INTEGRATED PLANNING INFORMATION SYSTEMS

D J COWEN AND W L SHIRLEY

This chapter addresses the use of GIS within planning. It examines the tasks typically performed by planners which involve spatial data handling and the consequences in terms of data sets and GIS functionality. An objective of the chapter is to assess, in a critical way, the GIS resources currently available and the needs for a spatial decision support system. The final part of the chapter utilizes a case study of a major GIS project in the United States to demonstrate how Digital Line Graphs, TIGER files and remotely sensed data can be integrated into a single system that successfully addresses many of the obstacles normally associated with the use of GIS in planning.

INTRODUCTION

A decade – and a GIS lifetime – ago, Edgar Horwood (1980:12) stated that '. . . to be credible, planning must be cast in an information system context'. Donald Cooke (1980:12) went as far as to say that 'urban and regional planning is a data business. The nature of the data distinguishes planning from other data business because virtually all planning data is intimately related to geography or spatial location'. Since these concepts and beliefs became widely rooted in the community, it is not surprising that the planning profession has been greatly influenced by developments in GIS.

It will be obvious that the concerns of this chapter cut across those of other chapters in this book – notably those by Calkins (1991), Densham (1991), Robinette (1991), Siderelis (1991) and Parrott and Stutz (1991) – all in this volume. These chapters form a set covering a variety of aspects of planning and emphasizing the heterogeneity of the tasks faced by planners: at the very least, the terminology used differs and the type of planning functions involved are also disparate.

However, before proceeding to more detailed matters of planning in relation to GIS, a generic description of the planning process is established. This is essential for, without a shared understanding of planning objectives, concepts and terminology, no understanding of the role of GIS is possible.

THE NATURE OF PLANNING

On a daily basis, planners are confronted with a myriad of *ad hoc* decisions which require accurate and current spatial data. In fact, planners in New York City estimate that 85 per cent of all information handled is associated with geographical entities (Stiefel 1987) and comparable estimates have been made elsewhere in the world (e.g. DoE 1987; Bromley and Coulson 1989). The details of the planning process, the legal basis under which it operates and hence the information demands differ considerably across the world: while a *Plan d'Occupation du Sol* is mandatory in France, the legal requirement for local government to collect detailed land use data in Britain was abolished by the 1968 Town and Country Planning Act. Despite such differences, there are more similarities than differences and, based on an evaluation of activities performed by several local governments, Dangermond and Freedman (1986) developed a list of 21 common procedural and 12 managerial tasks. These include such functions as site planning, vehicle routing, traffic analysis, facility siting, school and political districting, land use planning, facility management, provision of public information and simply handling enquiries from the public. These tasks can be collapsed into a broader set of planning functions such as the one developed by Meyerson (1956) in his classic work:

- Central intelligence
- Pulse taking
- Policy clarification
- Detailed development planning
- Feedback and review.

Each of these functions requires a set of procedures which enable the planner to convert a diverse amount of spatial data into the type of information needed to support the decision-making process.

The 'central intelligence' function requires that a planning organization maintains a comprehensive repository of socio-economic and land use information as varied as housing provision, office space and census information. Unfortunately, this information normally consists of a wide variety of maps, aerial photographs, reports and digital data. The promise of GIS is to provide the tools to assemble these diverse forms of spatial information into an integrated format that will improve the ability of planners to see (and, where possible, anticipate) the major trends that are occurring within the community. By the nature of this function, the information needs are sometimes difficult to predict.

'Pulse-taking' functions serve as early warning systems. These activities often require in-depth analysis of existing conditions. To support these functions, planners must be able to convert miscellaneous transactions into meaningful interpretations of patterns and trends. For example, the sites of crimes and other occurrences – traditionally delineated by 'pin maps' – must be aggregated into meaningful statistical areas. Once this is done, the counts for each area can be converted into rates that can be analysed across the community. For many of these functions, simple statistical mapping and analysis is very useful.

'Policy clarification' results from the comparison of alternative scenarios arising from public issues. For example, it may be very important that planners have the ability to develop and compare various suitability models. Kindleberger (1988) has suggested that the essence of planning is understanding the implications of policy alternatives and recommending those alternatives most likely to achieve community goals and objectives. For instance, the development of new school districts or zoning changes often use a type of recursive process that incorporates group decision making (see Calkins 1991 in this volume). An effective GIS would enable the planner to assemble the data needed to measure and portray the relevant information and also to generate the various scenarios expeditiously.

'Development planning' also takes into account a wide variety of spatial and tabular information pertaining to the land use pattern of a community. As part of this process, policy makers prepare zoning maps that direct land development and substantially influence property values. These policies also include the siting of public facilities such as schools, hospitals, police and fire stations. This aspect of the planning process often requires that public officials mediate the delicate balance between the economic development needs of the community and the need for social services. Planners thus need to rely upon systems which can present 'objective resolutions' to (or at least which follow replicatable and explicit procedures in dealing with) disputes that may arise with respect to the location of noxious facilities or when faced by the classic 'Not in My Back Yard' (or NIMBY) attitudes. The ideal GIS would enable the planner to model the process and to generate a scenario that aids in finding common ground among competing factions (e.g. see Berry 1991 in this volume).

'Feedback and review' functions are essential in a public arena within a democracy. Citizens have a right to review the information that is being used to zone their property as well as to question how public officials are spending their tax money (Chrisman 1987). Historically, the control of information has also been the basis of political power. However, modern information system technology, coupled with the legal rights of citizens to access information, has changed the entire process (Archer and Croswell 1989). In those countries where data access is guaranteed to the citizenry, it is certain that decision making will no longer be controlled by a few public officials. It will thus be impossible for planners to ignore the views of citizens who come to public meetings with different solutions derived from the same information sources.

This review of basic planning functions demonstrates that planning is inherently a spatially oriented profession which involves a great deal of *ad hoc* decision making based on the evaluation of alternatives. Accepting this generality, Dueker (1980) characterized the ideal planning process as one that involves the following steps:

- Defining the problem
- Determining objectives
- Inventing alternative solutions
- Evaluating alternatives
- Selecting the best alternative
- Implementing the systems or plan
- Monitoring the results.

In summary, the nature of the planning process would appear to be a perfect setting for GIS to demonstrate their ability to manage a diverse set of spatial information and to form the information infrastructure of more efficiently and equitably operated communities. At a minimum, a set of GIS tools linked to an integrated database of the basic socio-economic and land use information enable the planners to conduct exploratory spatial analysis (Goodchild 1989; Openshaw 1991 in this volume). In an optimal setting, GIS offers the possibility of supporting a sophisticated decision support system. Densham and Rushton (1988) consider planning in a public service setting to be a process-oriented activity that not only attempts to identify optimal location patterns but also is one with intrinsic values that can generate 'a just pattern, justly arrived at'.

PLANNING INFORMATION SYSTEMS

The goal of an information system is to convert a magnitude of data into meaningful information. Successful information systems for planning have long been discussed and anticipated. The technology has rarely been held to be the problem. Thus, in a prescient (if slightly premature) comment, Cooke (1980:14) suggested that, even then, there was '"excess technology" with no pressing unsolved geoprocessing needs'. At the same time, Horwood (1980:11) forecast that, 'The 1980s will be a decade of database and data management development for multi-purpose use'. He likened the situation in 1980 to 'having a high-powered locomotive available but few railroad tracks'. Kindleberger (1988) has divided the history of database creation, management and use in planning into three categories: the 1960s as a time of high information systems excitement; the 1970s as a time of some disappointment, despite considerable government investment; and the 1980s as a time of explosive change.

An obvious example of how GIS should be able to aid decision making – and one which will be recalled several times later in the chapter – is in the location of new industrial sites which meet specified criteria. Once the basic infrastructure data layers are created, the analytical functions of the GIS can generate automatically many of the variables required. For example, distance measures can be generated to calculate a number of accessibility measures. Other factors, such as labour force measures, can be aggregated by relevant census areas. In practice, the key problem is not one of combining the data sets but one of selecting and weighting of the relevant layers. Yet this is not a new problem nor even one specific to GIS: Sweet (1970) proposed a solution through the development of industrial screening matrices. A screening matrix attempts to match target industrial groups with the locational criteria that are judged to be most important to the industry. Candidate industries are selected and evaluated on the basis of factors such as wages, materials, linkages, markets and labour factors. Weights are assigned to the locational factors and industries are then selected in terms of their compatibility with local objectives.

Analytical functions needed to support planning activities

Access to a current and appropriate set of map layers at a usable scale (see below) is only part of the problem facing planners who wish to utilize GIS. A successful system must integrate the appropriate set of retrieval, analysis and display functions with the database. Over the past decade, major advances have included the ability to query and display ever-increasing amounts of spatial information (Croswell and Clark 1988). While these are not new facilities, they have been packaged into increasingly affordable, colourful and powerful computer systems. Thus these advances have resulted in better data management (providing electronic filing cabinets) and more mapping capabilities (electronic drafting); but they should not be mistaken for better decision-making tools. As Goodchild (1987:334) argued, 'in reality, most contemporary GIS place far more emphasis on efficient data input and retrieval than on sophisticated analysis'. The unhappy experience with the Decision Information Display System (DIDS) clearly demonstrated that GIS intended as decision support systems must be more than 'magical map-making systems' (see below). An atlas, even in electronic form, is not capable of providing the planner with the ability to evaluate alternatives, to deal with land use conflicts or even to handle simple routing or politically sensitive districting functions.

Data integration tools

Dangermond and Freedman (1986) suggested that the set of basic tools needed to support planning functions include the following:

- *Graphic overlay*: to produce a variety of maps.
- *Topological overlay*: to integrate two or more files to generate site suitability models and other forms of locational analysis.
- *Address geocoding*: to assign automatically a coordinate point or district to an address.
- *Polygonization*: to form new districts from the set of existing maps.
- *Relational matching*: the ability to relate two entities for functional purposes, such as parcels to tabular data or census data to census polygons.

At the technical level, the most important tools are those which permit the overlay and integration of different forms of geographical entities. Muller (1985:42) emphasized that the power of such tools is related to their ability to transform a map into 'a logical entity whose elements are subject to various combinatorial operations with other sub-sets of information'. Further, White (1984) emphasized that a multipurpose geographical data handling system must be able to perform true map overlay so that it can determine 'which regions cover a given region'. The importance of such map overlay was of course demonstrated long ago by Ian McHarg and has been widely used in a manual or photographic fashion by planners to create suitability and capability models (McHarg 1971). A fundamental question is whether these same analyses can now be performed economically on 'real world'-sized data sets by digital processing (McHarg 1987).

Some remaining problems

Goodchild (1987) claimed that the set of commercially available spatial analysis tools extant at the time he wrote still fell short of users' needs for combining spatial integration facilities, optimal location/allocation routines and statistical analysis capabilities within a common operating environment. It is obvious that these tools are of particular value to planners. Although he acknowledged that the interface between GIS and analytical modelling systems needs to improve, Dangermond (1987) responded by claiming that such a linkage was already beginning to emerge. This evolution is reflected in the appearance of location and allocation procedures in the standard set of functions included in some commercial GIS (Lupian, Moreland and Dangermond 1987).

But, despite recent developments (and as with any evolutionary process), there remain several barriers to the successful implementation of information system technology in general and GIS specifically. Dueker (1980:8) has argued that:

> '. . . the systems approach has severe limitations and is rarely applied successfully especially in long-range planning where the system is open-ended and the purpose of the plan is general and vaguely identified . . . The planning process itself is constantly shifting and, given the complexity and/or controversies in the planning decision, the scale of analysis is subject to considerable debate and change. Thus the design of information systems for planning cannot be considered a well-structured process'.

The complexity of these problems has led the

Urban and Regional Information Systems Association (URISA) to develop a research agenda which addresses 28 problems faced by planners and other professionals in attempts to implement GIS successfully (Craig 1989). Their list is divided into the following set of social and technical concerns:

- System adoption
- Social and legal impacts
- Management issues
- Economic factors
- Database development
- User interface and empowerment
- Software critique.

This list, assembled substantially by those active in some aspect or other of the planning profession, clearly indicates that a successful GIS involves a complex interrelationship between information, technology and human beings. More important still, it suggests that severe gaps currently exist between the ideal model that is often portrayed by the vendors and developers of GIS and those who are responsible for the daily operation of these systems.

Spatial Decision Support Systems (SDSS) in planning

An interesting parallel exists between the set of concerns that URISA has identified and the emerging debate on the adequacy of GIS to meet the needs for a Spatial Decision Support System (or SDSS). Specifically, the issues confronting SDSS are closely associated with the needs and obstacles that planners face in successfully implementing a GIS. Densham and Goodchild (1989:710) suggested that a SDSS can be viewed as 'spatial analogues of decision support systems (DSS) developed in operations research and management science to address business problems . . . [They] provide a framework for integration of analytical modelling capabilities, database management systems and graphical display capabilities to improve decision-making processes' (see also Densham 1991 in this volume). According to the definition provided by Geoffrion (1983), there are six distinguishing characteristics of a DSS:

1. They are designed to handle ill- or semi-structured problems.
2. They have an interface that is easy to use.
3. They enable the user to have full access to the database.
4. They are able to generate a number of alternative scenarios.
5. They support a range of decision-making styles.
6. They support interactive and recursive decision-making processes.

Given these characteristics, it would seem that the 'ideal' SDSS would overcome many of the specific problems identified by URISA. For example, a good SDSS should address the URISA objective of making GIS software accessible to users with different levels of technical expertise through the use of Artificial Intelligence, help screens, relational databases and software layering (Craig 1989). In other words, the ultimate success of GIS in planning is closely related to how well it can succeed as a SDSS in being incorporated in the decision-making process. The limiting factors presently relate most directly to data problems, inadequacy of the analytical functions and an inability to support the type of decision-making process that characterizes the planning environment.

The creation of Spatial Decision Support Systems

Later in this chapter, a specific project will be described as a worked example of an integrated approach to the use of GIS in planning. The goal of that project is to develop a SDSS which will be used in the highly visible and politically sensitive area of economic development. Decisions made in this context must consider the interrelationships between land use factors, economic growth, water and waste water facilities, and major transportation networks. The ultimate challenge will be to forecast the economic impact of infrastructure projects and to recruit new industry into the state. This requires a sophisticated SDSS that can support different styles of decision making (Calkins 1991 in this volume). In such situations – according to Densham and Goodchild (1989:714) – a SDSS 'should incorporate knowledge used by expert analysts to guide the formulation of the problem, the articulation of the desired characteristics of the solution and the design and execution of a solution process'. Yet the development of expert systems for such applications is relatively new territory and not all experts are convinced it is worth while. Kindleberger (1988:12), for instance, expressed his pessimism about expert systems in saying, '. . . local government issues tend to be complex to the degree that it would be foolish to expect major progress'.

The decision-making context

The meaningful interpretation and use of large scale GIS databases demands that the users of the system have the theoretical background required to develop conceptual models which incorporate the relevant dimensions of the problem. Therefore, the first step in creating a useful decision-making context for any project is to develop an analytical framework to select and weight the various layers of the GIS database. A research initiative by the US National Center for Geographic Information and Analysis (NCGIA) has begun to attack this problem by developing a taxonomy of users of spatial information. For example, Beard (1989) maintained that there are only six generic uses for spatial data (see also Maguire 1991 in this volume):

1. Siting of location
2. Logistics or allocation
3. Routing
4. Navigation
5. Inventory of spatial objects
6. Monitoring and analysis.

Obermeyer (1989) suggested that each of these generic uses needs a spatial theory or model as well as a database that can support the analysis. For example, the siting of an agricultural activity should be guided by agricultural location theory. The SDSS for locating such an activity would incorporate transportation costs, environmental factors, crop characteristics, etc. Each of these factors would be represented by specific data elements such as soil conditions, slope and length of the growing season.

One example where such theory-based approaches are guiding the use of GIS is in the South Carolina Infrastructure and Economic Planning Project (Cowen, Mitchell and Meyer 1990; see also below). In this, the selection of a suitable site for a prospective industry in the state is guided by industrial location theory: the decision-making process starts with a minimum transportation cost site and then compares that site with others which may offer savings in terms of labour costs, agglomeration factors or other variables. An interesting attempt to develop an expert system (ESMAN) to handle such decisions was also reported by Suh, Kim and Kim (1988). In their prototype, the authors used 13 components to develop a site suitability index for three hypothetical sites. The components included suitable plant site, availability of skilled and unskilled labour, wage rates, nearness to the market, accessibility to transportation, climate, utilities and tax rates. Each component was operationally defined. For example, accessibility to markets was measured by the distance to major cities, accessibility to transportation as distance to interchanges, airports and 'piggyback' services. Although this was only a prototype, the study provides a useful starting point for a SDSS to address industrial site selection problems.

SPATIAL DATABASES TO SUPPORT PLANNING

The simplest and fastest way to reach a decision is to use the minimum amount of information and to evaluate the fewest alternatives. Indeed, Horwood (1980) suggested that information systems often tend to make decision making more difficult. Simplistic analysis, however, often leads to simplistic and erroneous conclusions. Therefore, the overriding challenge to those creating a geographical database within a GIS is to combine the appropriate information in a format that can be easily queried, analysed and displayed – irrespective of the fact that detailed needs of the user may not emerge for some time after the system has been designed (see Mounsey 1991 in this volume)! The fundamental building block of a planning GIS must be an appropriate database.

A classic SDSS example of the importance of an appropriate database was the Decision

Information Display System (DIDS). This was a 'state of the art' system developed at the beginning of the 1980s by the federal government in the US (Cowen 1983). With the backing of the Executive Office of the President, DIDS was designed to serve as a central repository and display system for geographical information collected by all federal agencies. Using the (then) latest in colour image processing workstation technology, NASA created the system and assembled a large variety of statistical information for all the US counties. Unfortunately, the Bureau of the Census, the most extensive source of these data, was simultaneously in the process of conducting a new decennial census of population and housing; most of the DIDS data were therefore almost obsolete when it was made available. In addition, the system also was limited severely in terms of the data structure used and hence the analytical capabilities. For example, it was not possible to incorporate point or linear features, interstate highways being represented simply by an attribute 'miles of road passing through the county' while topography was denoted by average elevation within a county. In effect, a decade ago the 'state of the art' decision support system was nothing more than an expensive county-level map-making machine. Despite its technological sophistication in other ways, DIDS was doomed to failure because it did not contain relevant and up-to-date information to support decision making.

The fundamental database for planning

For a GIS to meet the needs of local government successfully, planners must have access to the databases that can describe the urban system in abstract physical, social and economic terms (see Parrott and Stutz 1991). Only if the database is designed to model the functioning, 'real-world' system can it be used for multiple purposes. A 1989 study of the ACSM–ASPRS Geographical Information Management System Committee suggested that, when building such a multipurpose geographical database, an organization should always 'future proof' the database as much as possible by following a fixed sequence of stages:

- Identify potential users.
- Identify output product requirements.
- Define spatial data categories.
- Establish required levels of accuracy.
- Evaluate data sources and quality.

In practice, of course, any process involving the expenditure of public funds will involve a compromise between the requirements of the perfect database and practical solutions. Building databases is all about making trade-offs between present needs and future opportunities, even though the level of costs involved may preclude some players. As Kindleberger (1988:11) stated 'The . . . question has to do with economics and the extent to which entrepreneurs, either for profit or non-profit, will be able to build and support comprehensive databases. Local government has little discretionary funding to pay for such services.' Thus – in the United States at least – planning databases may be too expensive for the public sector to create except for those which are created 'bottom-up' from transaction-based data.

This uncertainty over costs has led to many governments starting in GIS with project-based schemes, rather than the creation of comprehensive databases (Robinette 1991 in this volume; Siderelis 1991 in this volume). Such projects are inevitably diverse in nature. If this is accepted as a necessity for the start-up phase, what data do planners need to exploit GIS in the bulk of their everyday work? The analysis by Dangermond and Freedman (1986) suggested that commonality *did* occur in the needs of planners for spatial data. They claimed that the spatial database needed for local government planning purposes consists of the following components:

• A base map	Environmental overlays
• Engineering overlays	Plan/profile drawings
• Parcel maps	Parcel/street address data
• Area tabular data	Area boundary maps (administrative boundaries)
• Street tabular data	Street network file (geographical base file).

The collection of these layers of spatially registered information is actually a decision to establish a dynamic repository which, in principle at least, is capable of supporting all planning functions. The accuracy, timeliness, accessibility and flexibility of this 'digital atlas' will ultimately determine the success or failure of the system. The construction and maintenance process is an expensive one that involves the integration of a diverse variety of spatial information sources that normally include maps, aerial photography, surveys, census information and, increasingly, remotely sensed data (Ehlers, Edwards and Bedard 1989).

Scales of mapping

The survey by the ACSM–ASPRS committee found that there are about six different map scales, ranging from 1 : 600 to 1 : 24 000, which are commonly used in local government applications in the US. However, an application-oriented viewpoint would suggest that three levels of detail and representation of features are often employed in a planning context (Dueker 1988). The most generalized level is based on partitioning the region into a set of polygons which serve as geographical zones for aggregation of individual transactions or occurrences. These areal systems usually consist of census tracts, postal zones or traffic zones encoded from a scale of approximately 1 : 100 000, thereby confining much of the analysis to statistical analysis and mapping of socio-economic data.

An intermediate level of representation, at a map scale of about 1 : 10 000, is necessary to support locational analysis. Such applications are comprised of tasks which can be handled with an accurate representation of transportation networks, hydrological features and administrative boundaries. Many of the map layers identified by Dangermond and Freedman (1986) can be created at this level of resolution, in which an address can safely be represented as a single *X*,*Y* coordinate point. This level of analysis supports geocoding (typically, in North America, through address matching) which leads directly to point mapping, statistical analysis and network analysis (Plate 56.1). With an address matching capability, it is possible to convert any thematic information labelled with an address into a spatially registered layer. This approach is obviously useful for analysis of specific occurrences such as housing starts, registered voters, students, traffic accidents, emergency calls and criminal activities. Using such a GIS database, a planning organization can maintain a comprehensive and topologically correct base map for almost any size of planning region. Dueker has suggested that, for this level of analysis, a positional accuracy of 10 to 50 feet (3 to 15 m) is sufficient. In the United States it is common practice, however, to use 1 : 24 000 scale 7.5 minute US Geological Survey quadrangles for such applications. It is also striking that the US Bureau of Census used 1 : 100 000-scale maps as the base for the 1990 Census (see Starr and Anderson 1991 in this volume; Rhind 1991 in this volume).

In an urban setting, the finest level of spatial detail is required for facility management (Mahoney 1991 in this volume), maintenance of a multipurpose cadastre (Dale 1991 in this volume) and engineering design. For these applications, it is necessary to have geographical entities encoded at a scale of about 1 : 1000 with a positional accuracy of about 1 foot (0.3 m). This level of detail is required for tasks such as tax assessment which demand that geographical entities be represented as areas, not just as point features. Generally, compiling information at this level of detail costs two orders of magnitude more than the intermediate level database for the same geographical area. Therefore the decision to create and maintain such a database must be made with great care and the realization that a stable source of funding must exist. Such a financial requirement usually places this level of spatial detail beyond the scope of local planning departments and into the domain of tax assessors or utility companies. The situation differs, of course, in countries where national mapping agencies map at very large scales (e.g. see Sowton 1991 in this volume).

A SPATIAL DECISION SUPPORT SYSTEM FOR ECONOMIC DEVELOPMENT PLANNING IN SOUTH CAROLINA

Many planning activities are dedicated to fostering the prosperity of an area and of the people therein. Though they have only indirect influence on some factors which attract new industry or services (e.g. a pool of labour and its unit cost), planners can influence development in other ways. Commonly, they attempt to ensure that the area for which they operate has adequate infrastructure, an attractive environment, etc. For this reason, the remainder of this chapter forms a worked example: it describes a GIS project designed to support decisions on infrastructure improvement and industrial site selection. The South Carolina Infrastructure and Economic Planning Project is a collaborative one between the state, local government and university researchers (Cowen *et al.* 1990). It represents one of the first 'real world' implementations of GIS designed to support decision making in the economic development arena (Cowen and Shinar 1989).

One important aspect in the success of this project is the technological ability to share information. The system uses an existing federal digital database that can be accessed through a network of high performance workstations, enabling the partners in the project to share responsibilities and jointly participate in the processes of data gathering and use. For example, state officials have contracted directly with regional planning councils to create one of the most complex data layers. In turn, the ten regional planning councils contracted with nearly 600 water and waste water system administrators to gather their data in both spatial and tabular form. As Dueker (1988:104) suggested 'the technology provides the means by which economic constraints are relaxed, which reduces institutional barriers. Organizations can still maintain their institutionally independent layer of data and their control over it . But this increases incentives to share that data layer with others, which is leading to organizational innovation.'

Intermediate scale data from the federal government

The availability of intermediate scale digital data from the federal government was essential in this project since it provided a topographic framework on which many other data were 'draped'. The Bureau of Census GBF/DIME system represented an early (1967–71) attempt to develop a nation-wide geocoding system (Coppock and Rhind 1991 in this volume). These geographical base files, which represented skeletons of street centre lines, railroads, administrative boundaries and hydrological features, provided some address matching capabilities. However, they provided a poor cartographic representation of the geographical features and were limited to the 275 largest urban areas in the United States (Tomasi 1990). The needs of the Bureau of the Census to expand its geocoding coverage and to improve its cartographic capabilities prompted a joint effort with the USGS to create the 1 : 100 000 scale Digital Line Graphs or DLG (Starr and Anderson 1991 in this volume). In effect, this new database provides a reasonable cartographic and a good topological representation of the planimetric features on the standard USGS 7.5 minute quadrangles (Plate 56.2). The Bureau of the Census has converted these files into the TIGER database used to conduct the 1990 Census (Marx 1990).

Creation of the South Carolina database

The 1 : 100 000-scale DLG data provided a complete and unbiased representation of the basic transportation and hydrological networks of the state (Plates 56.3 and 56.4). The data were used to represent several important components of the state's infrastructure and as a template for the creation of other layers (Table 56.1) – just as in the CORINE project (see Mounsey 1991 in this volume).

Using the DLG base as a template to create other layers

The transportation layers in the DLG files were edge-matched between adjacent map sheets and reformatted into state-wide coverages. In conjunction with commercially available county boundaries, zip codes, census tracts and census county divisions, these transportation layers formed the basis of the 'molecules' from which other layers were created. One specific example is the way in which graphic DLG data were used as a template for the creation of the water and waste water networks. The procedure adopted required that a large variety of state-wide reference maps be plotted at various scales for local areas. In order to meet this need, a generalized mapping system was developed (Cowen and White 1989). This mapping system reads the original DLG files for any bounding rectangle and plots a base map of the highways, hydrography and miscellaneous transportation networks on an electrostatic plotter. For example, the map in Fig. 56.1 displays the

Table 56.1 Data layers to be included in the South Carolina system. ((DLG) represents those data that are derived from USGS 1 : 100 000 scale Digital Line Graphs and (SPOT) represents those that are derived from SPOT data.)

(a) Transportation
1. Highway location (DLG)
2. Traffic (count and type)
3. Railroad location (DLG)
4. Rail terminals and cargo loading sites (DLG)
5. Airport location (DLG)
6. Port location (DLG)

(b) Water supply systems
1. System extent and location
2. System capacities
3. System output (use)
4. Hydrology (DLG)
5. Stream capacities

(c) Waste water systems
1. System extent and location
2. System capacities
3. System output (use)
4. Stream discharge limits

(d) Air quality

(e) Land cover/land use (SPOT data)

(f) Flood plains

(g) Demographics and economics

(h) Business and industry
1. Directory of business and industry
2. Available buildings
3. Available 'developable' sites

various DLG layers for a section of the Columbia, South Carolina metropolitan area. Using this mapping system, it was possible to generate – as a matter of routine – a base map at 1 : 20 000 or 1 : 15 000 scale of the existing transportation and hydrography for each one of the 575 water and sewerage districts throughout the state. Local planners were used to transfer the contents of the water and sewerage lines engineering and standard maps on to the computer-generated base maps. The GIS coverages were created simply by selecting the relevant arcs from the transportation layer displayed on the workstation. Using this template approach, it was possible to create the complete water and waste water networks for the entire state in about nine months without ever touching a digitizing tablet (Plate 56.5).

Use of TIGER and remotely sensed data

The next stage of database development is focusing on the use of TIGER files to build complete census geographical area coverages for the state. The TIGER files provide a good county-oriented digital base (Plate 56.6). These files are superior to the DLG base for most applications because they contain street names for most roads and address ranges within the urbanized areas. Therefore, the TIGER data were used to create certain other layers, such as industrial locations, vacant buildings and commercial sites (Plate 56.7).

Another aspect of the project is focusing on land cover information from SPOT 20 metre multi-spectral satellite data (Plate 56.8). The creation of this coverage involves the integration of raster and vector data sources. The SPOT data are being handled in two different computing environments. A state agency is using standard remote sensing techniques to classify the data into a generalized land cover classification that will be converted into vector form for integration with the other layers. The data are also being used as raster graphic 'back planes' within the standard vector-based GIS workstation environment. In the second approach, the image-based data provide a basis for map edit and update. They also provide a quick overview of the basic land cover without going through the classification process (Plate 56.9).

Use of the system as an analytical tool

The South Carolina infrastructure GIS database is now beginning to be put into use for industrial site selection. The following scenario demonstrates how the data are being combined with GIS functions to determine quickly those areas which meet specific requirements for prospective industrial clients. For this example, it was assumed that the client has decided to locate a plant in the metropolitan Columbia SC area and needs to find an available building that meets specific infrastructure requirements. In particular, it has been assumed that the site should have good access to a major airport, interstate highway interchange, rail connection and be linked to a public water supply. In a GIS environment, each of the accessibility measures must be translated into a specific buffer

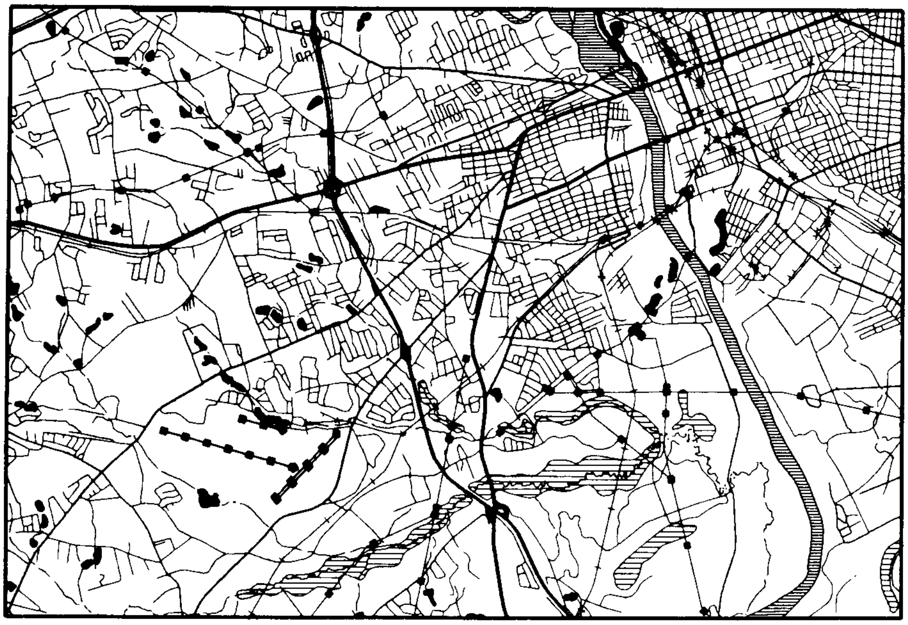

Fig. 56.1 Electrostatic plot of the 1 : 100 000 scale USGS Digital Line Graphs for a portion of the Columbia SC metropolitan area.

zone. The problem is then reduced to finding the Boolean combinations of the resultant proximity zones. For this example, the buffer zones for the airport, railroad and interstate interchange were set at 3500 m, 100 m and 1500 m respectively. Each of the layers was easily extracted from the TIGER base map and the zones automatically generated (Plate 56.10). From the resultant map, it was clear that accessibility to the airport was the most restrictive criterion. By examining the area around the airport more closely, it was possible to identify those areas that have good access to the interstate highway interchanges (Plate 56.11). An examination of the map also indicated there are only a few areas that would meet the narrowly defined railroad buffer criterion. Therefore, some compromise had to be made and the system had to be able to respond to the changes. In an interactive mode it was possible to display the three available buildings in the area and to examine the existing water supply lines to arrive speedily at a final site decision (Plate 56.12).

Although this is a somewhat simplistic example, it clearly demonstrates how TIGER files can be combined with locally generated information relating to water lines and industrial sites to create an extremely valuable GIS database for a wide range of planning activities. The interactive use of GIS analytical and display capabilities enables decision makers to retrieve and combine the relevant spatial information needed to arrive at the appropriate decision within acceptable time-frames. Given the performance of current graphic workstations, the type of scenario used in this example can be completed for the entire state in just a matter of minutes. Furthermore, unlike the situation where a static atlas of maps forms the information base, the decision maker in this environment can pick and choose the information that is relevant to the particular problem and can easily modify the proximity zones or other requirements. The next stage of this project is addressing the specific site requirements for different types of industries. For example, it has been empirically determined that major industrial water users in the state need to be located within 400 m of an existing waterline (see Cowen *et al.* 1990). This type of empirical work will result in a set of rules that can be built into an expert system to guide the initial determination of feasible sites throughout the state. The availability of 1990 Census of Population and Housing will provide the important labour market data needed to complete the model.

CONCLUSIONS

The objective of this chapter has been to examine the current status of GIS within the planning environment. It is apparent that planning is a form of spatial decision making which involves the detailed analysis of a complex set of geographical information. These activities require the creation of interrelated spatial databases and are perfect candidates for use of GIS technology. At the same time, there are several obstacles that have prevented GIS from gaining wide-scale acceptance within the planning profession to date. Many of these obstacles are related to the current limitations of GIS to fulfil its potential as a Spatial Decision Support System and to become an integrated part of the management and data processing systems within government. But the solution may partly lie outside GIS. Sommers (1987) maintained that local governments have to consider reorganizing the basic way they perform their responsibilities and cannot simply view the GIS as a substitute for manual processes. She recognized that it may be difficult for the GIS and the organization to adapt to each other yet this is the only way that the GIS can reach its full potential.

It is also increasingly evident that any public agency must address the complex legal issues relating to data ownership, accuracy, access, security and costs. For example, it may not be possible for an agency (at least in the US) to charge citizens for information that was compiled at taxpayers' expense. Any organization must also be aware that the development of a comprehensive GIS database is a long-term proposition. In particular, it must consider the cost and time associated with the inevitable migration to a higher resolution and more current base map.

In summary, then, GIS offers the potential to be the dynamic core for almost every aspect of planning. A truly successful planning-oriented GIS would be able to address a unified and current view of a community. This view would be maintained and updated on the basis of the transactions in which local government is already involved, thereby eliminating any redundant data collection and mapping. It seems clear that the ultimate success of GIS in planning depends on how well it serves the daily needs of the entire governmental arena and how well it is integrated into the entire realm of daily record keeping and data management. It is obvious that many difficulties still remain in bringing about this happy state. Yet the South Carolina Infrastructure and Economic Development Project demonstrates that, by using federally supplied databases and setting up local collaboration between autonomous agencies, it is possible to combine diverse information into an intermediate scale GIS database and exploit it successfully. Even more important, it also demonstrates that planning use of GIS cannot simply be a pragmatic exercise based on 'data crunching': industrial and other location theories must be used to inform economic development planning if the latter is to be successful.

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