

AN OVERVIEW AND DEFINITION OF GIS

D J MAGUIRE

Geographical Information Systems (GIS) have been generating massive interest world wide. Their comparative recency, rapid rate of development, commercial orientation and diversity have not assisted in producing a clear and unambiguous definition of GIS. This chapter attempts to provide an overview of GIS, focusing on efforts to develop a satisfactory definition, the fundamental principles on which they are based and the evolution of applications. The term GIS can be applied to computer technology, integrated systems for use in substantive applications, as well as a new discipline. Estimates of the size and importance of the GIS market suggest that it is of national and global significance and that it is growing at a rapid rate. Three widely held views of GIS emphasize the importance of map processing, databases and spatial analysis. The evolution of GIS is described as a three stage process encompassing resource inventory, analysis and management activities.

INTRODUCTION

The term *Geographical Information System (GIS)* and its synonym *Geographic Information System* used in North America, is frequently applied to geographically oriented computer technology, integrated systems used in substantive applications and, more recently, a new discipline which is generating massive interest world wide. For a number of reasons, GIS is more difficult to define than might at first be imagined. Although there has been some debate about the origin of the term and the date of initiation of work in the field (see Coppock and Rhind 1991 in this volume), it is clear that GIS are a relatively recent phenomena. Throughout the last 30 years there has been a very rapid rate of theoretical, technological and organizational development in the GIS field, culminating in a period of intense activity in the last five years or so. The recent origin and rapid rate of progress has not been conducive to the analysis and definition of GIS.

The commercial orientation of much GIS activity has led to a great deal of hyperbole and

rhetoric. There has been a mushrooming of new computer systems which purport to be GIS, many of which are existing systems re-badged and re-packaged in an attempt to exploit market opportunities. Associated with this has been a rise in the number of GIS consultants, many of whom appear to offer conflicting advice and information about GIS. Any subject or concept which is in widespread use by a heterogeneous group of users is almost certain to be difficult to define.

The GIS field is further characterized by a great diversity of applications. GIS are integrating systems which bring together ideas developed in many areas including the fields of agriculture, botany, computing, economics, mathematics, photogrammetry, surveying, zoology and, of course, geography, to name but a few. Inevitably, it is difficult to distinguish between the competing claims of different organizations and individuals all of whom wish to be represented in a vibrant and profitable field.

It is also difficult to define GIS because there are many different ways of defining and classifying objects and subjects. Not surprisingly, given the

diversity of the field, many different methods have been applied to GIS. Classifications based on functionality have been particularly popular (Maguire and Raper 1990; see also Maguire and Dangermond 1991 in this volume) and others have tried to develop schemes based on genealogy, cost, size, platform, application area and data model (Clarke 1986a).

The final reason for definitional difficulties stems from genuine academic debate about the central focus of current GIS activity. As the discussion below demonstrates, some people believe that hardware and software are the central focus, others argue that the key element is information processing or even applications.

Together these factors have conspired to obfuscate an issue which has never really been satisfactorily discussed or analysed in any detail. The individuals and organizations working with GIS have instead employed themselves developing new methods and applying the systems to substantive problems. Given the current stage of evolution of GIS it seems appropriate to attempt to develop a considered view of exactly what they are and how they relate to other similar systems.

This chapter aims to provide an overview of GIS. It focuses on efforts to develop a satisfactory definition of GIS, the fundamental principles on which they are based and the evolution of GIS applications. The discussion is intended to act as an introduction to some of the main themes and key issues discussed later in this book. The chapter begins with a review of existing attempts to define GIS and the relationship between GIS and other information systems. These ideas are synthesized and presented as three views of GIS. Next the benefits and then the basic elements of GIS are considered. This is followed by a brief review of some of the major applications of GIS. Finally, some conclusions are presented.

TOWARDS A DEFINITION OF GIS

GIS are seen by many as special cases of information systems in general (de Man 1988; Carter 1989). Information is derived from the interpretation of data which are symbolic representations of features (Benyon 1990). The value of information depends upon many things including its timeliness, the context in which it is

applied and the cost of collection, storage, manipulation and presentation. Information is now a valuable asset, a commodity which can be bought and sold for a high price (Openshaw and Goddard 1987). Information and its communication is one of the key development processes and characteristics of contemporary societies.

On the basis of the tasks performed, two types of information system can be identified: transaction processing systems and decision support systems. In transaction processing systems, emphasis is placed on recording and manipulating the occurrence of operations: banking and airline reservation systems are well known examples. Transaction processing systems, whether they operate in on-line or batch mode, can be update or retrieval oriented and are based on clearly defined procedures. In decision support systems the emphasis is on manipulation, analysis and, particularly, modelling for the purposes of supporting decision makers such as company managers, politicians and government officials. Decision support systems are used for applications such as tactical warfare and market analysis. They are normally retrieval oriented and need to be able to operate in a flexible manner.

Information systems have a number of important general attributes (de Man 1988; Carter 1989). The information in the system must be organized such that it will have utility when retrieved; access to information in the system must be managed and carefully regulated; there must be continued support and maintenance of the information and technology within the system over time; and staff and users need to be encouraged and educated.

Strictly speaking, GIS include both manual and computer-based information systems (Dickinson and Calkins 1988; Aronoff 1989; Starr and Estes 1990). In practice, however, all contemporary information systems are computer based. Some selected definitions of GIS are given in Table 1.1.

Table 1.1 Selected definitions of GIS

DoE (1987:132)	<i>a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the Earth.</i>
Aronoff (1989:39)	<i>any manual or computer based set of procedures used to store and manipulate geographically referenced data.</i>

- Carter (1989:3)
an institutional entity, reflecting an organizational structure that integrates technology with a database, expertise and continuing financial support over time.
- Parker (1988:1547)
an information technology which stores, analyses, and displays both spatial and non-spatial data.
- Dueker (1979:106)
a special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines, or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses.
- Smith *et al.* (1987:13)
a database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database.
- Ozemoy, Smith and Sicherman (1981:92)
an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation, and display of geographically located data.
- Burrough (1986:6)
a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world.
- Cowen (1988:1554)
a decision support system involving the integration of spatially referenced data in a problem-solving environment.
- Koshkariov, Tikunov and Trofimov (1989:259)
a system with advanced geo-modelling capabilities.
- Devine and Field (1986:18)
a form of MIS [Management Information System] that allows map display of the general information.

infrastructure (staff, facilities and supporting elements).

Cowen (1988) suggests that there are four basic approaches to defining and separating GIS from other types of information system: the process- or function-oriented, application, toolbox, and data base approaches. The process-oriented approach emphasizes the information handling capabilities of GIS and is typified by the DoE (1987) and Ozemoy, Smith and Sicherman (1981) definitions (Table 1.1). The application approach divides information systems on the basis of the problems they seek to address (e.g. welfare, banking and transport information systems). GIS themselves may also be subdivided on this basis as is shown in Table 1.2. The link between these apparently disparate intellectual areas is that they share common technology and methods. GIS vendors have recently started to use this as a sales ploy in an attempt to stimulate vertical niche markets. The toolbox approach emphasizes the generic aspects of GIS and is represented by the widely used definition of Burrough (1986). This approach is, not surprisingly, frequently used by GIS vendors who wish to maximize the size of their market. The database approach is probably the most widely used, because of the influence of database theory and practice on GIS. The definitions of Dueker (1979) and Smith *et al.* (1987) typify this approach. In addition to these four approaches many authors have also highlighted the importance of GIS as decision support systems (Cowen 1988; Parent and Church 1987; see also Densham 1991 in this volume) and management information systems (Devine and Field 1986). Other authors, however, (Densham and Goodchild 1989; Rhind 1988) have reservations about how well current GIS can be used in these ways.

Many of the definitions discussed above are relatively general and cover a wide range of subjects and activities. All of the definitions, however, have a single common feature, namely that GIS are systems which deal with geographical information. In GIS, reality is represented as a series of geographical features defined according to two data elements. The geographical (also called locational) data element is used to provide a reference for the attribute (also called statistical or non-locational) data element. For example, administrative boundaries, river networks and point locations of hill tops are all geographical features used to provide a reference for, respectively, census counts,

There has also been some debate about whether GIS should be defined in narrow technological terms, or whether a wider organizational/institution perspective is more appropriate. DoE (1987) typifies the narrow focus and Carter (1989) is a proponent of the wider view. Dickinson and Calkins (1988) also argue that GIS comprise three key components: GIS technology (hardware and software), a GIS data base (geographical and related data) and GIS

Table 1.2 Example types of GIS classified according to the application area addressed. It is also possible to consider these as alternative names for GIS.

Cadastral information system
Image based information system
Land data system
Land information system
Geographically referenced information system
Natural resource management information system
Market analysis information system
Multipurpose cadastre
Planning information system
Property information system
Soil information system
Spatial information systems
Spatial decision support system
Urban information system

river water flows or site elevations. In GIS, the geographical element is seen as more important than the attribute element and this is one of the key features which differentiates GIS from other information systems.

The terms 'spatial' and 'geographical' are often used interchangeably to describe geographical features. Strictly, the term spatial refers to any type of information about location and can include engineering and remote sensing, as well as cartographic information. On the other hand, geographical refers only to locational information about the surface or near surface of the earth at real-world scales and in real world space (Frank 1988). Similarly, the term 'aspatial data' is often used as a synonym for 'attribute data'.

GIS and other Information Systems

The relationship between GIS and computer-aided design, computer cartography, database management and remote sensing information systems is important in establishing a definition of GIS. It is sometimes argued that GIS are a subset or a superset of these systems (Fig. 1.1). Newell and Theriault (1990:42), for example, suggest 'almost any system that is capable of putting a map on the screen on a CRT these days calls itself a GIS' and Clarke (1986b) observes in the minds of many GIS

is simply a catch-all for almost any type of automated geographic data processing.

Computer-aided design (CAD) systems were developed for designing and drafting new objects. They are graphic based and use symbols as primitives to represent features in the interactive design process. CAD systems have only rudimentary links to databases which typically might contain part listings or stock reference numbers. They use only simple topological relationships and, on the whole, deal with relatively small quantities of data (Newell and Theriault 1990). CAD systems do not usually allow users to assign symbology automatically on the basis of user-defined criteria (Cowen 1988) and have limited analytical capabilities.

Computer cartography systems focus on data retrieval, classification and automatic symbolization (Cowen 1988). They emphasize display rather than retrieval and analysis. Computer cartography systems utilize simple data structures which lack information on topology. They can be linked to a database management system but only simple retrieval operations are normally undertaken. Computer cartography systems usually have many facilities for designing maps and producing high quality output in vector format.

Database management systems (DBMS) are well-developed software systems optimized for storing and retrieving non-graphic attribute data. They have limited graphical retrieval and display capabilities. DBMS are designed for the short-term retrieval and update of relatively small quantities of data (Newell and Theriault 1990) and lack anything other than simple analytical functions. They have very limited capabilities for implementing spatial analytical operations. (The characteristics of DBMS for GIS are reviewed in Healey 1991 in this volume.)

Remote sensing systems are designed to collect, store, manipulate and display raster data typically derived from scanners mounted on aircraft or satellite platforms, although they can usually handle any data in raster format (Mather 1987). Most remote sensing systems have limited capabilities for handling vectors and, therefore, are unsuitable for operations like network analysis and producing high quality plots from coordinate geometry which are best carried out using data in vector format. They usually have only very limited capabilities for handling attribute data and only

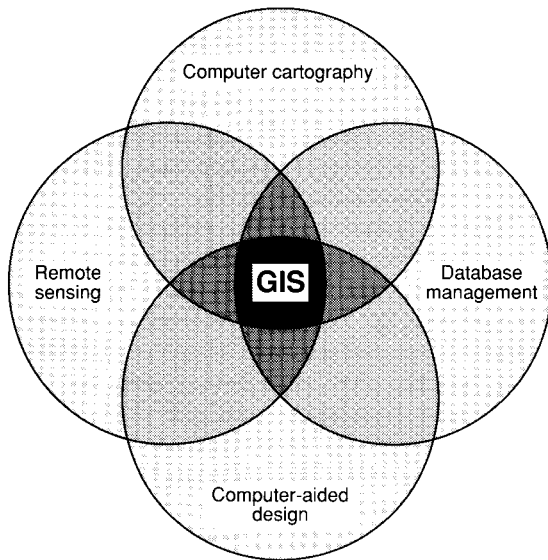


Fig. 1.1 The relationship between GIS, computer-aided design, computer cartography, database management and remote sensing information systems.

poor links to DBMS. Although they have quite sophisticated facilities for enhancing and classifying data, most have limited true spatial analytical capabilities. The relationship between remote sensing and GIS is discussed at length in Marble and Pequet (1983) and in Davis and Simonett (1991 in this volume).

These systems all predate GIS which, because they have evolved from them, have many features in common. GIS, however, have a number of other features not available in other systems. The major characteristic of GIS is the emphasis placed on analytical operations. Goodchild (1988:67) states this point clearly suggesting that 'the ability of a Geographic Information System to analyse spatial data is frequently seen as a key element in its definition, and has often been used as a characteristic which distinguishes the GIS from systems whose primary objective is map production'. In functional terms, Cowen (1988) believes that spatial searching and overlay are the only operations unique to GIS (see Maguire and Dangermond 1991 in this volume for further discussion of these terms.)

Thus it appears that GIS are best viewed as a subset and not a superset of the other types of information system represented in Fig. 1.1 and discussed above. The emphasis on spatial analysis in

GIS raises the question of the difference between GIS and statistical analysis systems. Goodchild (1988:68) again makes a useful contribution defining spatial analysis as 'that set of analytical methods which require access to both the attributes of the objects under study and to their locational information'. Conventional statistical analysis systems, such as SAS and Minitab, are oriented toward the analysis of aspatial data and lack appropriate capabilities for spatial analysis and modelling (Anselin 1989). These views of GIS as spatial analysis systems, must be tempered with caution, for as Rhind (1988:26) indicates 'virtually all GIS developments thus far have resulted in "data retrieval and sifting" engines; modelling work has not yet been brought together with this technically accomplished sub-structure'.

Three views of GIS

The various ideas about GIS can be synthesized and presented in the form of three distinct but overlapping views. These can be termed the map, database and spatial analysis views. Other views of GIS have been suggested, the most notable being the application view in which the idea of GIS as the technology to deal with global scientific problems is prominent. However, the disparate nature of these ideas and the lack of clear focus on GIS means that this view is not as well developed as the others and will, therefore, not be discussed here.

The map view focuses on cartographic aspects of GIS. This view has its origins in the work of McHarg (1969) and today is strongly represented by Berry (1987) and Tomlin (1990, 1991 in this volume). Supporters of this view see GIS as map processing or display systems. In map processing, each data set is represented as a map (also called a layer, theme or coverage). The maps are usually held in raster format and are manipulated by a function that might add, subtract or search for patterns. The output from these operations is another map. Topographic and thematic mapping agencies also support the map view and place great emphasis on the ability of GIS to produce high quality maps and charts usually in vector format.

The database view of GIS emphasizes the importance of a well-designed and implemented database (Frank 1988). A sophisticated database management system is seen as an integral part of a

GIS. This view predominates among members of the GIS community who have a computer science background. Applications which record transactions and require the frequent use of simple queries are particularly suited to this approach. Complex analytical operations which require the use of many types of geographical data can be incorporated into this view only with difficulty.

The third view of GIS emphasizes the importance of spatial analysis. This view focuses on analysis and modelling in which GIS is seen more as a spatial information science than a technology (Goodchild 1990; see also Openshaw 1991 in this volume). Although current proprietary systems have limited functionality for spatial analysis, it is clear that this is a major development area. This view looks likely to become the most widely accepted by the GIS community and already it can be used to differentiate between GIS and other information systems.

Although these views of GIS are widely held, few people see them as conflicting. A single system may be viewed in all three ways depending on the perspective of the user or the application in hand. Nevertheless, this classification serves a useful function in highlighting the ways in which GIS are used by the GIS community. It also illustrates once again the widespread applicability of GIS and the heterogeneity of the GIS community.

THE BENEFITS OF GIS

The reasons for the introduction and success of new ideas and technology are many and varied and they operate at a number of different scales. At the general level there are four main reasons why GIS has become so popular in the past decade or so.

There has without doubt been a massive proliferation of information about many aspects of the cultural and natural environment in the past few years. Remote sensing satellites, population and market surveys, topographic surveys, transaction loggers and the like are now being widely used to collect vast quantities of data in computer format. Many of these data have some type of explicit or implicit geographical reference associated with them. An explicit geographical reference might be a Cartesian or latitude/longitude coordinate and an implicit reference might be the name of an

administrative unit, a town, or a physical feature, such as a mountain. In many cases it is possible to derive an explicit reference from an implicit reference. This geographical reference has proved to be an effective means of linking data sets together and this principle, perhaps more than any, is the reason for the success of GIS.

GIS have great commercial application. Recent estimates by Daratech, USA (a leading firm of marketing consultants) suggest that GIS 'may become one of the most dynamic computer systems-related businesses of the 1990s' (*Computer Graphics World* 1989:22). The Daratech study shows that GIS is already big business world wide (Table 1.3) and, more importantly, that it is rapidly expanding. The study predicts a 32 per cent annual growth in the GIS market through to 1993. Another report (Smallworld Systems 1990), produced by polling users on their actual or budgeted expenditure, argues that the European market alone was worth \$322 million in 1989. Most of this spending was by utilities or government but some 9 per cent was being spent on environmental applications; this annual total was predicted to grow to \$546 million by 1991. Figure 1.2 illustrates the trends. GIS have commercial application because they can be used to address many significant global, national and local social and scientific problems. Some of the major application areas are briefly examined below and there are many detailed examples in Section III of this book.

Table 1.3 GIS market estimates for 1988 in \$ billion (*Computer Graphics World* November 1989:22).

Revenues of GIS software companies	\$0.52
Hardware sales arising from GIS	\$1.10
Market for GIS-related services	\$2.40

A final factor of great significance in the expansion and continued success of GIS has been the rapid reduction in the price of computer hardware and software over the past few decades. The introduction of the microprocessor and especially the microcomputer in the late 1970s has been of particular significance in this process (see Goodchild 1991 in this volume). Early GIS software systems were almost all mounted on mainframes or minicomputers, but recently lower priced

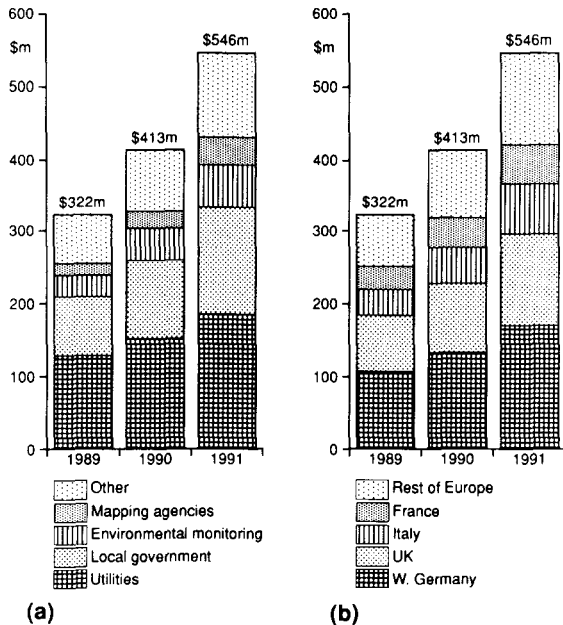


Fig. 1.2 Growth in the GIS market in Europe 1989 to 1991 (Smallworld Systems 1990).

microcomputers and workstations are being used (Dangermond and Morehouse 1987). Croswell and Clark (1988) estimate that the price : performance ratio of computer hardware increased 8 times in the period 1979–88, while at the same time the space required for computers decreased 5 times. With the continued development of smaller, faster and cheaper microchips in the 1990s this trend looks set to continue. It is not fanciful to suggest that by the end of the century GIS will be used every day by everyone in the developed world for routine operations.

THE ELEMENTS OF A GIS

GIS comprise four basic elements which operate in an institutional context: computer hardware, computer software, data and liveware. The hardware element can be almost any type of computer platform, including relatively modest personal computers, high performance workstations and minicomputers and mainframe computers (see Franklin 1991 in this volume; see also Goodchild 1991 in this volume). In the early 1990s the trend is very much towards workstations running the Unix

operating system. In addition to the standard input, storage and output devices, specialist peripherals are required for data input (e.g. scanners, digitizers and tape drives), data output (e.g. plotters) and, sometimes, data storage and processing.

There is now a great deal of what claims to be GIS software. The annual surveys in *GISWorld* (*GISWorld* 1990) and other similar reviews show that much of this software has been developed to sophisticated levels. Major software packages have several hundred commands and a wide variety of functionality. Although there are variations in the organization and capabilities of GIS software, three basic designs have evolved (Aronoff 1989; Bracken and Webster 1989). These are called the file processing, hybrid and extended designs. In the file processing design, each data set and function is stored as a separate file and these are linked together during analytical operations. Examples of systems using this design are IDRISI (Eastman 1987) and MAP (Tomlin 1986). This is the approach adopted in map processing systems. In the hybrid design, attribute data are stored in a conventional DBMS and separate bespoke software is used for geographical data. ARC/INFO (Morehouse 1989) and Deltamap/Genamap (Reed 1986) are examples of hybrid designs. In situations where attribute data are stored in a relational DBMS these are sometimes referred to as geo-relational (Morehouse 1985). In the third design type, the extended DBMS, both the geographical and the attribute data are stored in a DBMS which is extended to provide appropriate geographical analytical functions. The best known examples using the extended design are SYSTEM9 (Ingram and Phillips 1987) which extends the EMPRESS DBMS and TIGRIS (Herring 1987) which uses a bespoke DBMS.

The third important element in a GIS is the data. In many respects data are a crucial resource. Geographical data are very expensive to collect, store and manipulate because large volumes are normally required to solve substantive geographical problems. Although estimates vary, it is not uncommon for the cost of data collection to exceed the cost of hardware and software by a factor of two (Rowley and Gilbert, 1989, suggest 70 per cent of the total cost of implementing a GIS). Until relatively recently there was a paucity of data for use in GIS, but the widespread use of remote sensing satellites, the ambitious national mapping

programmes of many countries and the collaborative international ventures which aim to create global databases (Mounsey 1988; see also Clark, Hastings and Kineman 1991 in this volume) now mean that there are significant problems of data volumes.

The final and most significant GIS element is the liveware; the people responsible for designing, implementing and using GIS. Without properly trained personnel with the vision and commitment to a project little will be achieved. The lack of adequately trained personnel has been highlighted on a number of occasions (see for example DoE 1987) and although a number of education and training initiatives have been undertaken (see Unwin 1991 in this volume) much remains to be done before the skill shortage is alleviated. The significance of the people involved in GIS is, regrettably, all too often overlooked by those with a more technological focus.

APPLICATIONS

GIS can be applied to many types of problem. Rhind (1990) sets out a general classification of the types of generic questions which GIS are frequently used to investigate (Table 1.4). The location question involves querying a database to determine the types of features which occur at a given place (e.g. what is the population of a given census tract?). The condition question is really the converse, since it involves finding the location of sites which have certain characteristics (e.g. where is all the land within 200 metres of a road which is forest covered?). Where more than one type of data are involved this is sometimes referred to as the 'intersection' question since it necessitates finding the intersection of data sets (Maguire 1989). The trend question involves monitoring how things change over time (e.g. what is the change in the traffic flow along roads?). The other questions are more complex and involve some type of spatial analysis. The routing question requires calculation of the best (fastest, quickest, shortest, most scenic, etc.) route between places (e.g. which is the nearest doctors surgery?). The patterns question allows environmental and social scientists and planners to describe and compare the distribution of phenomena and to understand the processes which

account for their distribution (e.g. is there some pattern in the distribution of diseases which are thought to be caused by exposure to radiation?). The final question allows different models of the world to be evaluated (for example, which areas of the earth will be affected by a 20 centimetre rise in sea level?).

Table 1.4 Basic questions that can be investigated using GIS (after Rhind 1990).

1	Location	What is at ...?
2	Condition	Where is it ...?
3	Trend	What has changed ...?
4	Routing	Which is the best way ...?
5	Pattern	What is the pattern ...?
6	Modelling	What if ...?

Crain and MacDonald (1984) have developed a threefold scheme describing the stages in the evolution of GIS (Fig. 1.3). They suggest that the initial reason for establishing most information systems and, therefore, the main activity in the initial development phase is assembling, organizing and undertaking an inventory of features of interest. In a GIS context this might mean an inventory of forest types, soils, utility pipe networks or schools. During this phase systems are used primarily to undertake simple data queries such as the location and condition questions identified by Rhind (1990).

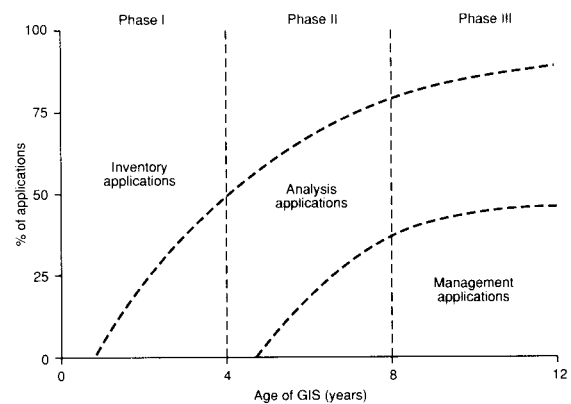


Fig. 1.3 Stages in the development of GIS applications (after Crain and MacDonald 1984).

The second phase in the evolution of information systems according to Crain and MacDonald (1984) arises from users' desires to undertake more complex analytical operations. Frequently these require access to data spread across several data layers and the use of statistical and spatial analytical techniques. GIS applications such as determining the suitability of land for locating, say, waste disposal sites or new retail stores, and monitoring changes in ice sheets are typical of this phase. More complex forms of Rhind's condition and trends questions fall into this category.

The third and most developed phase sees the evolution of an information system from a transaction processing system to a decision support system. In this management phase systems are used to support the activities of decision makers. There is considerable emphasis on sophisticated spatial analytical and modelling activities. During this phase a GIS might be used to determine which of a number of hospitals should close, or the optimum pattern of land use. Rhind's routing, patterns and modelling questions all fall into this category.

The Crain and MacDonald scheme was developed from their work in the Canada Land Data System (CLDS). This system contains the Canada Geographic Information System (CGIS) and is probably the best known and longest established GIS. For CLDS they suggest an inventory application phase from about 1971 to 1979, an analysis phase from about 1979 to 1987 and then a move to the management phase. Although systems initiated after CLDS have benefited considerably from the experience gained in the operation of this and other early systems and the software tools now available are more sophisticated, it is clear that there is still likely to be a 3–5 year lead time before current systems move beyond the inventory stage (Dickinson and Calkins 1988). It is also likely to be a further 3–5 years before they evolve into management information systems. Thus in the early 1990s, while there are many well developed GIS at the inventory stage, there is a much smaller number which are used for analytical purposes and only a select few which are employed in a management context. This is in part due to the state of maturity of systems, but it also reflects the lack of attention paid to spatial analysis until relatively recently. Given the statistical problems inherent in implementing spatial analytical

techniques and the almost total lack of appropriate functionality in current proprietary GIS software (see Openshaw 1991 in this volume), the transition from inventory to analysis and then management information system may take longer than some expect.

CONCLUSIONS

GIS are clearly big news. They have enormous commercial importance and, more significantly, they are already being used to make valuable contributions to the understanding and solution of key socio-economic and environmental problems. Interest in GIS is currently expanding rapidly and it is reasonable to expect that over the next decade there will be a several fold increase in activity.

GIS are used by a heterogenous group of individuals and organizations for an incredibly wide variety of applications. Inevitably this means that there are many different ideas about the nature and scope of GIS. A Geographical Information System is best described as an integrated collection of hardware, software, data and liveware which operates in an institutional context. Although many terms have been proposed for the name of the new discipline, because of its widespread use Geographical Information Systems is preferred.

It appears that the only satisfactory way to develop an appropriate definition of GIS is to summarize the many disparate ideas in the form of a series of views of GIS. Three main views are evident, namely, the map, database and spatial analysis views. A central element of all these views is that GIS are a special case of information systems in general and that they share many features in common with other information systems. The key features which differentiate GIS from other information systems are the general focus on spatial entities and relationships, together with specific attention to spatial analytical and modelling operations. In a technical sense it is the ability to organize and integrate apparently disparate data sets together by geography which make GIS so powerful. The spatial searching and overlay operations are a key functional feature of GIS.

The evolution of GIS can be described as a three stage process. Systems in their early stages of development are oriented towards data collection

and inventory operations. After about 3–5 years emphasis shifts to more analytical operations. Most systems reach maturity in a further 3–5 years when they evolve into true decision support systems. It is only in this last phase that spatial analytical and modelling operations are routinely employed. While there are many well-developed GIS in the inventory phase, only a small number have presently progressed into the analysis phase. This is due in part to the youthfulness of GIS as a discipline, but also it is due to the technical problems inherent in developing appropriate robust and widely applicable spatial analytical methods.

REFERENCES

- Anselin L** (1989) What is special about spatial data? Alternative perspectives on spatial data analysis. *NCGIA Technical Paper 89-4* NCGIA, Santa Barbara: 20pp.
- Aronoff S** (1989) *Geographic Information Systems: a management perspective*. WDL Publications, Ottawa Canada
- Benyon D** (1990) *Information and Data Modelling*. Blackwell Scientific Publications, Oxford
- Berry J K** (1987) Fundamental operations in computer-assisted map analysis. *International Journal of Geographical Information Systems* **1**: 119–36
- Bracken I, Webster C** (1989) Towards a typology of geographical information systems. *International Journal of Geographical Information Systems* **3**: 137–52
- Burrough P A** (1986) *Principles of Geographic Information Systems for Land Resources Assessment*. Clarendon, Oxford
- Carter J R** (1989) On defining the geographic information system. In: Ripple W J (ed.) *Fundamentals of Geographic Information Systems: a compendium*. ASPRS/ACSM, Falls Church Virginia, pp. 3–7
- Clark D M, Hastings D A, Kineman J J** (1991) Global databases and their implications for GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 217–31, Vol 2
- Clarke K C** (1986a) Recent trends in geographic information systems. *Geo-Processing* **3**: 1–15
- Clarke K C** (1986b) Advances in Geographic Information Systems. *Computers, Environment and Urban Systems* **10**: 175–84
- Computer Graphics World** (1989) Daratech survey. *Computer Graphics World* November, p. 22
- Coppock J T, Rhind D W** (1991) The history of GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 21–43, Vol 1
- Cowen D J** (1988) GIS versus CAD versus DBMS: what are the differences? *Photogrammetric Engineering and Remote Sensing* **54**: 1551–4
- Crain I K, MacDonald C L** (1984) From land inventory to land management. *Cartographica* **21**: 40–6
- Croswell P L, Clark S R** (1988) Trends in automated mapping and geographic information system hardware. *Photogrammetric Engineering and Remote Sensing* **54**: 1571–6
- Dangermond J, Morehouse S** (1987) Trends in computer hardware for geographic information systems. *Proceedings of AUTOCARTO 8*. ASPRS/ACSM, Falls Church: pp. 380–5
- Davis F W, Simonett D S** (1991) GIS and remote sensing. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 191–213, Vol 1
- de Man E** (1988) Establishing a geographical information system in relation to its use: a process of strategic choice. *International Journal of Geographical Information Systems* **2**: 245–61
- Densham P J** (1991) Spatial decision support systems. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 403–12, Vol 1
- Densham P J, Goodchild M F** (1989) Spatial Decision Support Systems: a research agenda. *Proceedings of GIS/LIS'89*. ACSM, ASPRS, AAG, URISA, AM/FM International, Falls Church, pp. 707–16
- Devine H A, Field R C** (1986) The gist of GIS. *Journal of Forestry* August, 17–22
- Dickinson H, Calkins H W** (1988) The economic evaluation of implementing a GIS. *International Journal of Geographical Information Systems* **2**: 307–27
- Department of the Environment (DoE)** (1987) *Handling Geographic Information*. HMSO, London
- Dueker K J** (1979) Land resource information systems: a review of fifteen years experience. *Geo-Processing* **1**: 105–28
- Eastman J R** (1987) *IDRISI: a grid-based geographic analysis system*. Graduate School of Geography, Clarke University, USA
- Frank A U** (1988) Requirements for a database management system for a GIS. *Photogrammetric Engineering and Remote Sensing* **54**: 1557–64
- Franklin Wm R** (1991) Computer systems and low-level data structures for GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 215–25, Vol 1
- GISWorld** (1990) *GIS Technology '90: Results of the 1990 GISWorld geographic information systems survey*. GISWorld, Fort Collins, 16pp.
- Goodchild M F** (1987) A spatial analytical perspective on

- GIS. *International Journal of Geographical Information Systems* 1: 327–34
- Goodchild M F** (1988) Towards an enumeration and classification of GIS functions. In: Aangeenbrug R T, Schiffman Y M (eds.) *International Geographic Information Systems (IGIS) Symposium: The research agenda*. AAG, Falls Church Virginia: pp. 67–77
- Goodchild M F** (1990) Spatial information science. *Proceedings of the 4th International Spatial Data Handling Symposium*. International Geographical Union, Ohio. pp. 3–14
- Goodchild M F** (1991) The technological setting of GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 45–54, Vol 1
- Healey R G** (1991) Database management systems. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 251–67, Vol 1
- Herring J R** (1987) TIGRIS: Topologically integrated geographic information system. *Proceedings of AUTOCARTO 8*. ASPRS/ACSM, Falls Church, pp. 282–91.
- Ingram I K, Phillips W** (1987) Geographic information processing using a SQL-based query language. *Proceedings of AUTOCARTO 8*. ASPRS/ACSM, Falls Church, pp. 326–35
- Koshkarirov A V, Tikunov V S, Trofimov A M** (1989) The current state and the main trends in the development of geographical information systems in the USSR. *International Journal of Geographical Information Systems* 3 (3): 257–72
- McHarg I L** (1969) *Design with Nature*. Doubleday, New York
- Maguire D J** (1989) *Computers in Geography*. Longman, London
- Maguire D J, Dangermond J** (1991) The functionality of GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 319–35, Vol 1
- Maguire D J, Raper J F** (1990) An overview of GIS functionality. *Proceedings of GIS Design Models and Functionality Conference*. Midlands Regional Research Laboratory, Leicester, 10pp
- Marble D F, Peuquet D J** (1983) Geographic information systems. In: Colwell R N (ed.) *Manual of Remote Sensing*, 2nd edn. American Society of Photogrammetry, Falls Church, pp. 923–58
- Mather P M** (1987) *Computer Processing of Remotely-sensed Images: an introduction*. Wiley, London
- Morehouse S** (1985) ARC/INFO: a Geo-relational model for spatial information. *Proceedings of AUTOCARTO 7*. ASPRS, Falls Church, pp. 388–97
- Morehouse S** (1989) The architecture of ARC/INFO. *Proceedings of AUTOCARTO 9*. ASPRS/ACSM, Falls Church, pp. 266–77
- Mounsey H** (ed.) (1988) *Building Databases for Global Science*. Taylor & Francis, London
- Newell R G, Theriault D G** (1990) Is GIS just a combination of CAD and DBMS? *Mapping Awareness* 4 (3): 42–45
- Openshaw S** (1991) Developing appropriate spatial analysis methods for GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 389–402, Vol 1
- Openshaw S, Goddard J** (1987) Some implications of the commodification of information and the emerging information economy for applied geographical analysis in the United Kingdom. *Environment and Planning A* 19: 1423–39
- Ozemoy V M, Smith D R, Sichertman A** (1981) Evaluating computerized geographic information systems using decision analysis. *Interfaces* 11: 92–8
- Parent P, Church R** (1987) Evolution of geographic information systems as decision making tools. *Proceedings of GIS '87*. ASPRS/ACSM, Falls Church VA, pp. 63–71
- Parker H D** (1988) The unique qualities of a geographic information system: a commentary. *Photogrammetric Engineering and Remote Sensing* 54 (11): 1547–49
- Reed C N** (1986) DELTAMAP just another new GIS? *Proceedings of the 3rd International Symposium on Spatial Data Handling*. IGU Commission on Geographical Data Sensing and Processing, Williamsville NY, pp. 375–83
- Rhind D W** (1988) A GIS research agenda. *International Journal of Geographical Information Systems* 2: 23–8
- Rhind D W** (1990) Global databases and GIS. In: Foster M J, Shand P J (eds.) *The Association for Geographic Information Yearbook 1990*. Taylor & Francis and Miles Arnold, London, pp. 218–23
- Rowley J, Gilbert P** (1989) The market for land information services, systems and support. In: Shand P J, Moore R V (eds.) *The Association for Geographic Information Yearbook 1989*. Taylor & Francis and Miles Arnold, London, pp. 85–91
- Shand P J, Moore R V** (eds.) *The Association for Geographic Information Yearbook 1989*. Taylor & Francis and Miles Arnold, London, pp. 85–91
- Smallworld Systems** (1990) GIS in Europe – summary report. *Geodetical Info Magazine* 4 (4): 28–9
- Smith T R, Menon S, Starr J L, Estes J E** (1987) Requirements and principles for the implementation and construction of large-scale geographic information systems. *International Journal of Geographical Information Systems* 1: 13–31
- Star J, Estes J E** (1990) *Geographic Information Systems*. Prentice Hall, Englewood Cliffs New Jersey
- Tomlin C D** (1986) *The IBM Personal Computer version of the Map Analysis Package*. Harvard University Graduate

School of Design Laboratory for Computer Graphics and Spatial Analysis, Cambridge Massachusetts

Tomlin C D (1990) *Geographic Information Systems and Cartographic Modelling*. Prentice Hall, Englewood Cliffs New Jersey

Tomlin C D (1991) Cartographic modelling. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical*

Information Systems: principles and applications. Longman, London, pp. 361–74, Vol 1

Unwin D J (1991) The academic setting of GIS. In: Maguire D J, Goodchild M F, Rhind D W (eds.) *Geographical Information Systems: principles and applications*. Longman, London, pp. 81–90, Vol 1