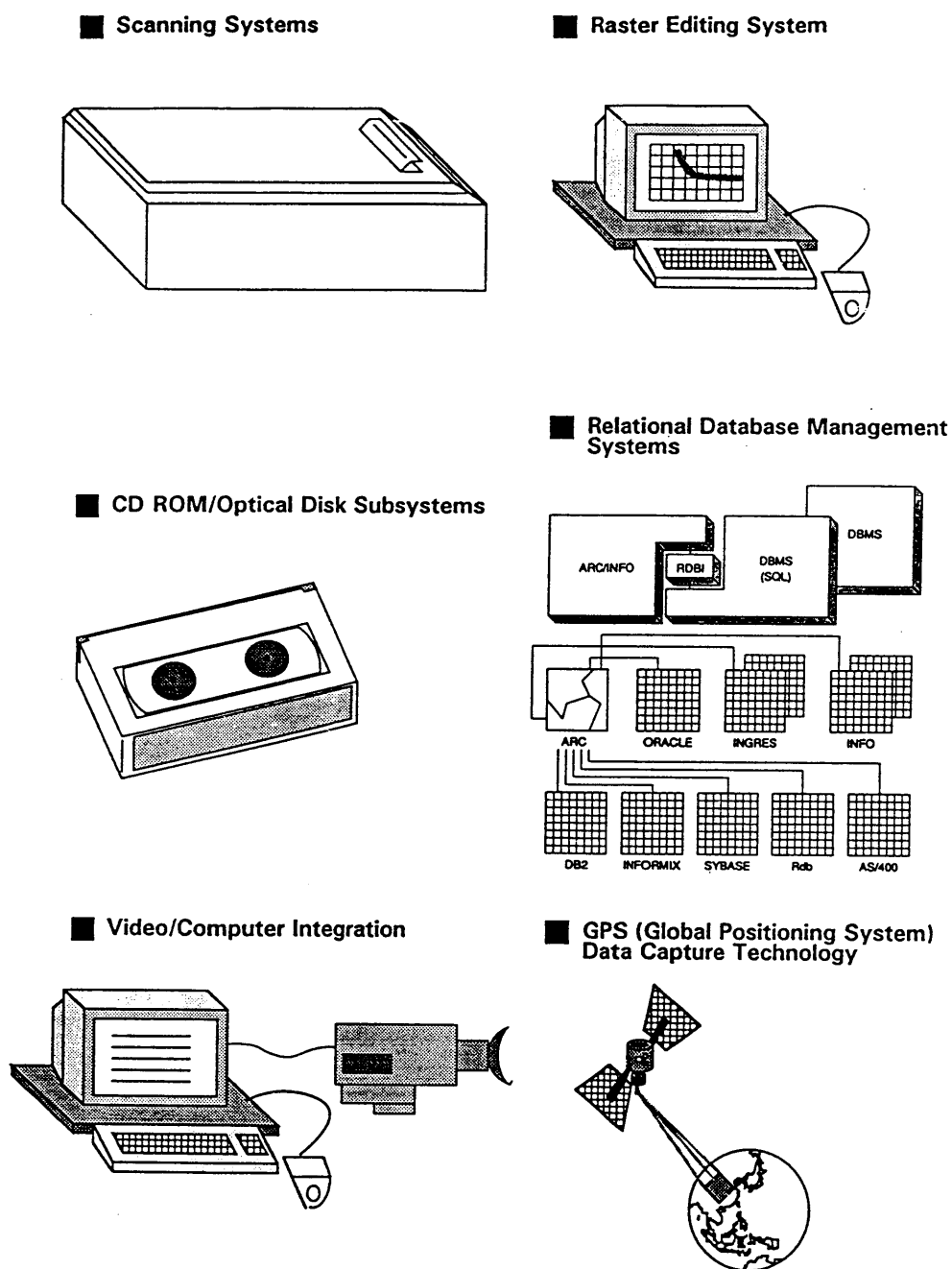


Figure 4.2 Related GIS technologies

Source: Newton, P.W.; Zwart, P.R.; Cavill, M.E. (eds) (1992): Networking Spatial Information Systems. Belhaven Press, London, pp 54.

CHAPTER FIVE

5. NETWORKING GEOGRAPHIC INFORMATION SYSTEMS

Koontz and O'Donnell[27] see that

'flow of information in an organised social system is an essential element for its effectiveness and efficiency. Much of the entire task of managers must be involved in seeing that communications networks and information systems work as well as possible'.

The problem facing many countries, especially the developing ones, is not scarcity of data, more than it is lack of communication of data, which is dispersed among different authorities. This leads to many drawbacks, such as difficulty in coordination, wasting time and money in producing duplicate information, conflicts in decision making etc.

A GIS will be used to its fullest potential if it acts as part of a network, which coordinates the efforts of all organisations concerned in a planning environment. This can only be carried out if there exists, in parallel, higher speed telecommunication systems.

In the computer business, the networking technology is advancing very rapidly. There are vast amounts of current literature and researchers in this field. For the purpose of this dissertation an attempt is made to discuss very briefly the types of networks, matters which relate to data sharing, problems and issues of networking and the GIS network environments.

5.1 Types of Networks

There are five types of networks (Figure 5.1) which are used to link computer systems as described by Pretty [26].

5.1.1 IEEE 802.3 and Ethernet Local Area Networks (LANs)

This network uses a coaxial cable to connect all the stations (computers) on to one single line (broadcast bus). The message transmitted on the main coaxial cable can be received by all stations. It is up to the station to decide which message to receive.

5.1.2 IEEE 802.5 Token Ring LAN

This network uses a twisted pair cabling, connecting the stations in a ring. Transmitted messages can be seen by all stations, but each station is limited to transmitting to the next station on the ring, one at a time.

5.1.3 IEEE 802.4 Token Bus LAN

This type is a combination of the previous two. A token is passed from one station to another forming a logical ring. Only the station which has a token can transmit to the main coaxial cable.

5.1.4 Fiber Distributed Data Interface (FDDI)

This type operates in a similar manner to the second type (802.5 token ring), but is reinforced by a second ring running in the opposite direction, to maintain continuity of stations in case of a line breakage. This system allows for a maximum of 100 km ring circumference network, therefore, it could be used as a metropolitan area network.

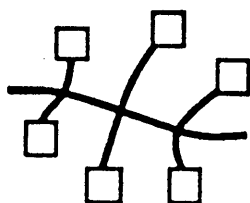
5.1.5 IEEE 802.6 Metropolitan and Wide Area Network

This type of network is the most recent and is unlike the other types. It utilises high speed capabilities which permit higher performance and area cover than other networks. A distributed queue dual bus (DQDB) is used to control the transmission in the rings flowing in opposite directions. When a station wants to transmit to the right, the other stations on the left are requested to give the requesting station a chance to transmit. This leads to efficient and very high speed performance.

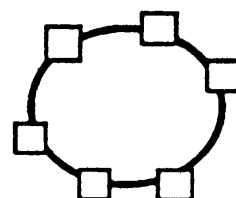
The 802.6 network system is desirable due to its capabilities to handle and carry voice, data and video images.

5.2 Data Sharing

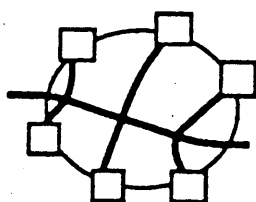
Calkins [26] sees that the drive toward sharing data between GIS users is to reduce costs, eliminate data redundancy and most importantly, a GIS can provide a wider range of spatial data in a network than a single system. Data sharing will effectively improve coordination, increase the capability to manage unforeseen events and improve quality and quantity of information to enhance decision making.



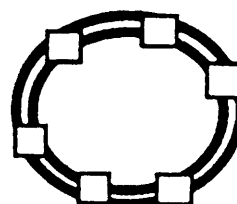
IEEE 802.3 and Ethernet LANs



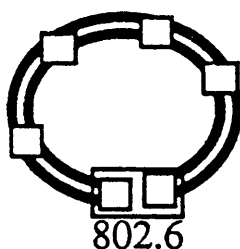
IEEE 802.5 Token Ring LAN



IEEE 802.4 Token BUS LAN



FDDI



802.6

Figure 5.1 Network Types

Source: Newton, P.W.; Zwart, P.R.; Cavill, M.E. (eds) (1992): Networking Spatial Information Systems. Belhaven Press, London, pp 21.

5.2.1 Administration of Spatial Data Sharing

Calkins [26] explains that administration of a spatial data can be implemented in two ways:

- *Centralised data sharing operation:* a central body supports and provides the necessary information to the integrated information systems, located in all participating organisations. This will probably require major changes in those organisations which have adopted their own systems in the past.
- *Distributed data sharing operation:* where each organisation is responsible for controlling and maintaining its own data and information.

The distributed data sharing operation gives an organisation more flexibility and freedom over its data and computer services. To implement a distributed data sharing scheme two distinct bodies are required. The first is a data sharing steering committee (representatives from all organisations) to formulate policies. The second is a data sharing operations office to provide the organisations with services, such as standard maps, assist organisations in implementing data sharing applications and keeping records of comprehensive data required by all organisations.

A centralised data sharing operation is appropriate for situations where organisations have a lot of experience in regard to data sharing programs and have a highly structured administration.

From the above it is clear that distributed data sharing is more suitable for developing countries as a start due to the weak structure linking different organisations. On the other hand, the centralised systems are more appropriate for developed countries who have already gained a lot of experience in handling computerised data sharing systems.

Calkins [26] argues in favour of integrating and locating the databases at a central site for several reasons: the growing availability of computer hardware and software, the advance in networking and telecommunication systems, and the ability to retrieve information without the need to know where the data is stored.

5.2.2 Problems of Data Sharing

Frank [26] refers to problems of data sharing specifically to difficulties in communication between organisations. Organisations have different objectives, standards and type of works. This always leads to difficulties when implementation of

data sharing reaches the detailed stages. It is much easier to share data which are commonly used by organisations. For instance, topographic maps are considered common data sets because they are broadly used and have common definitions.

Calkins [26] emphasises that it is important to address problems which are related to data sharing, in order to create a healthy organisational data sharing network. He refers to the problems and issues of data sharing to several points:

- *Access*: the system must be able to access only authorised users, to maintain data confidentially where required, and to protect data and prevent changes.
- *Cost recovery*: the cost of data provision must be recovered from the participating organisations.
- *Data documentation*: the amount of data to be shared is dependent on the amount of data documented by each organisation. Maintaining documentation at an appropriate level by the organisation or the data support unit is essential.
- *Liability*: data sharing must be in accordance to an agreement between the different parties involved. It should define the responsibilities of each party when exchanging or providing services.
- *Inter organisational agreements*: there should be an agreement between different departments of an organisation on data sharing procedures, before agreements with other organisations.
- *Legal authority*: the data sharing community must obtain state authorisation. This will define the scope of their activities and will help set procedures for cost recovery from different government agencies.

Therefore, most of the problems relate to organisational reasons. GIS and the telecommunication technologies are advancing very rapidly and soon will have the ability to allow for data sharing with minimum delay and costs, which will convince and lead organisations in the path of data sharing.

5.3 Integrated Distributed GIS

The recent trend is to use distributed computing systems capabilities, which allow several organisations to share data (Figure 5.2) using Ethernet networking. The necessity to improve the day to day operations, encourages improvement of these systems even further by integration of these technologies into a centralised system (Figure 5.3). The system will comprise a large file server or a combination of file servers which will be capable of storing data and information captured or processed by

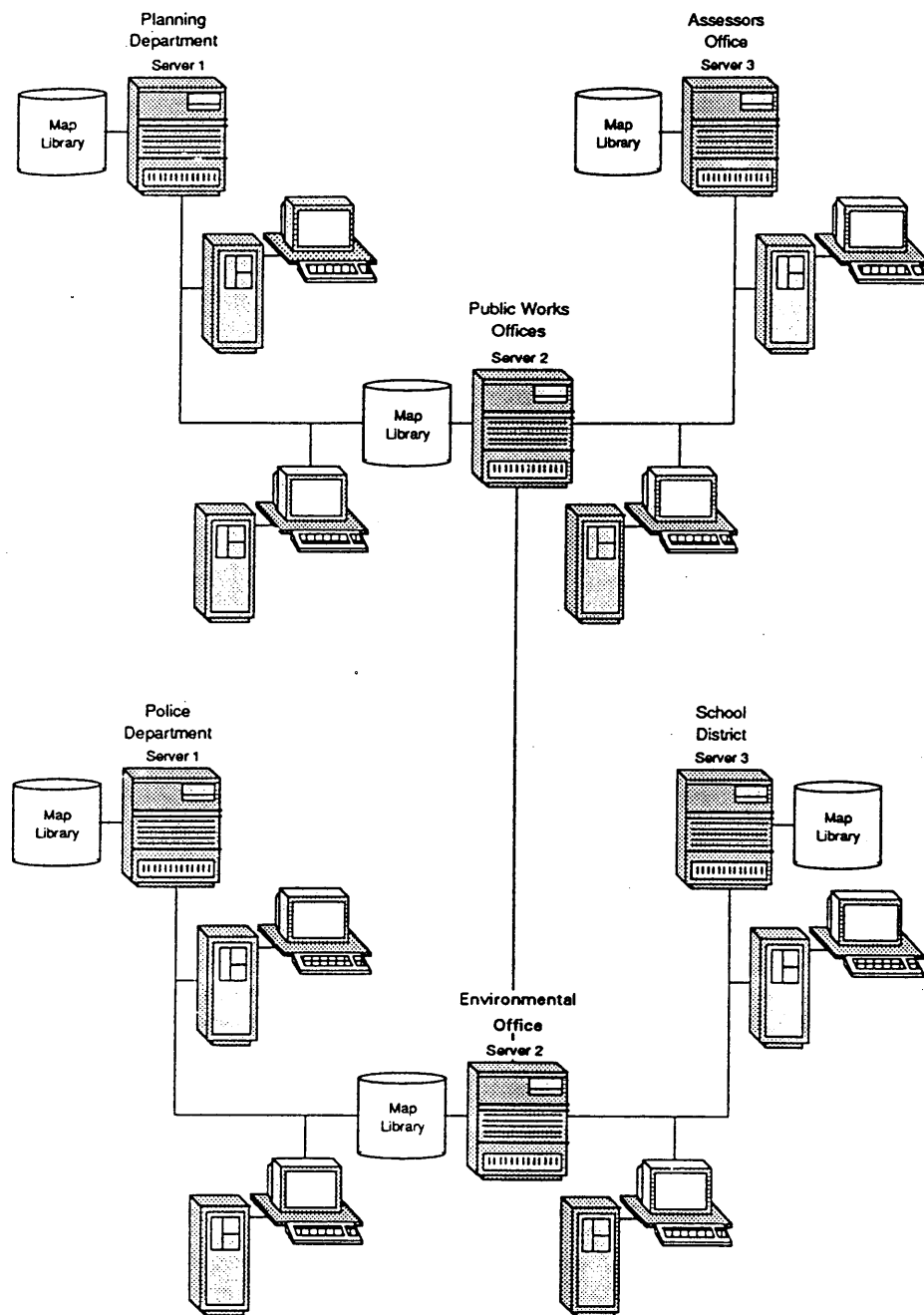


Figure 5.2 Distributed Computing Systems
 Source: Newton, P.W.; Zwart, P.R.; Cavill, M.E. (eds) (1992): Networking Spatial Information Systems. Belhaven Press, London, pp 59.

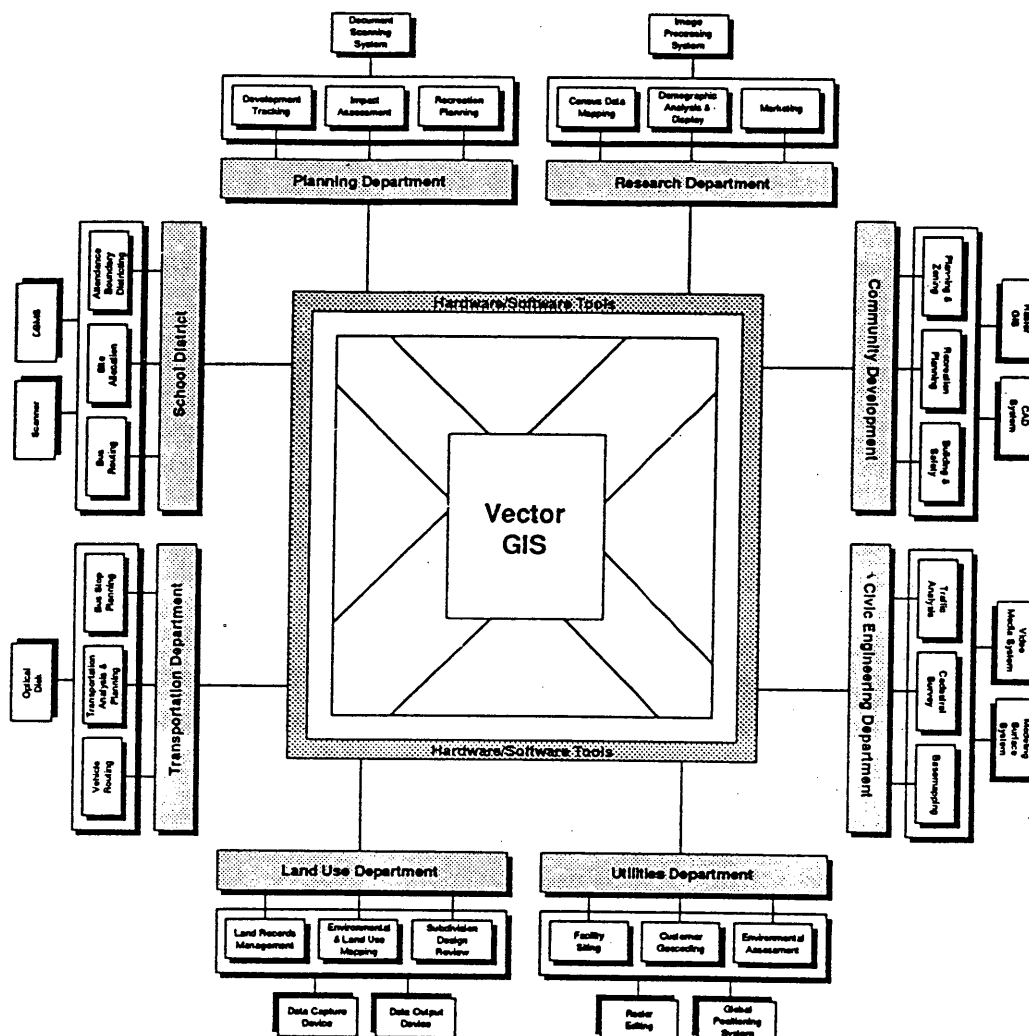


Figure 5.3 The Integrated Distributed GIS Environment
 Source: Newton, P.W.; Zwart, P.R.; Cavill, M.E. (eds) (1992): Networking Spatial Information Systems. Belhaven Press, London, pp 60.

the distributed data bases. In such systems, for example, data developed by an engineering department can be fully accessed by the planning department and could monitor any recent changes from their workstations [26].

The centralised system is an ideal situation for urban planning environments, but there are many issues to be tackled when it comes to implementation. Planners must participate in expressing their needs and must cooperate with the GIS designers to adapt GIS technologies to the environments of planning organisations.

5.4 Concurrent Engineering Environment

Concurrent engineering, which is also known as simultaneous engineering, and parallel engineering, is defined as 'a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support' [28]. In order to implement concurrent engineering, an organisation must consider all the elements of a product life cycle, from the development to the disposal stage. It should also include related elements such as quality, cost, schedule and user requirements. This approach is essential for companies wanting to be successful in the world market. It has been used by many well known private companies in the US, such as Xerox, Ford, Digital, IBM, Hewlett-Packard etc. [29]. The concurrent engineering approach was first developed primarily by private companies during the beginning of the 1980's due to high competition and the increase in product complexities [28].

Concurrent engineering environments must satisfy and balance the following four interlinked dimensions [28]:

- *Organisation*: consists of managers and product development teams.
- *Communications*: a sound communications infrastructure leads to better sharing of ideas and feedback.
- *Requirements*: the company ensures that the product will always satisfy the customers requirements, which will lead to maintaining a high standard of design.
- *Product Developments*: this activity involves the design and test of a product to the satisfaction of the customer, before production.

Adding to the above, White [29] describes the key criteria for a successful concurrent development in a company:

- 'Top level management must have, as a minimum, a five-year vision.
- An outside person should serve as an expert consultant.
- Management must stay out of the project's team and empower them to act on their own authority.
- Employees must be involved via training and corporate programs.
- Cross-functional teams are a must.
- Goals should be kept simple.
- Measurable quality results must be established and achieved.
- Quality training techniques should be customised to suit an individual company's culture.'

The above is a very brief description of concurrent engineering in a business environment and sounds alien to urban planning. But the main purpose of including it in the report is to seek future possibilities of taking advantage of these approaches and applying them in urban planning. Also it is to elaborate on the second dimension 'communication', which could be relevant to the reports' subject.

Production companies applying automated concurrent engineering concepts have reached the stage of implementing inter-operable systems. This system allows multiple users to have access to the original data and make a change to the data, which will be shared by the whole network in the company. This functionality permits users to share design activities very efficiently with minimum time waste. In a concurrent engineering environment the time saving could reach up to 40% [28]. The concepts are particularly relevant to fast track projects.

This technology is ideal for urban planning, but implementing it is another thing. The system can be efficiently used and would be successful if used within one organisation. Urban planning, as mentioned earlier, involves various activities and many government agencies and it is a slow process. This adds many complexities to the problem of adapting concurrent engineering as a network for all planning agencies involved in urban planning.

CHAPTER SIX

6. APPLICATIONS OF GIS IN URBAN PLANNING

Geographic information is a common reference for many governments and agencies which offer services to the public. The use of GIS in urban planning covers a wide range of applications which are becoming more sophisticated as the technology develops. The following sections will outline some of these applications in the urban planning field, to give the reader an insight into the facilities provided by a GIS.

6.1 GIS as an Analytical Tool

One of the most important aspects of planning is to relate and adapt it to the people's needs. This becomes a critical element in preparing plans for new urban areas which will be occupied by people from a previous community. In order to achieve a suitable plan, planners must study the behavioural pattern of that community.

Shalaby [30] describes an application of GIS, used to analyse social activities in Gormsheen Village, located in Southern Egypt. The study was part of a large research carried out by Nottingham University. The main aim of the research was to find the possibility of maintaining and incorporating social behaviours and values in new housing developments in El-Kharja Oasis in Southern Egypt.

The GIS can provide spatial, social and temporal analyses of behavioural patterns:

- *Spatial dimension:* is concerned with studying relations between activities and their locations.
- *Social dimension:* examines the social behaviour of humans in relation to the village building's structure.
- *Temporal dimension:* is concerned with how people pass and spend their time on a daily, weekly, monthly and/or yearly basis. It describes and analyses the sequence, duration and time spent on activities. Also the analysis shows the way spaces are used at different times which could indicate the efficiency of a facility or a new one should be added.

The GIS can offer analytical facilities of the above three dimensions, which is almost impossible to be carried out manually. To accomplish the research, Shalaby first digitised the map and details of the village (a total of three villages were studied) into the computer, to produce a base map (Figure 6.1), then the collected data was stored and analysed.

The activities were recorded by observation, 6 times every day for 8 days (48 sets of observations). Each set represented behaviour at a particular time. The details recorded included:

Temporal: date, time, weather, temperature
 Social: sex, age, number, kinship and neighbouring relations
 Body posture: sitting, standing, walking, running and riding
 Speech: silent and talking
 Purpose: socialising, playing, shopping, fetching water etc.

The 48 sets of observations were stored on 48 layers in the computer, and each layer was linked to behavioural details in the data base (Figure 6.2).

The GIS was used to manipulate and analyse the spatial, social and temporal layers, to show event positions and to produce a table indicating statistical analysis. A user could investigate a wide range of questions, such as what is the most frequent activity; who was involved (men, women, children, neighbours, relatives); which places were mostly used for this activity; and when was the peak hour (day and time).

For example, in the case of Gormsheen Village, the most frequent activity was social communication between the villagers. It represented 82.5% of the total. The output map indicated that the majority of social events took place near the entrances of the houses [30]. These findings help planners to cater for these requirements upon planning a new village in the region.

Shalaby described his study results in much more detail, which cannot be addressed within the scope of this report.

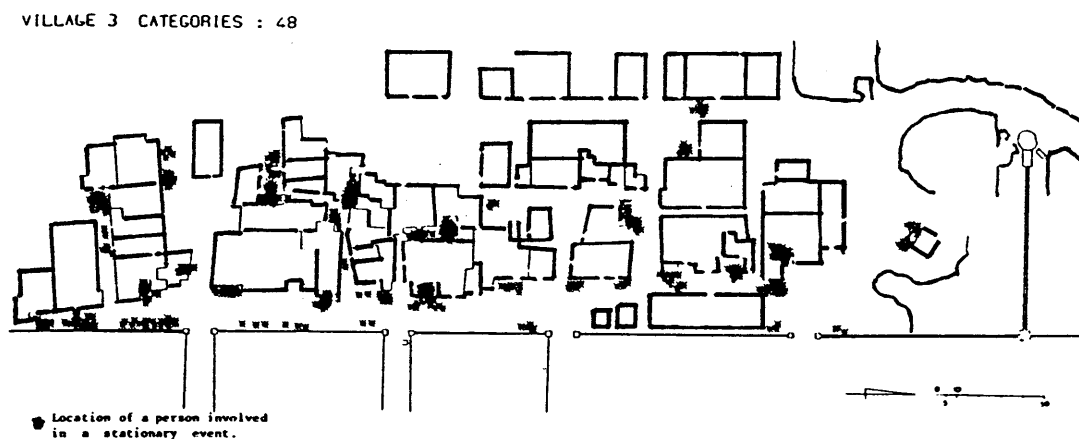


Figure 6.1 Gormsheen Village Base Map

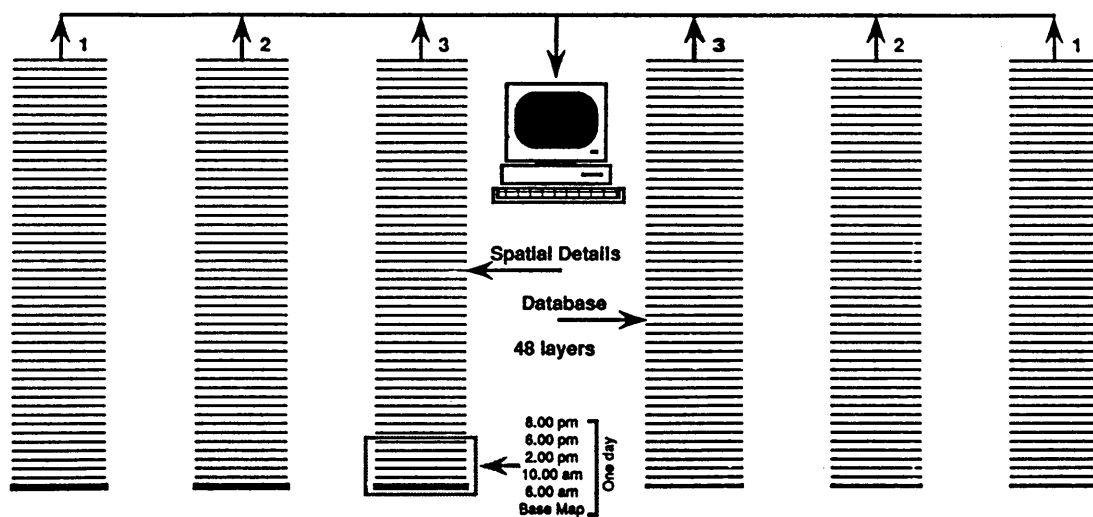


Figure 6.2 Data Organisation for the Three Villages

Source: (Fig 6.1 and 6.2): Shalaby, M.T. (1991): GIS in Behavioural Analysis and Activity Systems. Planning Studies, University of Nottingham Second European Conference on Geographical Information Systems, Vol 2, pp 1012.

6.2 Library Facilities Planning

The GIS is considered one of the technologies which has a great potential for research and application in the field of service locational planning [31]. A simple application of library facility planning by the City of Milwaukee, USA, is described below [1].

The intention of the library officials in the City was to find out the need for building an additional library facility in the north-west of the city in addition to the four existing libraries and one extended service library.

The Planning Department was requested by the library officials to study the need, and come up with a recommendation. The standard population that a neighbourhood service library can serve is 60,000 and an extended service library can serve 70,000.

The Planning Department used the City's GIS to carry out the task. First, the existing five libraries were located on the map (Figure 6.3). The user interacted with the system until circles with the nearest catchment populations (as close as possible to 60,000 or 70,000) were created around the libraries. Population of the City blocks were provided by the GIS data base.

Some of the circles overlapped indicating over serviced areas, and some areas were not covered. The user created polygons around the unserved areas to find the population. The overserved population was found to be much larger than the unserved population. As a result the final decision was not to build an additional library.

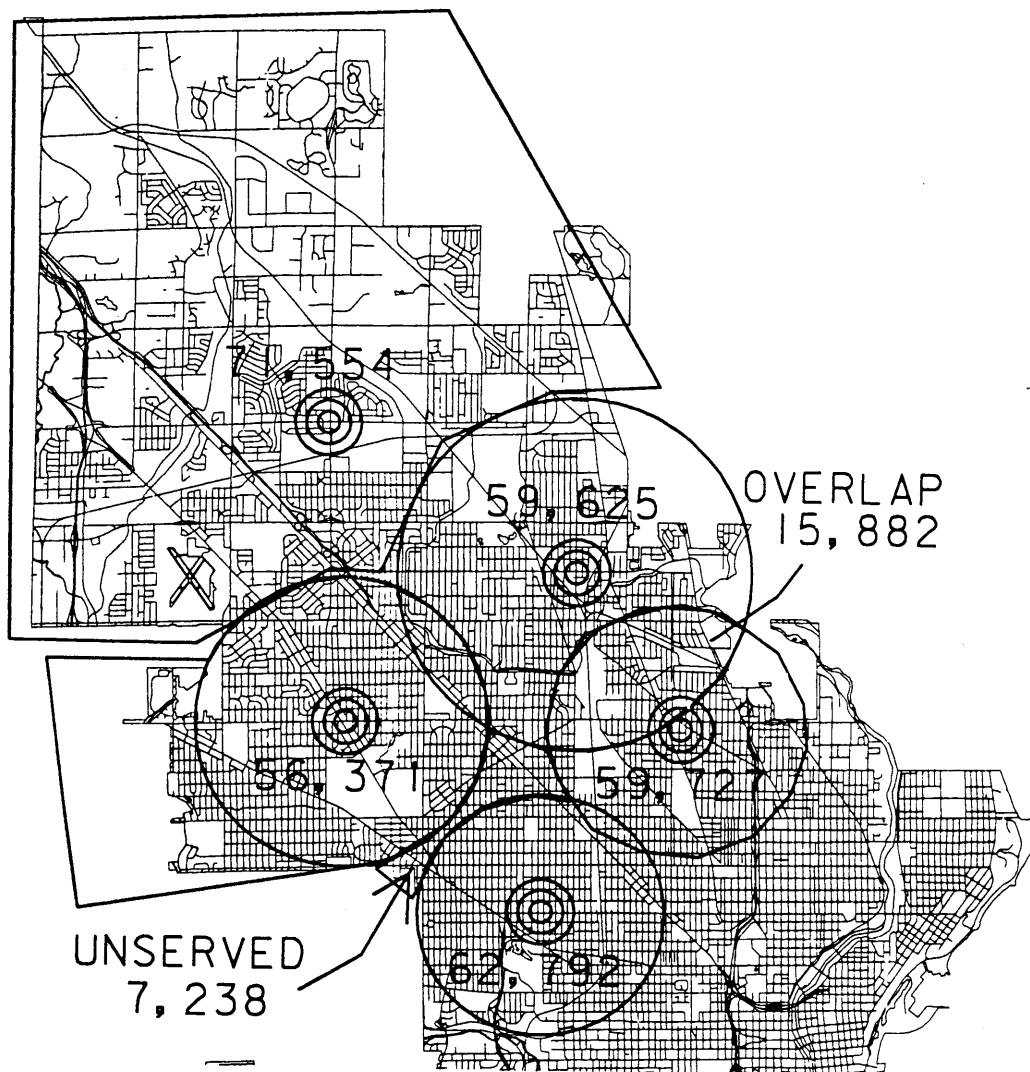


Figure 6.3 Library Facilities Planning
 Source: Huxhold, W.E. (1991): An Introduction to Urban Geographic Information Systems. Oxford University Press, New York, pp 123.

6.3 Forecasting Road Side Development

An expert system for forecasting road side development has been developed by Edamura and Kawai [2, 8], using the Japanese expert system 'sogen'. The system can operate on a personal computer, which makes the software available to a wider number of planners and engineers.

The system has been applied to Kobe City in Japan. The knowledge base (Figure 6.4) is constituted of three sub systems:

- *Subsystem 1*: rules related to road type.
- *Subsystem 2*: rules related to legislative control (land use, planning laws etc.).
- *Subsystem 3*: rules related to road side development (include final judgement on most appropriate buildings based on experience of experts and the socio-economic issues of the area).

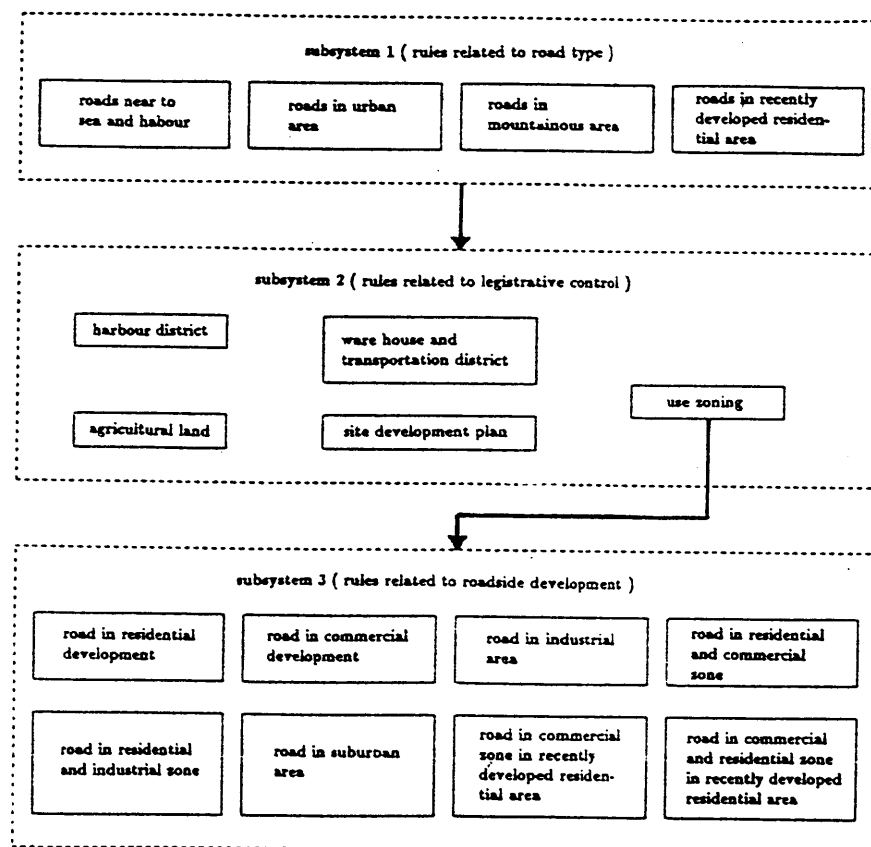


Figure 6.4 Composition of the Knowledge Base

Source: Edamura, T.; Kawai, T. (1991): An Expert System for Forecasting Road Side Development. Computer, Environment and urban Systems, Vol 15, No 3, pp 147.

6.3.1 Input Information

The user must input information requested by the expert system, which include: expected traffic volume, road type, number of lanes, road classification, existing land use, regulations, future land use plans, proposed sites for future services etc. The queries are programmed in a multiple choice form.

6.3.2 Output Information

The final outcome of the system not only defines the land use in the broad sense of being residential, commercial etc., but also further divides them into more detailed classification. For example, residential will consist of single family or multi-family residential; industrial will consist of factory or warehouse and so on.

This is a very brief description of the system. For more details the reader can read reference [32].

This expert system is designed as a stand-alone system to serve a particular purpose in planning. There are many other expert systems built for individual special cases like the above. For instance expert systems have been built for zoning [33], urban and building planning and management [19], facility planning and management [25] etc. Merging these powerful systems with the capabilities of GIS will produce indispensable tools for planners in the future.

6.4 GIS and Decision Support Systems (DSS)

In applications where simulation, optimisation and model based DSS are used, large quantities of information are required. This in itself limits the use of these systems. Merging DSS with GIS can provide the required background information and automatically downloads the data relevant to the model. Also a GIS is an excellent tool for graphical interpretations and display.

The Dutch Ministry of Housing, Physical Planning and Environment, developed an advanced computer package (Safeti) for risk assessment, by merging GIS and DSS. The system can provide facilities like display, evaluation and comparison of alternatives and scenarios. The alternatives obtained from modelling can be displayed against detailed geographic background data. For example, different scenarios representing transportation networks, pipelines, population etc. are displayed over a basic land use

map. This way the risk analysis can be performed on various and large numbers of options (Figure 6.5) and could lead very effectively to the selection of options [3].

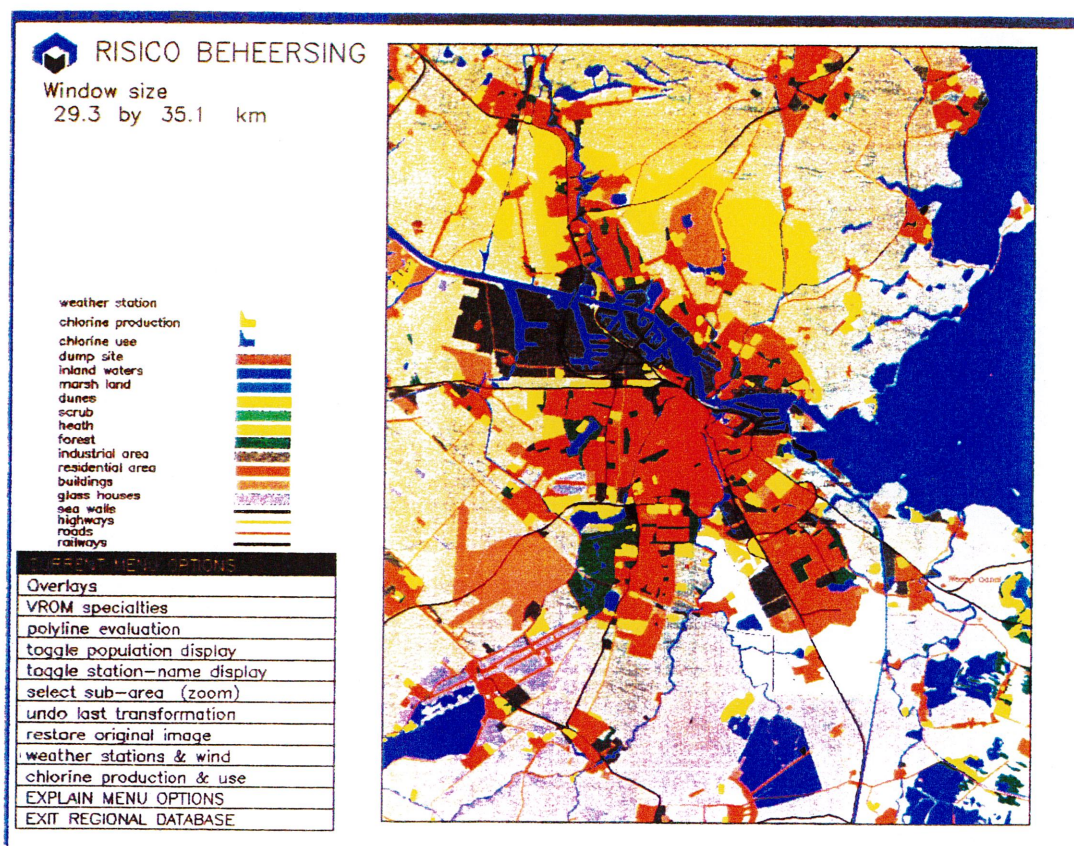


Figure 6.5 Risk Analysis of Policies Using GIS/DSS

Source: Scholten, H.J.; Stillwell, J.C.H. (eds) (1990): Geographical Information Systems for Urban and Regional Planning. Kulwer Academic Publishers, Netherlands.

6.5 GIS and Artificial Neural Networks

The accuracy of geographic information and in particular land use and land cover in a GIS are considered highly important for urban planning programs. Planners and engineers have continuously sought to improve remote sensing capabilities, to enhance earth data capturing [34], which enables the GIS to produce high accuracy maps.

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Recently, artificial neural networks have been researched and applied to the remote sensing field. But before talking about its application, a brief introduction is given.

Neural networks emerged as a branch of artificial intelligence, which is concerned with emulating the biological process of human thoughts [35]. Civco [34] defines artificial neural networks as 'models that attempt to parallel and simulate the functionality and decision making processes of the human brain'. This technology is still in its infancy stages, due to the limited understanding of the human brain. Neural networks consist of input weights, processing elements and output corresponding respectively to synapses, neurons and axons of a human brain. The inputs and the weights in a processing element are analogues to the dendrites of a human brain. The inputs are summed together by a mathematical function, and an output is produced after going through the transfer function (Figure 6.6).

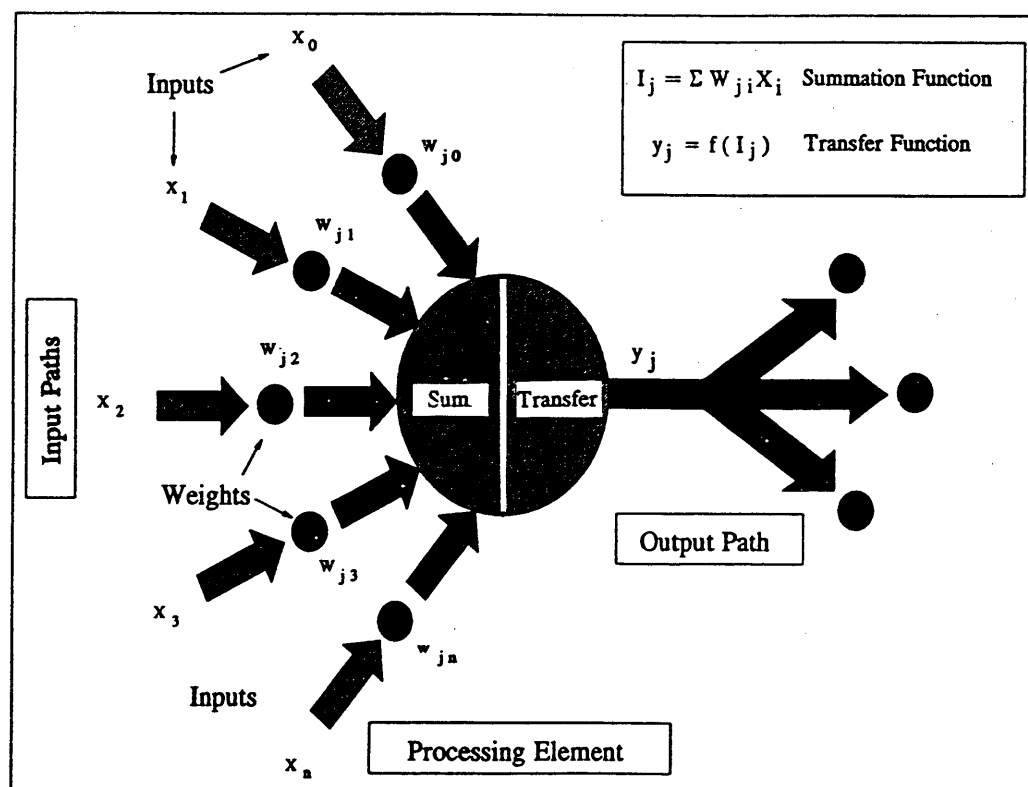


Figure 6.6 Artificial Neural Network Processing Element
 Source: Civco, D.L. (1993): Artificial Neural Networks for Land Cover Classification and Mapping. International Journal of Geographical Information Systems, Vol 7, No 2, pp 175.

Neural networks (Figure 6.7) consist of three or more layers [34]:

- *The input layer:* consists of one or more processing element which also acts as the element for the input of training data.
- *The hidden layers:* consist of processing elements to transform the input data into output information.
- *The output layer:* consists of processing elements which store the results of the network.

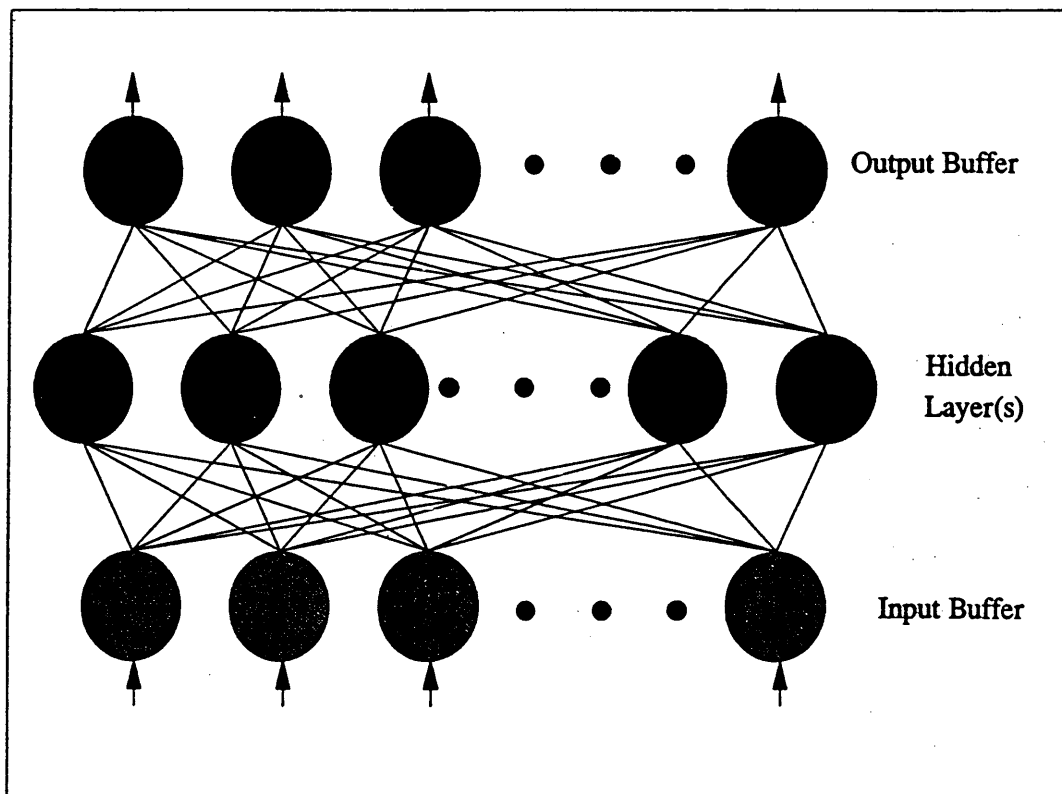


Figure 6.7 Artificial Neural Network
 Source: Civco, D.L. (1993): Artificial Neural Networks for Land Cover Classification and Mapping. International Journal of Geographical Information Systems, Vol 7, No 2, pp 176.

A fundamental and important factor that makes this system distinct from others is its ability to self-learn or learn through training [35].

Neural nets have been applied to many fields including speech recognition, data compression, pattern recognition etc. and many other fields. It can be used to reduce and dispose repetitive and undesired data and keep the worthy and important information [36].

Neural networks have been applied in remote sensing for the purpose of land cover classification. The input data consists of the different brightness values of the spectrum colours (seven, including infra red). This requires seven input nodes, each representing a colour band. The input patterns could also include elevation, slope, soil type, zoning etc. The hidden layer could be one or more layers consisting of processing elements, which transform the input data into land cover classifications (output) [34].

One of the problems which restrict neural networks is the data storage limitations. In complicated evaluations a large number of simulation and optimisation processes are required. The human brain is thought to contain 10^{11} neurons while present computer systems consist of 10^3 . But with the rapid advances in computer technology it is hoped that computational speeds will not be a problem in future [36].

CHAPTER SEVEN

7. IMPLEMENTATION OF GIS AND DIFFICULTIES

For a successful implementation of GIS, Innes and Simpson [20] take the view that 'planners must understand GIS as a socially constructed technology, including not just hardware and software, but also the practices, laws, organisational arrangements, and knowledge that are necessary for its use'. The authors further argue that many of the obstacles that hindered and are still hindering GIS are communication and organisational problems.

Polydorides [12] takes a view which complements the above view. He considers organisational and manpower important factors in applying computerised information systems in a planning process.

All observers agree that consideration of organisational and technological issues is important for implementing a successful GIS. Huxhold [4] summarises these issues into three categories: 'Evaluating geographic information needs, gaining organisational support and managing the GIS project'. Polydorides [12] adds to these, other factors such as that the organisation must practice a rational planning process, develop hardware and software on a piecemeal basis and finally conduct 'relevance tests' to check that input and output data are relevant. In the following sections some of the mentioned issues will be discussed in more detail.

7.1 Evaluation of Geographic Information Needs

It is essential that an organisation has full awareness of how its departments function and what type of geographic information they use, in order to take full advantage of GIS potentials. The GIS use must be consistent with the long term goals of the organisation. A proper plan will incorporate not only the concerned organisation goals, but also the needs of other related planning authorities to obtain maximum benefit nationwide. This will improve data sharing within an organisation and with other organisations [4].

Identification of geographic information needs of different planning authorities is crucial for implementing a successful integrated GIS. One simple example is map utilisation. Efforts should be made to figure out what type of information, scale etc. the planning authorities use for their maps. As mentioned earlier, planning is a multi-disciplinary decision making activity, which involves many people. Different

authorities might have their own data sets and systems, which have been developed over many years and in many cases they are non-compatible. Innes and Simpson [20] argue that the greatest challenge for implementation of a 'GIS' is to achieve compatibility. This will require the cooperation and coordination among agencies which do not work together and in some cases might be in conflict.

7.2 Gaining Organisational Support

Implementing a GIS in an organisation demands high costs and long term commitments. To justify its use it must be demonstrated that the benefits will be greater than the cost involved in implementing a GIS and maintaining it in the long run. The cost/benefit analysis of GIS, like any other computer system involves the short or long term costs of hardware, software, application programs, education and training and conversion of data into the digital format, and comparing it to the savings which the organisation will make once the system is operational. It has been found that the cost of digitising data is far higher than the hardware and software costs [4].

One way of gaining the organisations support is by carrying out a pilot project on a small geographic area to show the key personnel the capabilities and benefits of a GIS. Demonstrating that a technology pays off early is essential to build confidence. This will ease the decision of budgeting the system [37].

The planning institutions have been very hesitant in the past to implement GIS for two reasons, in Polydorides opinion [12]. The first is that many institutions have been involved in routine activities for many years and they resist any use of new technology to do an old job. The second, is that many professional staff, working in urban planning authorities, have not been exposed to the use of computers for urban planning applications during their educational years. This lack of information created mistrust and reaction to such technologies. The people within an organisation as a whole must be aware of the benefits and potentials of implementing a GIS in their organisation. The top management must express overt support for this.

7.3 Rational Planning Process

A rational planning process is very important, as mentioned earlier in subsection 2.2.1, in order to benefit from GIS. It must be 'a well structured process, with clearly defined objectives and procedural regulations. A process easily repeatable over time, with the

same rules and procedures, more or less independent of the problem or of the planner' [12]. The idea is not just using a computer system but it is mainly to incorporate it within the planning process. In other words, what is required is not a new map, but what planners should really look for is a map which involves the planning process.

7.4 Hardware and Software

The most appropriate procedure for GIS implementation in an organisation is the carefully phased development, that is to expand the information content of the system gradually responding to the planning process needs. This concept also applies to the development of the hardware and software of a GIS. This is particularly true nowadays due to the rapid computer advances and continuous drop in hardware prices [12].

In selecting the hardware and software many important questions must be asked to fulfil the organisation's requirements. The sort of questions that should be asked are, *will the hardware and software provide the capacity and functionality required; will the system be compatible with other systems;* and the most important question of all is, *will the hardware and software allow for future expansion of the system.* Obviously it is not wise to purchase a cheaper system that will lead to a dead end, while the technology is advancing [38].

Like any new computer system the GIS is used to perform old jobs in an organisation. As the staff get more familiar with the new technology, new ways are discovered for performing the same functions, taking advantage of the new system. A GIS at the beginning is used for data storage and retrieval. Later the interest will be more in analysis. Finally, management of the system will be the main concern [2]. Therefore, acquisition of software and hardware must be implemented in accordance with these phases.

7.5 Training and Education

A geographic information system will only be successful if it is operated by trained and educated personnel. Recently, due to the fast development of the computer technology and its availability to 'non-expert' users, the engineers, architects and planners are becoming more aware and capable of handling computers and advanced programs. This is true, but does not mean that the problem has been eliminated. In

fact there is still a big gap between planners and computer applications in many planning authorities.

Millette [39] takes the view that distinguishes between training and education. Training is a short intensive process which is performed in a compressed period. The main objective of training is to teach the trainee some basic functions to operate a new system. On the other hand, education is a much longer process. It provides the staff with general theoretical instructions so that they gain a wider knowledge based on the subject. For instance, an organisation has to educate the planning staff, in order to be able to integrate 'GIS techniques into planning problem solving'.

Therefore, it is important to train and educate planners to ensure successful GIS implementation.

7.6 Relevance Test

The relevance test is one of the prerequisites for a successful GIS. From the start, every single data analysis and application must be checked whether it is applicable and relevant for current and future uses of the system. It is a mistake to think that the more information stored the better is the system. The real challenge is to select and store only the relevant and useful information for more efficient GIS [12].

7.7 User-Friendliness of GIS

Most geographic information systems are complex systems [2], and require a lot of practice before one is able to work with the system. User-friendliness of GIS is a very important issue, yet the problem has not been addressed thoroughly by researchers and GIS designers.

Ady and Currie [40] emphasise the above point by stating that,

'GIS is a general tool for the manipulation of spatial and attribute data. In this form a GIS makes considerable demands on the user. To make effective use of a GIS a user must understand their own discipline, GIS concepts, and operation of GIS software. These requirements restrict effective use of GIS to a very small number of people. To be considered relevant to the majority of the users, future GIS environments must provide useful information without the excessive training requirements currently required'.

They argue that in other disciplines the professionals interact with their systems using tools which are conditioned to the education they received. What is required from a GIS is a user-friendly interface incorporating planners' education and profession. This will enable the planners to work with a GIS more easily and with less training.

CHAPTER EIGHT

8. CONCLUSIONS AND RECOMMENDATIONS

The world is becoming increasingly dependent on data collection and analysis of geographic information, in an effort to plan for improved environments. Planning of human societies involves many activities, which concern many authorities and the public. Planners now face the analysis of intricate information and complex decision making processes due to the continuous growth of various sources of information. Appropriate planning can only be achieved through following a rational planning process, and by coordinating the inputs of the different agencies involved in a planning environment.

The progressive rise in the complexity of the planning process has convinced many managers that it cannot be handled efficiently any longer using manual procedures. They have begun to accept that effective and accessible information systems are now vital for enhancing the performance of planners and are essential in aiding them in decision making.

Urban information systems have been classified into four main types in this report: DBMS, GIS, DSS and ES. These systems offer many facilities to planners, which could range from simple data storage and manipulation to sophisticated applications such as analysis of alternatives and expert advice. But, among these, GIS is considered the most common among planners due to its suitable functionalities for this field.

Geographic information systems are very useful and powerful tools for analysing and inter-relating different information from diverse sources. It can be used to assemble and apply geographic information in new ways. This technology has totally changed the way geographic information is produced and updated. A map which took months to update in the past, now can be done in hours. The GIS also has spatial analysis capabilities which makes it a par excellence tool for urban planning.

The GIS has developed very rapidly over the past two decades. This fast advance was technology driven, with a much slower pace in the institutional side. This was mainly due to organisational and communication obstacles. It is only recently that organisational issues have been addressed, as a result of the awareness of GIS potentials and its role in creating data sharing environments, which could not have been achieved without the latest technologies in the networking of computer systems.

8.1 GIS Technology

The rapid development of GIS technology and the increasing demand to pursue it, created a highly competitive market between the vendors. This resulted in a continuous fall in the cost of hardware while the software cost remained steady, because of their growing complexity and sophistication. These reasons, together with the increasing knowledge of users about GIS uses, were the main drive behind its technological advancements.

The present GIS's have the capability to capture, store, update, manipulate, analyse and produce geographic information in both soft and hard copy forms. These capabilities encouraged the wide spread of GIS's among planning agencies. But, this is not an indication that GIS's have been realised to their fullest potentials. It is true that the system has analytical abilities but they are rather limited and insufficient. Planners require more advanced functionalities in order to assist them in the decision making process. They should be able to select best options by comparing different policy alternatives or on a higher level they look for systems which will provide them with expert knowledge and solutions. In other words, they need an intelligent GIS.

Also, the improvement of other aspects of GIS capabilities, such as data capturing is crucial, when it comes to justification of the cost of the system. As was established earlier in the report the most costly phase in setting a GIS is the data capture and the maintenance of the data base which is necessary if a successful GIS is to be implemented. It is an incentive and has large benefit to planners to enhance the data capture of the GIS, including its integration with remote sensing facilities provided by satellites.

Above all, it is the duty of managers and planners to understand the principles, techniques and related technologies of GIS, to explain exactly their requirements to researchers and system designers of GIS, so as to adapt the system in future to the planning environment needs. However, users are now more experienced with GIS than ever before. They have the experience and understanding of what they need and what is not provided by their systems. They know what functionalities they require from a GIS, to create successful systems, and vendors must listen to satisfy these needs.

8.2 Towards a More Intelligent GIS

The available GIS's satisfies the needs of planners/users who are looking for a system which can store and manipulate large quantities of geographical data. But for users who are concerned with sophisticated analytical capabilities, the present GIS's are deficient in this respect. Planners usually carry out studies like forecasting, impact analysis, optimisation etc. These tasks cannot be provided by the GIS alone. To create an intelligent GIS, it must be coupled with other systems such as decision support and expert systems, in order to benefit from modelling and expert knowledge contained within these systems. There are some applications in these areas as discussed in chapter six, but they are still not properly tailored to the requirement of planners.

The present GIS's are powerful tool boxes and considerably complicated to use and require experience. This is because a GIS does not provide information about how to use the system. This makes it very difficult for the user to achieve the best results. The future GIS must be user friendly and should provide screen menu options which are simple and could be used by inexperienced users.

8.3 Future GIS and the Planning Environment

Many of the problems facing planners are related to acquisition of data and information, which are essentially required for the planning and decision making process. The main difficulties in setting an efficient GIS is to collect information in an organised, coherent manner to aid planners in performing their tasks. It is very hard to obtain and converge together information from various authorities or sources, and it is even more difficult and costly to keep this information updated. But, data sharing and the efforts towards achieving it will pay back in the long run. It will certainly provide a wider range of data, reduce costs and redundancy of data collection, improve coordination and relations between authorities, help planners to better predict unforeseen events, and finally but not last, will enhance the quantity and quality of information.

There are many obstacles and problems which have to be resolved between the parties involved, before a data sharing environment is set. These include differences in organisational objectives, standardisation, access authorisation, cost recovery

procedures, extent of data documentation by each party and many others, which have been discussed in section 5.2.2.

Data sharing was always a dream which planners wanted to become true. Today, due to the high technological developments in the areas of distributed computers and networking systems, these dreams can be achieved. GIS vendors are now designing to integrate the distributed computer systems into one common user environment. The technology does not stop at this point. The increasing capabilities of networking systems and telecommunications will improve communications between GIS users dispersed at remote locations. To achieve this, video, voice, text, image and telewriting communication capabilities are required. These connectivity levels can be reached by utilising the recent Metropolitan Area Networks (MAN) and the Broad Band Integrated Services Digital Network (B-ISDN), which can support video and high speed data services [26].

Some of the capabilities mentioned above have been already implemented in the concurrent engineering environments of private business companies as discussed earlier in the report. The planners must take advantage of these technologies and their applications in other fields, in order to learn and create concurrent planning environments, so as to improve the planning and decision making process.

8.4 GIS and Organisational Issues

Implementing a successful GIS requires overcoming many organisational barriers. A GIS cannot be implemented as a full or ready made package. It must be developed and tailor made to satisfy and grow with the needs of an organisation.

An organisation must be fully aware of what geographic information its different departments require before starting a GIS. The GIS also has to incorporate long term goals of the organisation and of the other related planning agencies, in order to set a proper data sharing environment. Bad communications between planning agencies will lead users to generate their own data sets which will duplicate efforts and incur larger costs on governments in the long run. A major obstacle in implementing a GIS, is data ownership by different departments or organisations. Each department or organisation thinks of data as being their own, while it serves all parties involved in planning.

When a GIS is introduced into an organisation, especially in developing countries, there is almost always a shortage of experienced personnel. To operate and make the best use of the system, training and education of individuals are prerequisites for running a successful GIS in an organisation. It is not just enough to train people on the technology of the system, most importantly it is to educate the users to develop skills, to apply the technology in the planning field. This demands the user to have sufficient knowledge of the problems and data involved. Education should be a continuous process, and should respond to the growing complexity of the planning process, the technology advancement and the organisational changes.

Therefore, organisational matters such as educational programmes, incentives and rewards for users to learn and use the system and their participation in the development of the system are all important factors for a successful GIS.

8.5 Recommendations

Successful implementation of GIS in a planning environment is complicated and time consuming which could drag on for many years. The following points are recommended as an effort towards achieving this objective, on both technological and organisational levels.

On the technological level a GIS must provide the following:

- Large data base storage which could cope with spatial and attribute data, and must cater for the continuous increase in the amount of data required in planning.
- Rapid information retrieval to improve the system efficiency, to compress the data base search time, especially when retrieving information from a remote site.
- It must be capable of accepting data in all forms, Raster and Vector, for more efficient data entry. Vector data allows for more accurate maps and Raster data makes calculations faster and easier [3].
- The ability to tailor and adapt the system to new applications.
- The ability to manipulate and analyse data to derive new information.
- The system must be compatible, which is essential for linking the system with other systems and expanding it as required in the future.
- To create an intelligent GIS, it must be integrated with other available and established decision support and expert systems, to provide modelling and expert knowledge abilities. Further, it should be linkable with neural networks in future.

- The GIS must be user friendly so as to simplify the interaction between the user and the system, which will then demand less training efforts.

On the organisational level:

- The organisation must follow a rational planning process in order to benefit from a GIS.
- The cost/benefit analysis of GIS must be fully carried out. The benefits must be more than the costs.
- A GIS must satisfy and incorporate the long term organisational goals and objectives.
- Implement the GIS in phases to properly integrate it with the organisational structure.
- The system must be capable of showing early successful results, through pilot projects, to gain organisational support.
- The individuals in an organisation working with GIS must be extensively trained and educated, to be able to fully use and operate the system.
- To make maximum use of GIS potential, it must be used as a data sharing tool, between the different agencies involved in planning.
- Proper management and maintenance of the system once it is established are essential for its continuing success.

Finally, the GIS is only a tool to aid planners in performing their tasks. Accomplishing these tasks is more important than the tool. Therefore, the technology must be suited to the planning activities and organisational needs, not the opposite. These and all other technologies are like points on an infinite line which do not have an end. They will continue to advance rapidly. But the real challenge is to adapt these technologies to the planning and organisational needs.

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