

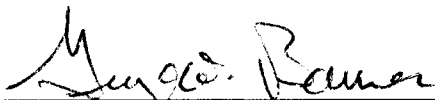
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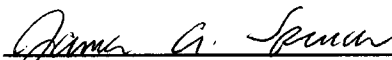


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GEOGRAPHIC INFORMATION SYSTEMS IN LOCAL GOVERNMENT PLANNING:
A REVIEW OF CURRENT AND POTENTIAL APPLICATIONS

A Thesis
Presented for the
Master of Science in Planning
Degree
The University of Tennessee, Knoxville

Jörg Land
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This thesis is dedicated
to my mother, Anna Land,
for her never ending
love and support.

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Finally, I would like to take this occasion to thank my former teachers Charles Tilly and Karen Fulbright from the New School for Social Research and Thomas Bender from New York University for the support and encouragement they provided during the earlier stages of my academic training.

ABSTRACT

Geographic Information Systems (GIS) are a new technological innovation that is of great importance to local government planning. This thesis investigates whether, and to what extent, planners should be involved in GIS. It also tries to determine what local government planners can do with GIS, and what they will be able to do with it in the future.

GIS is defined and its relevance to local government planning is discussed. Reviews of applications in the fields of comprehensive planning, land use planning, economic development planning, environmental planning, and transportation planning are presented. Several short systems descriptions were constructed from information collected by use of a mail survey and telephone interviews. This thesis concludes that GIS can be, and has been, applied to all of the fields of planning discussed in the application review. GIS is of great importance to planning and planners should become more involved in its development. Further development of applications is needed to make use of the full potential of this technology. At this point, only a few local governments can be considered sophisticated GIS users. In the future, the know-how on GIS applications will be more evenly distributed. Database integration, automation, the further development of spatial analysis

techniques, a more extensive use of modeling, and the use of digital maps as legal documents can be expected to be areas of future development in applying the GIS technology to local government planning.

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CHAPTER I

INTRODUCTION

1. GIS IN PLANNING

Geographic Information Systems are getting much press lately. The acronym GIS has become another buzzword in the planning profession. Many periodicals and popular magazines have reported about this new technology (for examples see Bylinsky, 1989 and Bell and Page, 1989). Some publications, e.g., Government, American City & County, and Planning, are full of advertisements of the major GIS vendor companies (especially ESRI, Intergraph Corporation, Tydac, and McDonnell Douglas). Several cities and counties across the country have already acquired or are considering the procurement of Geographic Information Systems.¹ Several professional organizations have given this new technology a lot of attention - most notably the Urban and Regional Information Systems Association (URISA), The American Society for Photogrammetry and Remote Sensing (ASPRS), and The American Congress of Surveying and Mapping (ACSM).

Practicing planners have to ask: what is the importance of GIS to planning? How can this new technology help planners be more efficient and effective? What are the

¹ A few examples of cities which are operating a GIS are, Nashville, Atlanta, Las Vegas, Minneapolis, and San Diego. See also Table 1 in Chapter III of this thesis.

advantages and disadvantages of having a GIS in, or available to, a local planning agency?

2. STATEMENT OF THE PROBLEM

There seems to be a general notion that GIS, much like word processing and spreadsheets, could be very helpful to the planning profession. However, this belief is generally not based on a clear understanding of what a GIS is and can do. The GIS technology is so new that only very few practicing planners have been introduced to it during their graduate studies. Even today, only a small number of planning schools offer courses in GIS. Books on the subject are rare (see Star and Estes, 1990, p.xi-xii). The technical articles that can be found in conference proceedings and journals are often written in a jargon that is unfamiliar to planners. Moreover, the technological development is so rapid that it is difficult to keep current.

Most planners have heard about the importance of this new technology and its alleged ability to create "supermaps." Some planners have a vague notion that in the future - whenever that might be - GIS will give them a superior grasp of their urban environments and will help them manage their information resources. Some have heard about the substantial costs of those systems and are doubtful whether they will ever reach down to the level of

the smaller local governments. Others are very much confused about the whole idea of a GIS and do not really understand what is so fascinating and new about it. They all operate with necessarily incomplete knowledge of this new and rapidly developing technology. Furthermore, even those who have some idea of the technical capabilities of a GIS often know very little about the financial feasibility of developing and implementing these capabilities. For these reasons, it can be said that planners have yet to come to terms with GIS.

How, then, can planners obtain a better understanding of what GIS has in stock for them? Do they have to study the computer manuals of GIS packages? Do they have to learn how to operate these packages? Do they have to dig into the jargon-laden technical articles that are published in various journals and conference proceedings? Yes, that is what at least some planners will have to do. However, this would hardly be enough. One of the distinctive features of the GIS technology is its general utility and need for final development by the end user. A GIS is a general tool. It can deal with vegetation types and soils classifications just as well as with zoning districts and parcel ownership. However, unlike other general purpose computer products, e.g., spreadsheets and word processing packages, a GIS does not come ready to use "off the shelf." It rather is a software that needs to be further developed by the end user.

After its initial installation a GIS has to be customized to the specific needs and requirements of the operating agency or agencies. Databases have to be designed and constructed and applications have to be developed. How to do this is still not perfectly clear - some GIS projects have failed. Somebody needs to develop the body of knowledge that is needed to effectively implement GIS in local government. But the people who develop GIS commercially are not necessarily planners, and their primary focus is not really the development of planning applications for GIS.² In short, it would not be wise for the planning profession to hope that somebody from the outside will present them with a GIS that gives them the capabilities that they always wanted to have. The planners themselves will have to do at least a part of the job of developing the planning applications of GIS.

Individual planners and the professional organizations that represent planning need to help generate the body of knowledge that is necessary to make full use of the GIS technology for the benefit of our local communities. Planning expertise and imagination will have to be applied to generate this body of knowledge. By getting involved in

² The urgent need for research in this area was expressed by Jack Dangermond, the president of the GIS-vendor company ESRI. He is quoted in Lang (1988) as having said, "Research is sorely lacking in this industry - we still need to know how users want to use geographic data."

the development of GIS applications, planners will gain an understanding of GIS and develop a realistic view of its capabilities and costs. Moreover, such an involvement would also guarantee that planners can make use of this new and important technology.

It is important that planners become acquainted with GIS. They have to understand it. They have to know what to do with it. This thesis is based on the premise that GIS is a significant technological innovation that opens a range of opportunities for the planning profession. These opportunities are best realized if planners themselves learn to understand the GIS technology and develop planning specific applications. Ultimately, it will probably be enough for most planners to know how to use GIS as a tool for various planning tasks. However, the "GIS planning tool" (application) has yet to be created. Therefore, planners will have to become involved with the technology to the degree that they can effectively participate in the development of the application of GIS to the field of planning.

This thesis has the purpose of making a step in the direction of creating the body of knowledge that is needed for an adequate use of GIS in local government. It attempts to do so by, first, collecting some of the existing knowledge on planning applications of GIS from the available technical literature, and second, by envisioning realistic

and useful additional applications.

Three research questions will be addressed:

- 1) What are planners currently using GIS for?
- 2) What GIS applications are likely to be developed soon? In other words, what GIS applications have appeared on the horizon?
- 3) What additional GIS applications in the field of planning are feasible and likely to be developed in the future?

Research questions one and two are of an empirical nature and were approached through literature study and a mail survey. Research question number three is of a more speculative nature. Accordingly, question three was approached in a tentative and exploratory manner. The information collected for the answering of the two preceding questions was used in the task of answering question three.

3. THE STRUCTURE OF THE THESIS

This thesis begins with a chapter answering the question: What is a GIS? This chapter defines and discusses the unique features of a GIS, such as its analytical capabilities, its capacity to quickly retrieve and manipulate geographical information, the importance of database maintenance, and problems and limitations inherent in the technology and its application to local government planning. A brief sketch of GIS's historical development is also presented in this chapter.

After having defined GIS, the study proceeds by

reviewing existing applications of GIS that appear in the literature. This part of the thesis describes currently existing GIS applications in local government planning. The review will address the subfields of planning sequentially. It will start with Comprehensive Planning, and then discuss applications in Land Use Planning, Economic Development Planning, Environmental Planning and Transportation Planning. General types and categories of applications will be identified. The information for this chapter was collected from the available literature (mainly journal articles and conference proceedings). The literature was surveyed and the relevant material summarized.

Short system descriptions of a sample of seven GIS installations in counties and cities across the country supplement the applications review. The system descriptions are a different way to address the question of how GIS is used in local government. The system descriptions accentuate the interactions between the planning department and other departments in local government more than the applications review.

To collect the information necessary for the system descriptions a questionnaire (see appendix) was sent to a sample of ten GIS installations. Additionally, a number of telephone interviews with managers of existing GIS installations were conducted.

Finally, the investigation is taken a step further by

attempting to anticipate future applications that are not yet on the horizon. Most of the work in this chapter is creative and speculative. The collected information on existing and planned applications along with the conceptual discussion of the previous chapter was used to speculate on the future of GIS in local government planning.

4. THE SCOPE AND LIMITATIONS OF THE STUDY

This study focuses on the range of possible applications of GIS in local government planning. Although some GIS applications outside of planning are discussed no attempt has been made to review these in a comprehensive fashion.

Furthermore, this study also does not specifically consider the feasibility of any of the mentioned applications in the specific situation of certain local governments. In this context it is important to note that this study is not geared towards a certain size of community. Obviously, the data needs and financial limitations vary according to the size of the community that a local government is working for. This thesis does not argue for the general applicability of the discussed applications. Some applications might be appropriate only in communities of a certain size and financial strength. A detailed analysis of the local capabilities and needs is always necessary before one can determine which applications

are feasible and appropriate.

The study has mainly an illustrative and exploratory purpose. True comprehensiveness in terms of the full range of applications in local government planning cannot be achieved by this study. Given the uneven distribution of expertise and experience in this field and the still evolving nature of GIS, a comprehensive review of the 'state of the art' may indeed be impossible to achieve at this point in time. However, it is hoped that the following presentation will lead the reader a good distance on the way to developing an understanding about how GIS can be used in local government planning.

CHAPTER II

GIS IN LOCAL GOVERNMENT PLANNING

1. WHAT IS A GIS?

Before one can start considering applications of GIS one has to understand what a GIS really is. A definition is in order. This paper will use three different approaches to defining a GIS. The paper will first quote Carter's (1989) definition of a GIS and briefly discuss its meaning. The second approach to defining GIS is made by considering the essential elements or components of a GIS. The third and final approach is the description of the basic functions of a GIS. It is hoped that all three approaches combined will illuminate this subject matter better than each of the approaches alone.

Carter (1989) defines a GIS as follows:

...any of those information systems that focus on spatial concerns and phenomena in the range of scales from the whole earth to the land parcel. Geographic information systems share the concerns of all information systems, with the added need to accommodate the spatial/temporal dimensions. There are a variety of geographic information systems, many of which are known by other names.
(p.6)

This definition points to a number of aspects of GIS. Firstly, GIS is part of a larger group of information systems. Information systems as such are not all that new and many professionals, including planners, have had some

exposure to computerized information systems. GIS belongs in this group of information systems and shares many of the ideas, concerns, functions, and capabilities with these systems (for an introduction to computers in planning see Rycus [1982]). We should think about GIS in terms of these information systems and apply our experience with, and knowledge of, these systems to GIS as well. Chapin and Kaiser have defined the term 'information system' and its significance for use in planning. They wrote,

As the term is used here, an information system is more than the content of the information files. It is the whole organized approach to obtaining, storing, retrieving, analyzing, and presenting data in response to specific information needs...[An information system's] purpose is to make the information planners and decision-makers need readily available, in usable form, at reasonable cost, when they need it (pp. 81-83).

Secondly, a GIS is characterized by its ability to process spatial data. This is something that "traditional" information systems do not do to the same extent as a GIS. The novelty and specialty of GIS is to a large part due to this ability to handle spatial data and link and crossreference them with non-spatial data (also called attributes or attribute data).

Thirdly, a GIS deals with a specific type of spatial data, namely spatial data of a geographic nature and scale. The scale of the geographic features is here defined as ranging from the size of a land parcel to the entire globe.

Finally, Carter's definition points to the fact that

still a lot of confusion exists about the term GIS. Other terms - that sometimes do denote GISs and sometimes do not - are: CAD/CAM or Computer Aided Design/Computer Aided Mapping, AM/FM or Automated Mapping/ Facilities Management, LIS or Land Information System, MPC or Multipurpose Cadastre, and UIS or Urban Information System. The confusion might be reduced by a brief definition of these terms.

The term **Computer Aided Design (CAD)** refers to graphic design that is done with computer based technology. CAD is often used to support engineering functions such as the design of buildings, roads, and water and sewer systems. Due to their fairly advanced graphic capabilities CAD systems are also used for mapping. If they are used for mapping, CAD systems are also called **Computer Aided Mapping (CAM)** systems. CAD/CAM systems can be superior to GISs in their graphic display capabilities. They do not, however, have the analytical capabilities of a true GIS (Burrough, 1986, p.81). CAD/CAM technology tends to be used in situations where engineering work needs to be done.

Automated Mapping/Facility Management (AM/FM) systems are designed specifically for the management of the facilities of utility companies (and similar institutions). Their databases are usually limited to the lines and facilities of a distribution system, like electric, water, sewer, and telephone networks. They usually do not include

information that is not linked to the management of these distribution systems. For example, land cover, land use, and zoning information is not part of the database of an AM/FM system.

A **Land Information System (LIS)** is a GIS focusing on the ownership information and the exact location of land parcel, right-of-way, and easement boundaries. A LIS is likely to contain exact information about ownership, value of parcel, parcel size, and applicable tax rate (Leykauf et al., 1989, p. 245). It is, as Kjerne and Dueker say, "specialized to answer questions about land records" (1986, p. 143).

A **cadastre** is a concept very similar to an LIS. A cadastre also deals with the legal land parcel. A **Multipurpose Cadastre (MPC)** is "the basis for a carefully planned and implemented land information system for the entire local community of land records users" (Kjerne and Dueker, 1986, p. 143; emphasis in original). Although the MPC is primarily concerned with land records, it may contain other types of information. In this sense, a MPC seems less exclusive in its focus on land records than an LIS.

Urban Information System (UIS) is a generic term for all types of information systems that are used in local government. They may or may not involve spatial data handling.

Another way to define a GIS is by listing and

describing its essential elements.³ These elements are:

- hardware
- software
- database
- personnel
- institutional structure maintaining the system.

The absence of a single one of these elements prevents the other elements from fulfilling their potential of constituting a GIS. The elements personnel, database, and institutional structure speak to the point that a GIS is not an ad hoc kind of effort. To obtain and maintain a spatial database is a time consuming and expensive effort, which really only pays out over the long run. Moreover, it only pays out if it is done in a systematic and continuous fashion. Spatial data lose their currency rather quickly - new roads and houses are built, streets are widened, and parcels are sold. Updating the database becomes a very important task soon after the initial data acquisition. The usefulness and rationality of a GIS depends to a large extent on maintaining the currency and integrity of the database. Only a well structured institutional arrangement can guarantee the upkeep of the database. Personnel has to

³ These elements are the elements of a computerized GIS. Conceptually, manual and non-computerized GISs are possible (see Parent and Church, 1989). However, this thesis deals only with computerized GISs. Manual GISs, like a simple paper map, are well known and understood in their day-to-day use. Computerized GISs are not generally well understood and have great potential for increasing spatial data handling capabilities. Therefore, this thesis focuses on computerized GISs and ignores manual GISs altogether.

be hired and trained to work with the system. It takes time to develop a qualified staff of operators and technicians. Carter (1989, p. 3) makes the same argument by pointing to the need for continuous funding over time and the need to maintain a staff that operates the system and accumulates expertise.

Another point needs to be made in this context. The prices for GIS hardware and software appear to many as being very high, although they have decreased considerably in recent years. It is, however, important to realize that the largest cost items of a GIS are not hardware and software, but the initial data acquisition and the subsequent database maintenance. Moreover, one has not bought a GIS by simply buying the hardware and software! Indeed, the phrase "buying a GIS" should be avoided altogether. It would be more appropriate to talk about "building a GIS" because the purchase of the hardware and software is merely a first step in the creation of a GIS. Data acquisition, application development, and database maintenance as elements of an institutional arrangement still have to follow to make the GIS.

A third approach to defining a GIS is to discuss its general functionality. What does every GIS do? A number of basic functions of GISs have been identified (Star and Estes, 1990, pp. 24-31 and 61-190; Carter, 1989, pp. 3-4; Guptill, 1989, pp. 1583-1584; Marble, 1987, p. 3; Dueker,

1987, p. 389; Leykauf et al., 1989, pp. 245-246). The four basic functions of a GIS are:

- spatial and non-spatial data entry
- data storage and management
- analysis and manipulation
- product generation (report and map creation).

Data entry is a fundamental function of every GIS.

Digitizing tablets, scanners, and keyboards are used to enter data into a GIS. Digitizing tablets and scanners are used to input spatial information from existing maps or aerial photographs into the system (Burrough, 1986, pp. 59-60 and 61-63). The analog map information is thereby converted into digital form, thus the name digitizer. Most systems also allow the direct input of digital data, such as satellite images and DIME or TIGER files. Spatial information can also be input by typing numbers of coordinates into a keyboard. However, more commonly keyboards are used to enter attribute data. Most GISs also have the capability to read existing digital attribute data. Once the spatial data are entered they frequently have to be corrected. So-called 'rubber sheeting' and rectification techniques are used to make the new data fit a set of known reference points on a base map. Rubber sheeting involves the stretching and or contracting of the map to make it fit those reference points (Burrough, 1986, pp. 67-68). Rectification is "the process of converting the spatial locations of objects in a dataset to those of a specified

map projection" (Star and Estes, 1990, p. 154). A third technique called 'edge matching' is used to remove misalignments of objects in a spatial dataset. If several map sheets are digitized to create a continuous digital map of an area, misalignments occur around the edges of the map sheets. The 'edge matching' procedure realigns these artificial edges (Tomlinson and Boyle, 1987, p. 41).

Related to the function of data entry is the data editing and updating capability. A system that would only allow initial entry of data and no editing and updating of the database would soon become obsolete.

Data storage and management is another basic function. By and large the requirements and tasks for GIS database management systems (DBMS) and traditional DBMSs are the same. Guptill (1989) observes many commonalities and a few differences,

GIS database functions parallel those of a nonspatial database management system (DBMS), but with extensions beyond the addition, deletion, revision, and Boolean retrieval capabilities of a standard DBMS. The GIS DBMS contains hardware and software facilities for the storage, retrieval, and update of spatial information (in both alphanumeric and digital graphic forms), and incorporates storage structures to minimize data redundancy and to aid spatial searches. In addition, the GIS DBMS (like non-spatial DBMS) must have the file management capabilities to handle a potentially large archive of data files (p. 1583).

The design and management of the database fundamentally influences the way in which the data can be used. A

database management system has to facilitate the storage, retrieval, deleting, and updating of the data. Access to the data may be restricted to certain users for data security or other reasons. Good database management is essential for efficient use of a GIS. As Star and Estes (1990, p. 26) observe, good data management is hardly noticed by the GIS users. Poor data management, however, is very noticeable, due to long retrieval times, loss of currency, and database corruption.

The ability to **manipulate and analyze** the data is the heart of any GIS and the aspect which planners should be interested in the most. Spatial queries, overlays, reclassifications, buffering techniques, etc. are important tools that a GIS provides. Star and Estes describe manipulation and analysis procedures as follows,

Some of these procedures will modify the form or structure of a data layer in specific ways...Other more general-purpose procedures can create data that may be non-spatial (such as the mean elevation in a region of interest or the linear miles of roadway in a city) or can create new information in a form similar to the original data (for example, creating a data layer of elevation in meters referenced to a local benchmark, which is derived from elevation in feet referenced to a regional benchmark). The development of derived data layers, which may form the input for further analysis, is an important function of any GIS (p. 143).

Reclassification is a simple but very powerful spatial analysis tool. Spatial information often comes in classifications that are unsuitable for a given analysis

task. By reclassifying the original data into a few distinct classes that are meaningful for the task at hand, a new data layer or thematic map can be created. This new layer or map will contain new information derived from the original data (see Chapin and Kaiser, 1979, pp. 308-315). An example for such a reclassification procedure is a soils map. A soils map usually identifies a great variety of soils types with varying characteristics. By aggregating the soils types that are suitable for development without sewers we can create a new map. This new map will distinguish those areas that are suitable for the use of septic tanks from those that are not.

Overlays are one of the most powerful spatial analysis tools (see McHarg, 1971, pp. 31-41; 79-91; 103-115; 189-193; and Chapin and Kaiser, 1979, pp. 308-315). Staying with our earlier example, let us assume that part of the map area is served by sewers. To make a complete suitability map - a map that shows all areas suitable for development - we can simply overlay a map of the sewer district over the reclassified soils map. All areas that are either served by the sewer system or have developable soils types will be classified as developable land. Additional overlays could introduce other factors, like excessive slope, zoning, access to transportation, into the suitability analysis. Overlays can be used with Boolean operators (see Figure 1). Such an overlay could be described as follows: Classify an

area as developable if it has sewer access OR if it is of a soils type suitable for development without sewer. Other overlays may use other operators (see Star and Estes, 1990, pp. 148-149). According to a survey conducted by GIS World, Inc. about 80 percent of the surveyed systems performed Boolean operations (Parker, 1989, p. 1589).

Spatial aggregation is a data manipulation technique that decreases the resolution of a map (Star and Estes, 1990, pp. 151-153). This might be desired "if regions of less than a specified area must be ignored for a particular application" (Star and Estes, 1990, p. 151) or to reduce data volume. Certain decision rules have to be applied. If for example, in a raster based system, four pixels are combined into just one pixel - of the same size as the four original pixels combined - a decision rule has to specify how this new pixel is classified. If all four original pixels had the same classification the new pixel will assume that classification. If, however, one pixel is classified as A and the other three as B we can either create a new class for 1 A & 3 B or classify it as B because B predominates. The same choice has to be made for all of the other possible permutations of pixel combinations. The result is a coarser and more generalized map. The resulting information loss might be substantial.

Some spatial operations deal with the connectivity between locations. These operations determine the proximity

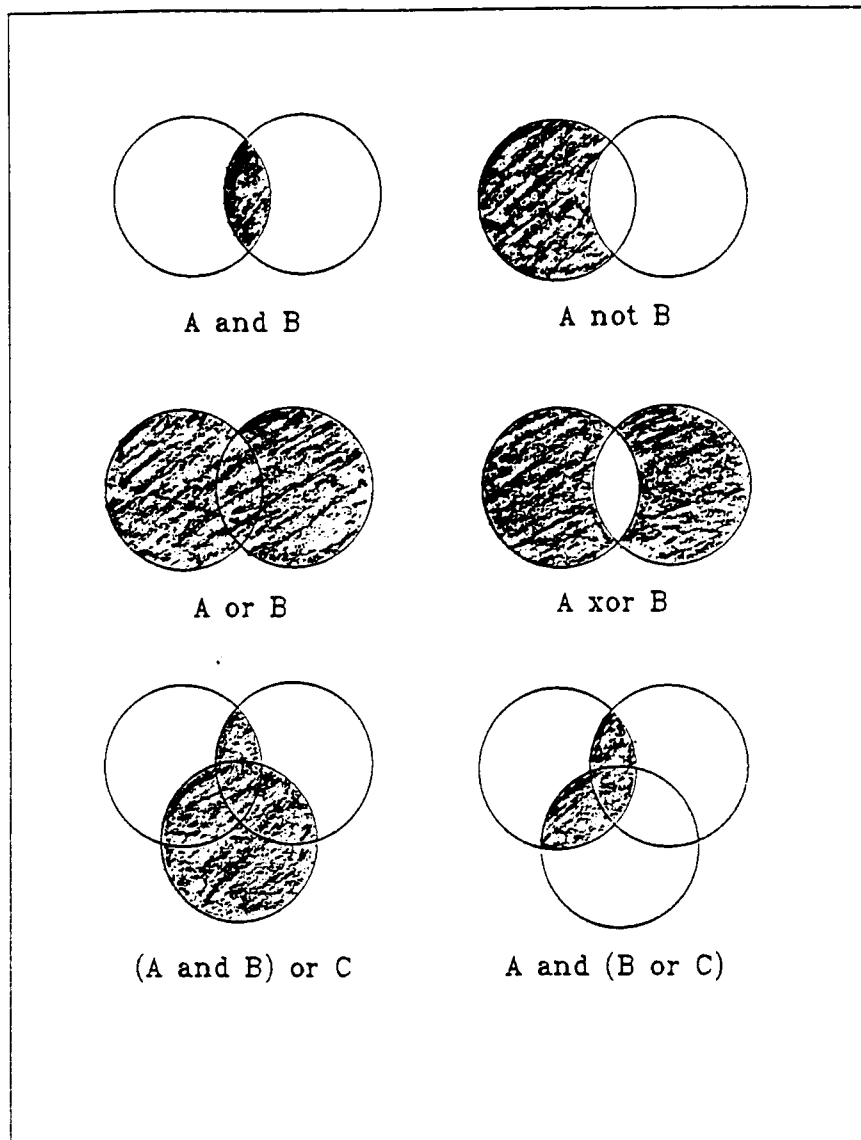


FIGURE 1

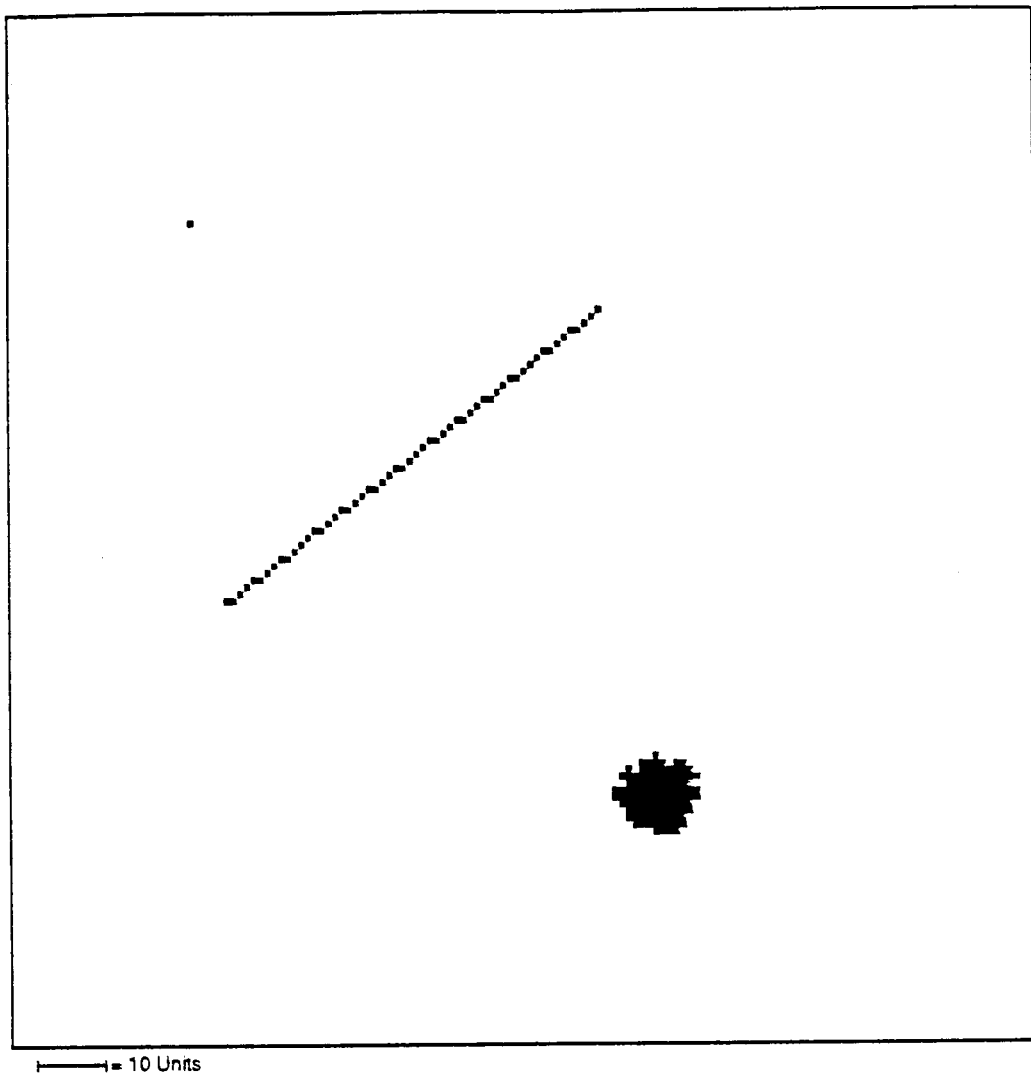
BOOLEAN OPERATORS

Source: Burrough, P.A. (1986) Principles of Geographical Information Systems for Land Resources Assessment. Oxford, UK: Clarendon Press, p. 82

of map items. Buffering techniques belong to this group of operations. A buffer area of a certain size is created around a map item - this may be a point, line, or polygon (see Figure 2). According to the same GIS World, Inc. survey mentioned above, 90 percent of the surveyed systems featured at least some form of buffering (Parker, 1989, p. 1589).

Within networks, like a road system, the connectivity among a set of points can be defined as an optimal path through the network. This procedure is often referred to as routing. An allocation function in a network analysis lets us, similar to the buffering technique, determine the connectivity among map items. However, in an allocation the buffering is done along the paths of the network (see Lupien et al., 1987).

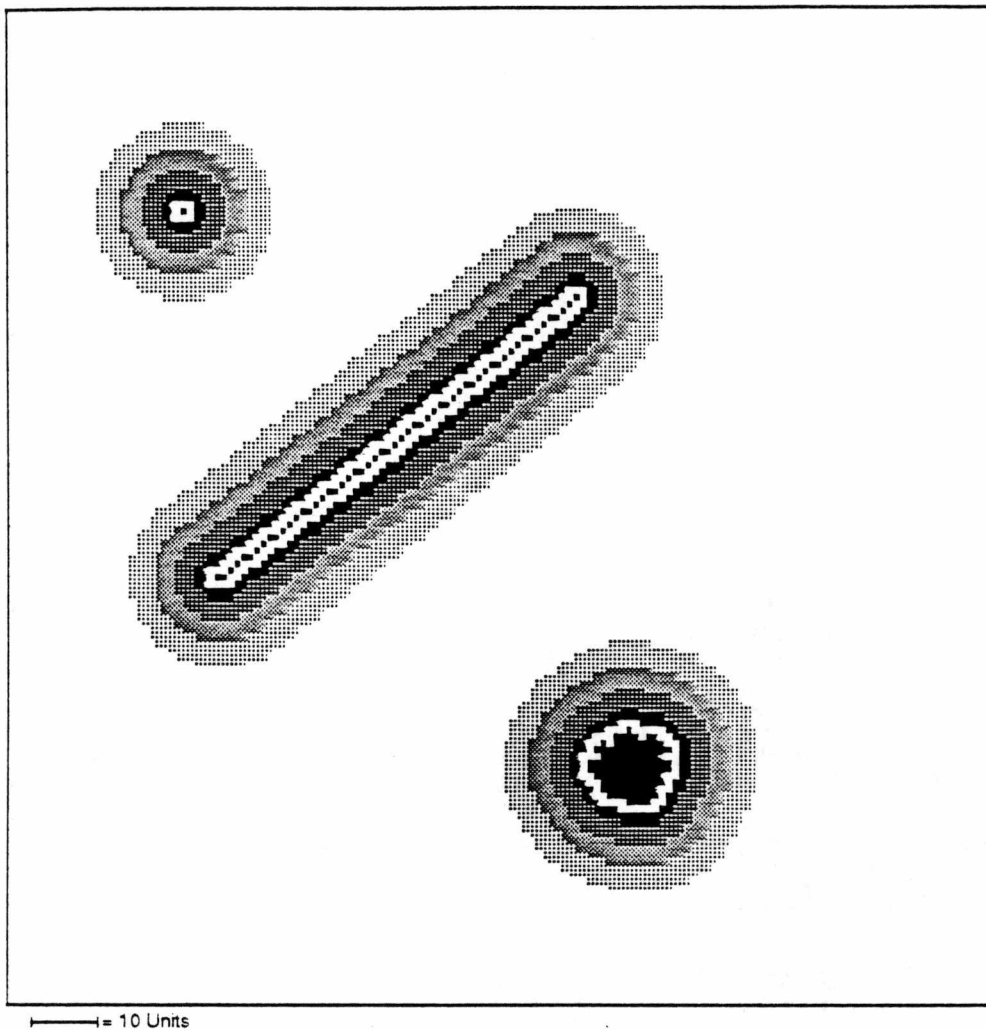
Another set of operations try to determine neighborhood characteristics, like the types of land-uses surrounding a parcel. In a raster database we can analyze attributes of the pixels surrounding a pixel or set of pixels. Related to this operation are filtering techniques, like spatial convolution, which are frequently used to process remotely sensed images. In a spatial convolution procedure a mask of a certain size is moved across the map. The mean value of the values covered by the mask is calculated. On a new map this mean value is assigned to a set of pixels at the same relative location as the original pixels. This procedure



A. Before Buffering

FIGURE 2

POINT, LINE, AND POLYGON FEATURES BEFORE AND AFTER BUFFERING



B. After Buffering

FIGURE 2
(CONTINUED)

generalizes the map information but maintains the original resolution. The mask (also called kernel) can be of varying size - the larger the mask the greater the generalization. There are several filtering techniques that follow similar procedures (for more information on filtering see Star and Estes, 1990, pp. 159-164).

A wide range of statistical analyses can also be performed with a GIS (Star and Estes, pp. 167-169). For this it is often desirable to export the data out of the GIS into a standard statistical analysis package. Descriptive and inferential statistics can be used to analyze attribute data. To generate data on spatial phenomena one can use the GIS's ability to measure the dimensions of map features. For example, the length of roads or the area of parking lots can be calculated within the GIS and then exported for further analysis. The GIS World, Inc. survey showed that 94 percent of the surveyed systems had at least some ability to measure distances (Parker, 1989, p. 1589).

These techniques and their use in combination are often referred to as cartographic modeling. Burrough (1986, pp. 93-100) gives some examples of cartographic modeling using the well known Map Analysis Package (MAP) developed by C. Dana Tomlin. These examples are similar to the land suitability example discussed above. For a list and brief description of the many spatial analysis operations

available in MAP see Burrough (1986, pp. 88-91). For an in depth discussion of these operations see Tomlin (1990).

Finally, any GIS should have **product generation** capabilities (see Star and Estes, 1990, pp. 174-190). A GIS must allow the relatively easy and quick generation of paper or mylar maps and written reports showing the results of analyses and manipulations. Some statistical graphics like histograms and line graphs are also desirable. High quality pen or electrostatic plotters are used for graphic output.

2. SOME COMMENTS ON THE HISTORY OF GIS

Some planners might be asking themselves what is so new about GIS and why has it developed so rapidly in the recent past. Computers have been around since the 1950s, so why did GIS not develop sooner? Why have we seen so much activity in this field in the last couple of years?

These questions are not at all easy to answer. A few elements of an answer, however, can clearly be identified. Obviously, the need for improving spatial data handling has been present for a while, at least as long as computers have (Parent and Church, 1989). As Marble (1987, p. 3) observed, "the advent of the digital computer as a data handling device soon raised the question of its applicability to the storage and manipulation of spatial data."

There were some early attempts to create maps with

computers dating back to the 1950s and 1960s. These attempts were largely experimental in nature. With the exception of some military applications, the high costs and limited capabilities of then available hardware confined these attempts largely to academic circles. The lack of adequate data structures for spatial data held back the development of the technology. It took many years to develop data structures and software adequate for spatial data handling. In 1960s and early 1970s a number of workshops held at the Harvard Laboratory for Computer Graphics provided an important forum for the development and exchange of information on spatial data handling. An early GIS package called SYMAP was developed at the Harvard Laboratory (Antenucci and Brown, 1989, p. 53). In the early 1970s, Jack Dangermond, a participant at the Harvard workshops, founded the Environmental Systems Research Institute (ESRI) - the vendor of the currently leading GIS package ARC/INFO - and started to develop GIS software commercially (see Bylinsky, 1989; Lang, 1988). Research and development efforts in both the private and public sector lead to a gradual maturing of the software.

Parallel to the development of GIS software, the field of computer graphics evolved and the computer equipment needed for it - i.e., graphics terminals, plotters, scanners, and digitizers - matured. Computers became cheaper and faster. Disk storage became more affordable.

In the early to mid-1980s the prices, quality, and speed of both hardware and software reached a level that made GIS look affordable and appealing for use in local government (Marble, 1987, p.3). Although the concept and some of the technology had been around for a while, it was not until the early 1980s that GIS became technically feasible and affordable to a wide range of users, local government among them. These developments resulted in the current wave of activity in the GIS field.

Computer technology is still advancing at a rapid pace and the further improvement and dissemination of the GIS technology will undoubtedly continue in the 1990s. Additionally, major advancements in the applications of GIS in various fields, ranging from military defence mapping to environmental planning, can be expected.

3. THE VALUE OF GIS

The preceding discussion has pointed to some features of a GIS and hopefully increased the readers understanding of what a GIS is. However, some readers might ask: Well, we have been doing some of these things all along - what is so special and new about a GIS? It is true that a GIS does a number of things that have been done all along, e.g. thematic mapping, map storage, map overlays. In fact, one could argue that a (computerized) GIS does nothing that could not somehow be done with traditional techniques.

The argument in favor of GIS, and the answer to the question above, has two components. Firstly, a GIS does a lot of things that have been done all along but more effectively, efficiently, and with greater accuracy. Secondly, a GIS allows us to do things that are not commonly done, not because they are impossible to do, but rather because they are too costly or cumbersome to do.

Let us examine this argument more closely. Paper maps are the traditional form of storing and displaying spatial information, and, by way of map legends, to link spatial data to attribute data. However, a map can only store a limited amount of data before it becomes cluttered, difficult to read, and finally unusable. To be useful maps have to be limited in size, number of features shown, and the amount of legend information displayed. A map of the size of a football field is useless. A map that displays so much information that it becomes blurred and unreadable is equally worthless. And for any given size of map we can only display a limited amount of legend information before the legend becomes unreadable. Moreover, legend references through color or pattern coding can only be used to a certain extent before the map becomes undecipherable. These are the natural limitations of hard copy maps. A GIS as a spatial information storage device overcomes these limitations. The spatial database of a GIS can represent an area as large as an entire city, or larger, in a continuous

fashion and on a small scale (e.g., 1''=100'). The otherwise daily occurring problem of reconciling the edges of map sheets, if the area of interest happens to be on more than one sheet, is handled automatically in a GIS. Furthermore, the continuous database may contain many independent map layers. Each layer represents a category of spatial data and related attribute information. All of these layers combined would make an absolutely unreadable and incomprehensible map. But, using the GIS's ability to display any combination of the layered map information, we can produce an almost infinite number of thematic and general purpose maps. Moreover, we can customize these maps in such a way that they display exactly the information that is needed for whatever the task at hand might be, not more and not less. Thus, a GIS not only stores more information than any single paper map could, it also allows a large amount of flexibility in the selection of combinations of map elements for display. If paper maps are used for spatial data storage, cumbersome tracing, and scale conversions are frequently needed to generate thematic maps. This is a costly and time consuming task, which a GIS can complete almost instantly and at greatly reduced cost (Guptill, 1989, p. 1583).

Another important advantage of GIS over paper maps is the ease of update. Paper maps are expensive and cumbersome to update (Marble, 1989, p. 2-3). In contrast, a GIS is

designed to allow frequent updates at relatively low cost. In fact, a GIS makes continuous update feasible where, with traditional procedures, it was generally understood to be prohibitive.

Moreover, the accuracy of thematic maps that were created manually from several map sources is often questionable. Although the issue of accuracy of thematic maps requires more research (Burrough, 1986 pp. 103-132), it seems generally clear that GIS generated thematic maps composed from different map sources are less error prone than manually produced maps using the same map sources. Therefore, we can say that a GIS has the potential of improving accuracy.

A GIS's map generating functions lead to a new way of map making. Traditionally map making is a time consuming and tedious task which is usually delegated to a professional draftsman. A GIS allows the planner or analyst needing a map to create it him or herself, and this often in a fraction of the time that it would have taken using manual techniques.

Another advantage of a GIS is that it tends to keep map information in a central and universally accessible place. Regular paper maps are not easily stored and archived. Moreover, since few local governments keep up-to-date inventories of all the maps that have been created by various departments, it is hard to know what maps are

available. This often leads to redundant data gathering and map creation. Information that is available is often not used because potential users are not aware of its availability. A well-managed GIS will help avoid these inefficiencies. It will list all the map information that is available and give easy access to it. The GIS becomes a central data depository that optimizes data exchange among users. Thus, a GIS has the potential of coordinating the data gathering efforts of a local government. It helps avoid redundant data gathering and makes the problem of redundant map generation a non-issue. It challenges departments to overcome parochial thinking and provides a framework in which individual departments can contribute to the data needs of the local administration as a whole.

Spatial queries that were before the advent of GIS so cumbersome and time consuming to perform that planners and other analysts hardly ever used them, can now be performed on a day-to-day basis. Some well known cartographic techniques, like dot density maps, reclassifications of choropleth data, view shed analyses, and comparative circle maps, can now be used almost without regard for the staff-time and costs involved in applying them.

These are some of the advantages of GIS that are apparent now. The application of GIS to planning is still at its beginning and many unknown potential benefits and uses of GIS will probably be discovered as more use is made

of this technology. Local governments, just like everybody else, are still at the beginning of making use of the potentials of a GIS. Local governments still have to learn more about how to use a GIS effectively. In this situation the sharing of experience is very important. Information on successes and failures in using GIS in local government should be shared.

4. WHY SHOULD LOCAL GOVERNMENT PLANNERS BE INTERESTED IN GIS?

After having discussed the general value of GIS let us now turn to the utility of GIS for the planning profession. Why should local government planners be interested in GIS? To answer this question we first need to define planning in general and local government planning in particular.

What is Planning?

Planning is the design of courses of action that are intended to reach a desired future state of affairs. Planning tries to maximize positive and minimize negative consequences of future developments. Planning is distinguished from unplanned (ad hoc, piecemeal) decision making and action. Planning applies rationality to the problems of information gathering, forecasting, predicting, decision making, and implementing. The availability and proper use of information is essential for rational

planning.

Planning is action oriented. It implies the willingness to intervene with ongoing processes if intervention would bring about, or increase the likelihood of, a desirable outcome.

Planning also implies problem definitions and goal formulations. Planning is possible if, and only if, a set of desired and principally obtainable results (ends) can be identified. Therefore, a fundamental element of planning is goal formulation. Goal formulation is generally preceded by some form of analysis of the current state of affairs and projections of current trends into the future. Once a set of general goals is defined, planners can start to define concrete states of affairs (objectives) that are steps in the direction of goal attainment. They can, furthermore, identify and describe certain ways (means) to bring these states of affairs about. If there are alternative ways to reach the objectives, the planners will consider these alternatives and choose, or recommend, the alternative which they consider the best.

Once a certain way (mean) has been selected a specific course of action - the plan - will be defined. The plan is then implemented. During and following implementation the planners will evaluate the effectiveness of their plan. In doing so they will compare the achieved and anticipated results of their plan with the goals and objectives that

were initially defined. They will also reconsider these goals and objectives to see whether they are in need of refinement and improvement.

The above outlined process is called the 'planning process' (see Chapin and Kaiser, 1979, pp. 72-76; Levy, 1988, pp. 89-97). In summary the planning process involves the following five steps.

- Step 1: Analysis of the Situation
- Step 2: Problem and Goal Formulation
- Step 3: Means Selection and Plan Formulation
- Step 4: Implementation
- Step 5: Evaluation.⁴

Local Government planning is planning applied to the problems and needs of local communities. Local government planning is devoted to furthering the interest of the community as a whole. It deals with a wide range of issues. Land use controls, i.e. zoning and subdivision regulations, are its exclusive domain. But it also deals with economic development, environmental protection, historic preservation, transportation, urban design, health care, hazard mitigation, school location, and many other

⁴ It is important to note that this process is not as strictly sequential as the description makes it appear. Moreover, the steps within it are not as discrete in praxis as in theory. For the purpose of explaining the planning process, one is forced to dissect it into its basic elements. These basic elements are analytical constructs that appear in reality as the interwoven parts of a whole. This is to say, that all of the steps in the planning process take place simultaneously rather than sequentially. The planning process is also an iterative process. It does not end after one run. It is cyclical rather than linear. All five steps in the process are continuously executed.

miscellaneous issues. The planner in local government is primarily an advisor to the decision making bodies of the community. The planner directly reports to a planning commission, a body of citizens appointed to the job of reviewing planning issues.

One of the important tasks of the planner is the formulation of a comprehensive plan (also called general plan). In preparing the comprehensive plan, planners follow the general planning process outlined above. Planners will study the community in its physical, economical, and demographic aspects. They will engage in a process of goal formulation, during which they will consult the public, local interest groups, and their professional knowledge and convictions. After the goal formulation is completed they will define objectives and means to reach these objectives. They present the whole (i.e. the results of their analysis, the goals, the objectives, and the means) in a comprehensive plan using text, graphs, tables, and maps. The plan is then presented to the planning commission and legislative body for approval. After the plan is officially adopted by the legislative body, it will be used as a general guide for decision making in the community. It describes the communities general plan for the future.

Planning in the context of local government has three basic functions (see Chapin and Kaiser, 1979, pp. 69-72). These functions are:

1. Information Gathering and Dissemination
2. Goal Formulation and Comprehensive Planning
3. The Regulatory Function

Information Gathering and Dissemination. The planners produce reports and plans that contain important information about the community. The planner's reports and plans are often the information basis used for public and private decision making in the community. Planners are also supposed to alert the community to the existence of major opportunities and propose ways to make use of them. Chapin and Kaiser (1979) call this the "intelligence function" of land use planning and describe it as the "gathering, organization, and dissemination of information"(p. 69).

Goal Formulation and Comprehensive Planning (see Chapin and Kaiser, 1979, p. 70). The planners, in their comprehensive planning efforts, are collecting information about community attitudes. Using this information and their own professional judgement they formulate community goals. The local planning agency is, therefore, one of the institutions in the community that is engaged in goal formulation. Because this goal formulation is rather formalized, continuous, and oriented towards public (general) and not private (special) interests, the planning department is one of the most important goal formulating agents in any local community. Moreover, in the comprehensive plan the planners describe ways of goal attainment. No other local agent (e.g. interest groups,

political parties and organizations) is doing this to the same extent and as systematically and publicly as the planning department.

Regulatory Function. The regulatory function of planning, by and large, consists of the administration of land use controls. Land use controls are intended to minimize negative third party effects that result from private action. Land use actions that have positive third party effects are to be encouraged. The regulatory function also involves "day-to-day input to community land use decisions" (Chapin and Kaiser, 1979, p.71).

It is important to realize that one of the constraints on the rationality of planning are the limits of access, accuracy, and the ability to analyze information (see Simon, 1955). A GIS improves the planners access to information by making more information more easily available than traditional techniques. A GIS is a far better repository for spatially referenced data than was ever before available. The ease and speed of data retrieval, update, and the ability to crossreference spatial with attribute data are a GIS's mayor advantages. The data in a GIS are not only more up-to-date but also more accurate with regard to the representation of spatial information. But probably most importantly, a GIS improves the use of information by putting a number of analysis tools right into the hand of the planner. A GIS makes all of the spatial data analysis

techniques described above available to the planner. With these tools planners can use the information relevant to the tasks that they are facing effectively and efficiently.

Additionally, a GIS is likely to improve the access, accuracy, and use of information in all divisions of local government and beyond. It has been argued that planning is done not only in the planning department, but in many departments and institutions inside and outside of local government and that staff planners should be concerned with this entire planning and decision making network (So and Getzels, 1988, p. 408; 415; 419-427). Planning departments are frequently information providers for the various elements of this decision making network and the general public (Warner, 1982, pp. 125-128). It is often in the best interests of the planning department to provide these entities, and the general public, with up-to-date and accurate information. A GIS serves this interest in better ways than traditional techniques can. Chapin and Kaiser (1979) emphasize this function of information systems in planning. They write,

[An information system's] purpose is to make the information planners and decision-makers need readily available, in usable form, at reasonable cost, when they need it. In this sense, the information system program element is almost synonymous with the intelligence function of providing information services ... Its value depends solely on the support it provides for the other elements in the planning program and for community decision-making, private as well as public (p. 83; emphasis added).

A GIS improves the planners understanding of the environmental inventory and its dynamics. For general planning tasks it is important to know what is out there in the community - variables like office vacancies, areas with poor soils types, vacant industrial sites, etc. can be monitored much easier with the help of a GIS than without. The dynamics of urban and economic growth can be understood much better if they can be mapped with high accuracy and currency.

Another reason why planners should be interested in GIS is the availability of many relatively high paying jobs in this field (see PlanGraphics, 1990, p.3). Due to the small numbers of planners with GIS training a lot of GIS jobs in local government are going to people with degrees in geography, remote sensing, or other related disciplines. Planners who are committed to promoting their profession should be concerned about this trend. GIS is a technological innovation central to the concerns of local government planning. Planners should have a major part in the development, implementation, and operation of this technology.

5. PROBLEMS AND LIMITATIONS

In discussing the values and potentials of GIS one easily loses track of reality. One must point to the problems and limitations of a GIS in local government to

avoid the raising of unrealistic expectations. The equipment costs, the institutional changes that might be required, the legal problems relating to the public records law, and the difficulties and costs of database management, are all examples of issues that need to be on the mind of the local planner who is considering the procurement of a GIS. Let us briefly address a few of these problems and limitations.

Staffing is usually a significant problem (PlanGraphics, 1990, p. 3). GIS expertise is in short supply and the salaries of GIS managers and technicians are high. Turnover tends to be very high in local governments that cannot pay competitive salaries, especially among well qualified GIS experts. High turnover is very undesirable and may cause very serious problems, especially in the early stages of the development of a GIS (see Anderson and Preecs, 1989). Local governments are competing with the private sector and state and federal governments for skilled GIS technicians and managers. Unfortunately, because of the enormous expansion that the GIS industry continues to experience an easing of this tight labor market is not in sight.

There are also some legal problems surrounding GIS of which planners need to be aware (see Archer and Croswell, 1989). The public records law requires all government entities to make 'records' available to the general public

for the cost of reproduction. The question which parts of the GIS database and which GIS products are to be considered 'records' and which are proprietary information is a difficult one to answer. Due to the enormous cost of database acquisition, the commercial potential of many GIS products, and the cost of answering public requests, a number of installation's have opted for trying to recover some of the costs for the GIS by selling GIS products instead of just giving them away (Salmon, 1989). Whether and to what extent cost recovery is legal is not entirely clear at this point. Moreover, another legal issue arises from possible liability for damages resulting from faulty "GIS-produced" information (Sookman, 1989).

A very important issue concerning every GIS manager is database maintenance. As mentioned before spatial databases have to be continuously updated to remain useful. The costs for this updating are high. Furthermore, especially in a multi-user installation, it becomes important to determine who is responsible for updating which data. How can the accuracy of the updates be continuously checked in a cost efficient way and who may have access to which data and which data must be protected to insure privacy are other difficult questions that need to be answered.

Since GISs tend to cross over institutional boundaries they raise a number of institutional issues that are difficult to handle (see Metcalf, 1989, pp. 55-66).

Although a GIS can be a great opportunity to stimulate cooperation and coordination within local government it may also result in 'institutional turf battles' and other organizational problems. A GIS has to be neatly fitted into the existing organizational structure to work well.

Theoretically the applications of GIS in local government seem boundless. However, in reality, we face limitations as to what can be done with a GIS. Resources are limited and even a relatively efficient technology like GIS cannot do everything we might wish it to do. Assuming a fixed level of funding, GIS is limited in many ways, e.g., available data storage capacity, computing speed, and complexity of data analyses. Some applications might be "nice to have" but would cost too much in storage capacity, staff time, or CPU-time to be worth the effort. Some applications are more sensible than others - however, the distinction is often very hard to make.

GIS is still a young technology and there still is a lot to be learned about its application in local government planning. The sharing of information about successes and failures with GIS in local government is of great importance for all of those involved in this technology. The publications of professional organizations like the Urban and Regional Information Systems Association are a vehicle for this information sharing. Anybody considering the acquisition of a GIS should turn to these publications. And

anybody who has accumulated some experience with implementing or managing a GIS should be encouraged to present his or her insights at a URISA conference.

CHAPTER III

METHODS AND PROCEDURES

This thesis attempts to make a step in the direction of creating the body of knowledge that is needed for an adequate use of GIS in local government planning by, first, collecting some of the existing knowledge on planning applications of GIS from the available technical literature, and second, by envisioning realistic and useful additional applications.

Three research questions are addressed:

- 1) What are planners currently using GIS for?
- 2) What GIS applications are likely to be developed soon? In other words, what GIS applications have appeared on the horizon?
- 3) What additional GIS applications in the field of planning are feasible and likely to be developed in the future?

Research questions one and two are of an empirical nature and will be approached through literature study, a mail survey, and follow-up telephone interviews. Research question number three is of a more speculative nature. Accordingly, the approach to question three will be exploratory. The information collected for answering the first two questions will help in the task of answering question three.

1. THE MAIL SURVEY AND TELEPHONE INTERVIEWS

A questionnaire was sent to a sample of ten GIS installations. A non-random⁵ judgmental sampling technique (see Babbie, 1983 pp. 178-179) was used. The sample was designed to contain systems of large, medium, and small size communities. City and county systems were represented. Finally, systems in various stages of development (older versus younger systems) and geographical location were present in the judgmented sample. A wide range of GIS literature - including the proceedings and newsletters of the Urban and Regional Information Systems Association, the GIS-News section of Photogrammetric Engineering and Remote Sensing, and Metcalf (1989) - was used to identify and select these systems.

Table 1 lists the systems which were included in the sample and the way they responded to the request for information. The addresses of contact persons (the project managers if identifiable) at each system location were obtained from the official directory of the Urban and Regional Information Systems Association. A letter introducing the author and the research topic (see Appendix) was mailed to the contact persons. After a waiting period of a few days, several copies of the questionnaire were

⁵ This is permissible because the data gathered through the questionnaire will merely be used for exploratory, rather than inferential, purposes.

TABLE 1
SAMPLE OF GIS INSTALLATIONS
AND TYPE OF RESPONSE

LOCATION OF GIS:	TYPE OF RESPONSE:
City of Austin, Texas	none
Clark County, Nevada	telephone interview
City of Dayton, Ohio	telephone interview
City of Eugene, Oregon	mail survey
Hennepin County, Minnesota	none
Johnson City, Tennessee	mail survey
Johnson County, Kansas	none
Knoxville/Knox County, Tennessee	mail survey
City of Little Rock, Arkansas	mail survey
City of San Diego, California	none

mailed to each contact person. The questionnaire used unstructured and open-ended questions (see Appendix). The data gathered by use of the questionnaire were used for descriptive and exploratory purposes. Inferential statistical techniques were not used to analyze these data.

A number of telephone interviews with managers of existing GIS installations were a third source of information. An attempt was made to contact by telephone all systems that did not respond to the mail survey. These attempts were successful in the cases of Clark County, Nevada and Dayton, Ohio.

2. THE APPLICATIONS REVIEW

The study begins by reviewing existing applications of GIS that appear in the literature. The review addresses the subfields of planning sequentially. It starts with Comprehensive Planning, and then discusses applications in Land Use Planning, Environmental Planning, Economic Development Planning, and Transportation Planning. General types and categories of applications are identified. Some applications are genuine GIS applications and are presented as such in the literature. Other applications are not specifically GIS applications but are presented in the context of GIS and intended to be integrated into the larger framework of a GIS at a later date (for examples see Arbeit and Heald [1988] and Covington [1984]). Suggestions are

made on how certain "traditional" (or "non-GIS") computer applications could benefit from being integrated into a comprehensive GIS.

The information for the applications review was collected from the available literature (mainly journal articles and conference proceedings). The relevant material was summarized. Note that this particular step is part of the methodology for this research effort, and is not the same as the standard "literature review" which typically is done very early in the research process for purposes of obtaining relevant background information for a research topic. The research proposed herein is similar to meta-analysis (Glass, Gene et al., 1981), which is a term referring to studies characterized by the fact that they use the results and conclusions of previous research (output) as the actual source data (input) for a subsequent study. This approach was developed as a way to promote theory development in the social sciences, since it emphasizes the practice of directly building upon previous research. This is particularly appropriate for this study, since at least part of the conclusions presented in this thesis will be based on the aggregated 'results and conclusions' of previous researchers and practitioners in the area of GIS.

3. THE SYSTEM DESCRIPTIONS

Summaries of the results of the mail survey and the

telephone interviews are presented. Short system descriptions were compiled from the information collected with the survey forms and telephone interviews. These system descriptions give some sense of the various approaches to GIS development and the different levels of involvement with the GIS technology in local government. They give an integrated and holistic view of the development and use of the technology, which supplements the preceding more narrowly focused descriptions of applications.

4. ENVISIONING FUTURE APPLICATIONS

Finally, the investigation is taken a step further by attempting to anticipate future applications that are not yet on the horizon. These are applications that would need additional efforts and time to be developed. The questionnaire results point to some of these tentative applications, since one of the questions specifically asks for ideas on possible future applications (see question 7). The collected information on existing and planned applications along with the conceptual discussion of GIS in Chapter I were used to identify such applications. Most of the work in this chapter is creative and speculative.

CHAPTER IV

A REVIEW OF PLANNING APPLICATIONS OF GIS

The following is a discussion of GIS applications in local government planning. The discussion is divided into five sections. Each section examines one major subfield of planning. The subfields covered in this chapter are: comprehensive planning, land use planning, economic development planning, environmental planning, and transportation planning.

1. COMPREHENSIVE PLANNING

Comprehensive planning involves the preparation of a long term plan addressing a wide range of community goals and interests (see Levy, 1988, pp. 87-97). It is comprehensive in its geographical scope. It is designed to address the future of the entire local community. Furthermore, it takes a comprehensive approach to the problems and opportunities of the community by viewing them as resulting from the interaction of many economic, demographic, and other processes.

The preparation of a comprehensive plan follows the rational planning process described in Chapter II of this thesis. Accordingly, it usually starts with an analysis of the situation (Levy, 1988, p. 89). This analysis encompasses a wide range of issues. Issues considered in

the comprehensive planning process include:

- economic vitality
- demographic trends
- availability of adequate housing
- public health
- flow of traffic
- adequacy of public services/infrastructure
- environmental hazards
- fire protection
- crime reduction
- support for cultural activities
- growth management
- urban design
- downtown revitalization
- effectiveness of land use controls.

Most of the factors relating to these issues are somehow distributed in space, and their relative location is of significance. Thus a GIS can be a helpful tool for the display, analysis, and monitoring of the factors that relate to these issues. A good example is traffic flow. A GIS can store traffic counts and capacities and the location of traffic accidents. It can help analyze the adequacy of the current traffic system. Expansions of the traffic system and the effects of the expansion could be modeled and displayed on a GIS. Land use is another example. Every comprehensive planning effort involves the mapping of current land use and land cover (see Yarp, 1990, p. 27). A GIS is likely to have one or two data layers containing information on land use and land cover. If these layers are properly maintained, a relatively up-to-date land use map is always available and easy to produce. Refinements and updates can be made very easily, if needed.

The capabilities of a GIS improve the access and use of all digital data, but especially spatially referenced data. With the GIS the planners have a set of very sophisticated spatial analysis tools at their disposal. Overlays and thematic maps of the various factors involved in the comprehensive planning process can be created. Inventories of, for example, industrial properties, low income housing, recreational facilities, and open space can be maintained - and are more likely to be at hand in a municipality with a GIS than in one that has not automated its mapping and information storage - to support the comprehensive planning efforts. With regard to routine data collection and storage in a GIS Arbeit and Heald (1988) observe,

Planning is a data-hungry activity. In many cities, data collection does not take place until a specific need emerges. An intense, time-consuming, and often incomplete rush to identify sources and compile data in a meaningful format usually follows. Much of that data, however, was initially collected as part of a routine transaction during the development review cycle. [A GIS], therefore, [can be] designed to collect data needed for the review process and then store it in a database for future use, thereby greatly reducing the data collection effort needed for planning analysis functions (p. 74).

The GIS can also help to produce presentation graphics for public hearings (see Yarp, 1990, pp. 27-30). Moreover, the GIS-generated information can be shared with the general public to improve public understanding of the issues that the comprehensive plan is addressing (see discussion of the intelligence function of planning in Chapter II of this

thesis).

The GIS can aid the comprehensive planning process in many ways. Many small mapping tasks will be easier to complete with a GIS than without. And many analyses can be done in a fraction of the time that they would take in a manual environment. In a more conceptual way a GIS's advantages over traditional techniques with regard to the comprehensive planning process can be described as follows. Compared to traditional techniques, a GIS:

- improves analysis capabilities of existing spatial and non-spatial data;
- improves mapping capabilities; any part of the planning area can be easily mapped at varying scales and displaying varying combinations of features (see Lin, 1989, pp. 224-229 and p. 233); improves thematic mapping capabilities;
- increases the likelihood that important data are available in a ready-to-use (digital) format (road network, property maps, sanitary and storm sewer systems, etc.);
- increases the likelihood that analyses and reports that are important for the comprehensive planning process are being prepared on a continuing basis and are, therefore, available, e.g., current land use, industrial property inventories, traffic studies, population forecasts;
- improves the capabilities to monitor urban development and the effectiveness of public policies;
- improves the access to and use of historic data, if properly archived (see Prosperi, 1989, pp. 122-123);
- improves the ability to use digital data from sources outside the planning department, e.g., US Census and local utility companies (see Prastacos, 1989, p. 133; Lin, 1989, p. 229); and

- opens new opportunities to use spatial modeling (see Kunkle, 1988; Prosperi, 1989).

It is impossible to give a complete review of all the possible applications of GIS to comprehensive planning. The number of possible uses is almost infinite and ranges from the creation of simple thematic maps to the most involved modeling algorithms. A few illustrative examples, however, might be helpful.

A good example of the use of simple but effective thematic mapping is described in Lin (1989, pp. 224-229). For a city center redevelopment plan a set of maps of appropriate scale and areal coverage were produced. One map displayed the needed detail information, i.e., buildings, property lines, streets, railroad lines. This map was published in the local newspaper and widely used in the public discussion of the redevelopment plan. Another map showed the major road system and the land uses in the downtown. A third map was created by combining the property parcel map of the area with a utility line map obtained from the local utility company. A fourth map showed the phasing of the redevelopment by identifying the sequence in which certain areas would be affected by the project. Any comprehensive planning process will require a large number of these simple thematic maps (see Wicks and Brooks, 1989, pp. 193-196). Thematic map features may include historical buildings, crime incidents, distribution of ethnic groups,

average income by census tract, building code violations, average home values, etc.

Zwick and Schneider (1989) describe an automated method for the identification and mapping of substandard housing from county property tax records. Based on parcel based data this process classifies housing units as standard, borderline, suspected substandard, or substandard (Zwick and Schneider, 1989, p. 100). These classes can be mapped and address listings of substandard houses can be generated. Field testing of the process has demonstrated its high reliability - 99% of the units checked were correctly identified by the automated process (Zwick and Schneider, 1989, p. 93). This automated method seems to be a highly cost efficient and accurate way to identify, locate and map substandard housing. Many planning departments could benefit from this system that was successfully implemented and tested in Alachua County, Florida.

An example of school location planning with a GIS is given by Reyes and Reyes (1989). The distribution of primary and secondary schools was analyzed. Undercapacities and overcapacities were identified. Average travel times from student homes to the schools were calculated. Based upon these analyses capacity increases at existing schools or the building of new schools were planned.

Lyle and Stutz (1987) present a method called land use suitability mapping. This method expands on the overlay

methodology mentioned in Chapter II. Using this method the suitability of land for certain land uses is determined by use of map overlays containing information about factors constraining or facilitating the particular land use. These factors have certain predetermined weights attached to them according to their constraining or facilitating potential. Arithmetic procedures calculate the composite suitability values resulting from the weighted overlays. The result is a suitability map identifying the relative suitability by use of a pattern or color scheme (see Lyle and Stutz, 1987, pp. 74-75).

This method can be used in the comprehensive planning process for the design of a future land use plan. The entire area of the local jurisdiction can be mapped in this way to determine the suitability for land uses like, industrial parks, recreational areas, agricultural protection areas (see Williams, 1987), and landfills.

Kunkle (1988) describes the Projective Land Use Model (PLUM) which is used by the San Diego Association of Governments (SANDAG). PLUM has been used for many years to forecast land use, population distribution, number of households, and employment. Kunkle reports a number of improvements that have been made to make PLUM even more effective. Modifications of the original PLUM have made it possible to apply the model to local area (district) plans. PLUM can now integrate information about current development

activity and its results are now adhering more closely to the general plan and zoning ordinance. It also takes account of infill development. PLUM is not a GIS but could be a model for a similar algorithm that could be put on a GIS. Alternatively, PLUM data could be exported to a GIS or CAD/CAM system to generate maps.

These applications illustrate the many possible applications of GIS to comprehensive planning. Comprehensive planning itself overlaps with other fields of planning, like the fields of planning that are discussed in the remainder of this chapter. Accordingly, many of these applications can also be used in other fields of planning. The above described principal advantages of a GIS also relate to all the fields of planning in local government in so far as they deal with spatially referenced information.

2. LAND USE CONTROLS AND LAND RECORDS MANAGEMENT

The mechanisms of land use control, zoning and subdivision regulations, are arguably the most important tools of local government planning. The administration of land use controls is indisputably one of the largest day-to-day responsibilities of local government planning. Moreover, it is probably the arena in which planners have the most opportunity to influence the shape and appearance of the community they work for.

At the heart of the application of the GIS technology

to the land use control process is land parcel mapping. Land use control is based on an official zoning map (Bair and Bartley, 1966, pp. 15-21) and the subdivision regulation process produces map products that are used to update the property map. Both processes involve mapping on a parcel level of precision. Moreover, land use controls involve review processes that are information and staff intensive. All or most of the information needed for the review process could be made more easily available in a GIS if it is linked to the land parcel.

Accurate and up-to-date parcel mapping is vital to the day-to-day operations of two other departments in local government - the tax assessor, and the register of deeds (Sonnenburg, 1988; Holloway, 1989, p. 58). The tax assessor, the register of deeds, and the planning department all three are dependent on elaborate and cumbersome record keeping relating to the land parcels. They are, therefore, natural allies in the process of keeping accurate parcel maps and to standardize and rationalize land records storage and retrieval by way of a GIS. In manual land records systems, the interaction between the tax assessor's and the planning department's mapping efforts is apparent in the fact that planners usually use the property tax map as the base map for the official zoning map.

Land records modernization is one of the major applications of GIS in local government. Land records

keeping with traditional techniques has become a costly and cumbersome task and the need for rationalization and automatization in this field has been widely acknowledged (Panel for a Multipurpose Cadastre, 1980; Holloway, 1989).

Land records modernization involves the use of parcel numbers as unique identifiers of any single land parcel in the community. Land parcels are stored on a digital map with a unique parcel number and the exact shape and location of the property. Property lines, easement, and right-of-way boundaries are represented with high positional accuracy.

An accurate digital parcel map is an ideal base for the creation of a GIS. For local government planners such a system has the potential of improving the efficiency of the land use control process. The tremendous task of keeping accurate records of the legislative land use decisions in the community would be made much easier (Parr, 1989, p. 154). The GIS could crossreference the land records and zoning information to the parcel number or refer to a manual archiving system.

The address matching capabilities of a GIS allow the instantaneous identification of the exact location of a property on the zoning map. The associated information such as ownership and zoning districts could be retrieved equally fast. Public requests for information about the zoning characteristics of a property could be answered without requiring much staff time. Up-to-date zoning maps could be

printed and made available upon request. A GIS could also monitor the consistency between zoning and land use designations on the comprehensive plan.

The efficiency and speed of the review of rezoning requests by the planning staff could be increased if the GIS contained all or most of the information relevant to the review process (Parr, 1989). The planner could enter a rezoning request into the system and have the GIS generate a report on the property in question. Such a report could include any information that is available from the GIS. The zoning reports could also be made available to the public for a fee. The report could contain:

- the zoning district that the property is in
- a brief description of all uses and constructions allowed in this zoning district
- a map of the property including surrounding land uses
- ownership of the property
- exact measurements of the area and shape of the property
- the rezoning history of the property (references to minutes of public hearings)
- a listing of similar rezoning cases in the same area or the community as a whole
- the public services (sewer, water, public transportation) available at the site
- traffic counts at the major roads at the site
- references to policies of the comprehensive plan that are relevant to the site and/or the proposed land use
- location of environmental constraints or protection

areas in the surroundings of the property

- a list of the addresses of owners of properties surrounding the property in question

The system would help the staff planner evaluate the zoning request by giving easy and quick access to the information that is needed for the review. The system could be even more helpful if it would include an expert system (Chu and Newkirk, 1989). Chu and Newkirk (1989) describe an experimental zoning expert system that was created for Huron County, Ontario. They define an expert system as a system that "stores expertise in the forms of procedural and declarative knowledge and simulates a human expert's reasoning processes" (Chu and Newkirk, 1989, p. 103). Such a zoning expert system would evaluate a rezoning request. It would make a recommendation based on the expertise of planners, which has been entered into it. The staff planner can use the expert system's decision as a guide to finding his or her own decision, which may or may not concur with the computer's decision. A full automation of the review process is not practical because of the large number of factors involved and the variability of the cases (Parr, 1989, p. 163).

Arbeit and Heald (1988) report about another way in which the review process can be automated. They describe a system that the City of Austin has implemented that structures and automates the review process.

Austin responded to a development boom in the 1980s by intensifying its growth management efforts. Environmental protection, effective infrastructure management, and keeping housing affordable to the middle class were important concerns affected by rapid urban growth. Austin's growth management efforts resulted in complex review requirements, lengthier review processes, high personnel cost. Public complaints about the inefficiencies of the review process increased dramatically. An automation of the developmental review processes was identified as a way to increase the speed of the review process and reduce administrative cost. The city decided to build an automated system to solve its current problems with the review processes and, also, provide long term planning support.

Austin's Land Development Review System (LDRS) is a transactional database that is used for development review monitoring. Moreover, the system's analytical capabilities are used in support of long term planning. LDRS is not a true GIS but could be implemented on a GIS. In fact, Austin's system was designed with the idea of later integrating it into a larger multi-departmental GIS (Arbeit and Heald, 1988, p. 72).

LDRS is 'networked,' allowing all departments that are involved with development assessment to access it. Review applications are entered into the menu-driven system in a form environment. File numbers and project addresses are

automatically verified by reference to a DIME-based address database. Review fees are calculated. Planning commission and city council meetings are automatically scheduled. A packet of information containing case summary sheets for each zoning case and maps identifying the project is automatically distributed via electronic mail to as many as 27 agencies that are linked to the system. The replies of these agencies are also sent by electronic mail and automatically compiled into a report.

The system provides extensive help in report preparation. Prewritten responses are made available as menu options. Cross references to similar or nearby projects are made. Help screens and specific user documentation are available. The system allows inquiries about the project status by all departments connected to it. The Planning Commission Memorandum (an agenda attachment with summary data) is now automatically generated and can easily be updated and changed on short notice. The preparation of the memorandum was previously a tedious and time consuming task that required frequent cross checking of data.

As a long term planning tool LDRS allows users the query of its database. The data base can be queried by file number, project name, street name, hearing dates, owner, engineer, architect, or designated contact person.

Arbeit and Heald (1988) report that LDRS was

successful. The review service has been substantially improved and speeded up, while staff was reduced significantly. Austin's experience with LDRS demonstrates that GIS can be a solution to some immediate planning problems as well as being a smart choice for the long run. The enhancement of system functionality and design flexibility (responding to changes in the ordinance) had to be guaranteed, while a high level of functionality for immediate needs had to be provided. These requirements provided both technical and political (institutional) challenges. Arbeit and Heald (1988, pp. 86-87) conclude that LDRS is too specific to Austin to be translated to other local governments. However, Austin's experience should encourage others to try to develop similar systems.

The City of Georgetown, Texas is in the process of implementing a system that not only automates the review process but departs from the standard concepts of zoning (Kingma, 1989). Georgetown has adopted a form of performance zoning. Georgetown decided to regulate development by the intensity of its use of public facilities. It defines intensity as "each land parcel's allocated capacity for water, wastewater, and transportation services" (Kingma, 1989, p. 189). Instead of assigning zoning districts to specify allowed uses in a certain area, Georgetown intends to regulate the intensity of uses on a specific land parcel. The city follows the philosophy that

"the level and type of public services provided to a given parcel of land largely determines the potential of that land for development." (Kingma, 1989, p. 190). To determine and monitor the level and type of public services available to every land parcel in its jurisdiction the city developed, in cooperation with a private consultant, a GIS-based application program called IMAGE (Infrastructure Management for a Growing Environment). IMAGE contains information about current levels of water, wastewater, and transportation services, but also accounts for planned improvements in those services. Moreover, based on the demand that is placed on the utility systems that provide these services IMAGE identifies future needs for expansions in these systems. It, therefore, not only helps to regulate development but also monitors it (Kingma, 1989, pp. 191-192).

Each land parcel is placed in one of six intensity categories based upon existing and planned services allocated to the parcel by IMAGE. IMAGE calculates the allowed intensity of uses at the site and lists them by number of dwelling units or square feet. For example, a development site of about 204 acres of which 17 acres are categorized as intensity level six and 187 acres are intensity level 3 would be allocated not more than 1,059,823 gallons of water per day, 303,392 gallons of wastewater per day, and 8,630 trip ends per day. These allocations

TABLE 2
ALLOWED DEVELOPMENT INTENSITIES BY LAND USE

Land Use:	Allowed Intensity:
Detached Single Family, Large Lots.....	916 dwelling units
Detached Single Family, Small Lots.....	1,062 dwelling units
Attached Single Family.....	1,630 dwelling units
Multi-Family.....	1,945 dwelling units
Mobile Home.....	1,572 dwelling units
Lodging.....	4,974 dwelling units
Institutional.....	3,089,863 square feet
Medical Offices.....	2,547,651 square feet
General Offices.....	2,911,602 square feet
Retail, Mixed.....	522,460 square feet
Retail, Restaurant.....	632,067 square feet
Retail, Store.....	1,797,168 square feet
Employment Center.....	1,885,927 square feet

Source: Kingma, Hildy L. (1989) IMAGE: Infrastructure Management for A Growing Environment, in Urban and Regional Information Systems Association, 1989 Exemplary Systems in Government Awards Washington, D.C., p. 201

translate into the allowed development intensities shown in Table 2.

IMAGE seems to be an ideal tool for infrastructure and growth management. Whether it can completely replace traditional zoning or just add to its arsenal of land use controls remains to be seen. However, it is clear that the type of information analysis and monitoring capabilities that this form of land use control requires can, at reasonable cost, only be made available by a GIS.

3. ECONOMIC DEVELOPMENT PLANNING

GIS can be used in two ways to support economic development planning. It can provide and assist in the analysis of background information about the conditions of a community that are relevant to economic growth and it can be helpful to economic development planning by providing a computer platform for an industrial and commercial property inventory (ICPI). Such an inventory is designed to aid the process of finding suitable sites and buildings for locating businesses.

A GIS can help in the description and analysis of local conditions that are relevant to economic development. These conditions are, for example, population growth, growth in employment, labor force participation, availability of industrial land, conditions of industrial land. This information can be used for the preparation of profile

reports of the local community. The analytical capabilities of the GIS can be used to improve the planners understanding of the local situation. For example, the acreage of industrial land can be matched to expected industrial growth (forecast via population and employment growth trends) to see whether enough industrial land is available to accommodate anticipated growth (Chapin and Kaiser, 1979 pp. 411-438). The characteristics of the available industrial sites can be analyzed in terms of their highway and rail road access, water supply, the proximity of environmental protection areas, and other factors that are available in the database of the GIS (see Strong and Lenz, 1988, pp. 495-497). This analysis might identify areas that need infrastructure improvements, like the development or extension of public roads and services. GIS will help determine when, where, and how much physical development is needed or desired to support the economic development (Cowen, 1989).

The characteristics of the available sites may be matched to the specific location requirements of certain industries (Strong and Lenz, 1988, p. 495). The marketing efforts could then be targeted towards industries that have location requirements that match the characteristics of available local sites. In a reverse procedure, growing industries with certain location requirements might be identified and the availability of sites within the local

jurisdiction meeting these requirements can be analyzed using the GIS. If adequate sites are available this fact should be made known and marketing efforts should be directed at these industries. If adequate sites for the growing industries are not available, efforts could be made to make them available.

The importance of site and area assessment for the economic development process has been established (see Friedman and Darragh, 1988, p.309). GIS promises to become a very important analytical tool for this economic development application. Moreover, GIS will facilitate a monitoring of economic development (see Friedman and Darragh, 1988, p. 300) to an extent never before feasible.

Industrial and commercial property inventories (ICPI) are inventories of vacancies in industrially zoned areas, industrial parks, industrial and commercial buildings. They aid businesses interested in locating in a local area in finding a site or building adequate for their needs. ICPIs do not require GIS capabilities and have been created using conventional relational databases (see State of New Hampshire, 1989; Strong and Lenz, 1988). However, a well designed ICPI on a GIS can provide more flexibility in the use of various factors in determining site suitability for a given commercial or industrial use than a ICPI based on a conventional system. Additionally, the GIS based ICPI can provide map output, which is usually not available from

relational databases. A GIS based ICPI could provide both ease of use by customizing the input of location requirements and the flexibility to respond to requests from businesses with complex and unusual location requirements by using its powerful analytical capabilities and extensive database.

Current experiences using traditional data bases have proven the desirability of such inventories. For example, Covington (1984) reports the successful use of an Industrial Vacant Land File (IVLF) in Memphis and Shelby County in Tennessee. The IVLF is based on traditional relational database technology. It operates by use of questionnaires. The interested industry or developer fills out a questionnaire specifying location requirements, such as maximum slope, road frontage requirements, maximum distance from interstate highway interchange, air pollution standards, etc. The computerized IVLF then selects sites that fulfill those requirements and produces a detailed description and a location map for each of the suitable sites. Covington (1984, p. 342) reports that the two major drawbacks of his IVLF were related to the relatively slow updating process. One of the problems that Covington observed were inaccuracies in the IVLF due to sluggish and error ridden updating of the data base. A problem which IVFL's clients often complained about was the omission of ownership information. Although ownership information is

very important for such a system, it was omitted from the IVLF because of the difficulty of keeping this type of information up-to-date. From the above discussion it should be clear that a GIS could solve these problems and, thereby, significantly increase the utility of this inventory. Due to its relative efficiency in the updating process, GIS lends itself to ICPI applications. Moreover, GIS could provide a wider range of information about the sites than the conventional ICPI can. Kevany writes about GIS's capabilities with regard to site selections:

An example of [GIS's] capabilities is evaluating a site's suitability for development by overlaying maps of ownership, floodplain, slope, soils, and geological conditions. This procedure would identify areas with desirable combinations of these characteristics, calculate the areas composite or resultant polygons, store these characteristics in the database, and produce a colored map of the results. This analytical operation can often be performed in seconds or minutes, thus allowing a decision maker to evaluate several alternatives and perform numerous "what if" analyses in a very short period of time (Kevany, 1987, p. 7).

Although it is not immediately relevant to economic development planning in local government, it should be mentioned that GIS is also of significance to economic development and environmental planning in the Third World. Especially in connection with remote sensing techniques (areal photography from space or air), GIS has already become an important planning and analysis tool in the Third World. Remote sensing is an ideal technique for the

gathering of geographical information in vast and remote areas in many developing countries. The Agency for International Development (A.I.D.) has therefore provided substantial funding for the use and development of combined remote sensing and GIS techniques in the Third World (Paul, 1986). These techniques are especially important with regard to natural resource management, including environment assessment and monitoring. Remote sensing and GIS have already achieved a significant improvement of the information collection and processing for environmental and resource assessments in many developing countries. Paul (1986) lists successful projects in Thailand, Peru, Bangladesh and Egypt. With increases in funding for GIS projects in the Third World further improvements can be expected.

In summary GIS promises to be a very useful tool for the economic development planner. GIS will improve access and control over information about our physical environment. It will thereby enhance the planner's capabilities to plan the physical environment, so that it supports economic development in the best possible way. One can conclude, that GIS has the potential of aiding economic development planners in their work.

4. ENVIRONMENTAL PLANNING

Environmental planning deals with the "minimizing of damages that human activity does to the natural environment" (Levy, 1988, p. 237). It deals with the protection of water quality, air quality, soil conditions, wetlands, wildlife, and natural parks. The proper disposal of hazardous and non-hazardous waste is also an important environmental planning issue. Environmental planners are frequently engaged in hazard mitigation efforts, involving natural hazards like earthquakes, hurricanes, and larger scale industrial accidents. The evaluation and monitoring of environmental conditions is a daily task for the environmental planner. Local environmental planning also involves the administration of local, state, and federal environmental regulations.

Ventura (1989) presents the Dane County (Wisconsin) Land Conservation Information System which deals with the interconnected problems of soil conservation and farmland protection. Federal legislation required Dane County to determine which farms had 30% or more of highly erodible lands (HEL). To do this, a map of the location of highly erodible soils types (as designated by the USDA Soil Conservation Service) had to be made and compared with the areal extent of farms. The Land Conservation Information System accomplished this with the use of overlay techniques and over-night batch processing.

In a similar overlay task the system identified farms that contain wetland areas. The farm owner's addresses were identified through an address matching procedure and the owners were notified about the wetlands designation of their property.

Moreover, the system collects information about soil erosion and crop types. This information is used to model soil loss. The modeling capabilities of the system are used in the creation of farm plans. The compliance with the farm plans is monitored by the system using data collected during field inspections. Compliance over time is recorded and a crop and compliance history is accumulated for every farm. Dane County is currently considering the use of satellite imagery for the monitoring of farm plan compliance (Ventura, 1989, p. 242).

Atkinson (1988) describes the use of a GIS in combination with remote sensing data to determine the feasibility of wet detention basins for non-point water pollution control (see also Smith and Blackwell, 1980). Atkinson (1988) analyzed 21 watersheds that are draining into the Trinity River in the Dallas-Forth Worth region. He tried to determine whether wet detention basins could be used to reduce water pollution caused by run-off. Wet detention basins collect storm water and allow some pollutants to settle or to become degraded in a biochemical process before the water is lead back into the stream

(Atkinson, 1988, pp. 688-689). For his analysis Atkinson had to consider a range of site specific characteristics, like required size of the detention basin based on run-off characteristics, maximum and minimum distance from the stream, and compatibility of surrounding land uses (Atkinson, 1988, pp. 689-692). His analysis revealed that only 30% of the analyzed watersheds could employ the detention basin pollution control methodology. Lack of suitable sites of sufficient size for the basins was the major reason why this pollution control methodology was deemed inappropriate for the remaining 70% of the analyzed watersheds.

Picket et al. (1989) used a GIS to model the impact of land development on nonpoint source water pollution for the Town of Burke in Dane County Wisconsin. Their study was directed at the problems of urban sprawl and its effect on the water quality of the nearby Yahara Lakes. The effects of several land use scenarios on nonpoint source pollution were evaluated using the Wisconsin Source Loading and Management Model (SLAMM) in combination with a GIS. The GIS provided the tool for integrating a wide variety of data - such as land use, land cover, soils type, zoning, floodplain, elevation, and watershed boundaries - that were needed for the modeling task (see Picket et al., 1989, pp. 378-380). The analysis resulted in a comparison of different future land use scenarios with regard to their

effect on run-off pollution. One of the results was that current zoning allowed more pollution intensive land uses than the comprehensive plan. Accordingly, closer adherence to the comprehensive plan would help reduce water pollution. In a subsequent analysis the GIS was also used to "construct a composite digital open space coverage which reflected [local] natural resource protection laws and policies" (Picket et al., 1989, p. 382). The resulting map was overlaid with parcel information and address matching was performed to identify owners of land affected by open space regulations.

Hopkins (1988) considers the use of a GIS for monitoring of surface water quality. Timing and extend of agricultural practices, varying soil characteristics, conditions for runoff, spatial distribution of land uses, and hydrologic events are analyzed with regard to their effect on surface water quality. Hopkins (1988) demonstrates how a GIS can be used to monitor the effects of agricultural land use on the quality of surface water. For this purpose digital elevation models (DEM) were use to model the watersheds of the La Platte River and the St. Albans Bay in Vermont.

For a discussion of the importance of applying GIS to groundwater monitoring and protection see Jadkowski and Dutram (1989) and Lee (1989).

The capabilities of a GIS find an ideal application in

waste management. Traditional and non-traditional waste disposal techniques require site evaluations. Waste management has to deal with a multiplicity of site related variables, such as overland flow, infiltration, soils types, land uses, slope, biological, chemical, and physical factors. All these data have to be stored, manipulated, and analyzed. A GIS can help to do this (Buckley and Hendrix, 1988).

Buckley and Hendrix (1988) propose the use of a two step process for the evaluation of a site: an initial feasibility study, and a detailed system design and cost analysis. A rating system would be used for variables like permeability, height of watertable, and depth to bedrock. These ratings would then be added up to a total score. After this is done the sociopolitical suitability should be evaluated. Richason and Johnson (1988) used a composite suitability mapping technique to identify landfill sites in the tri-county region of Benton, Sherburne, and Stearns Counties in Minnesota. Four separate suitability maps were created identifying areas as constrained, unconstrained, and somewhat constrained. The four maps featured ownership (private or public), soils types, and proximity to transportation and surface water. A composite map created by the GIS shows the composite constraints as shades of gray and displays completely unconstrained (suitable) areas in white (Richason and Johnson, 1988, 703).

Yoos and Sellers (1988) demonstrate how a GIS can be employed for the design and management of a local recycling program. A GIS can help analyze the composition, quantity, and distribution of solid waste throughout the collection area. The distribution and expected quantities of recyclable waste is estimated by the use of land use, zoning, and census information. For example, commercial uses can be expected to produce different types of waste than residential land uses. Areas of higher density uses will produce more waste than areas of lower intensity (see Yoos and Sellers, 1988, pp. 200-202). The census provides rather detailed information on population densities and characteristics. The GIS can help to compile and correlate the census and housing information. Based on this combined information collection districts can be delineated by waste type as well as frequency and mode of collection. Yoos and Sellers (1988) write,

Areas may be designated for residential curbside collection of separated materials as well as less frequent yard waste collection. Drop boxes may be located at strategic sites to accommodate residents in multi-family dwellings. Other areas may be identified for OCC [Old Corrugated Cardboard] and/or office paper collection. Some areas may be eliminated from the recycling plans due to industrial activity or simply too few residents (p. 202).

The collection strategy is derived from the GIS-based analysis of waste characteristics and distribution. Yoos and Sellers (1988, p. 206) also suggest the use of network

analysis techniques to organize the collection process. Network analysis if applied to this problem could identify collection routes that optimize the amount of recyclable waste and suggest locations for processing and storage sites. The GIS could help monitor the performance of the collection program and thus facilitate continued optimization.

Another area of application are Environmental Impact Statements (EIS) that need to be prepared for larger projects. The environmental analyses that are conducted for an EIS can involve a wide range of variables. A GIS can help to process these data. Ladha and Robertson (1988) have demonstrated GIS's utility for evaluating the environmental impact of electric transmission facilities.

Moreno and Siegel (1988) suggest the use of a GIS for corridor selection studies for linear features, e.g., highways. They emphasize that the corridor selection studies have to "simultaneously address several environmental, socioeconomic, and engineering design criteria which are geographically spread across large study regions" (Moreno and Siegel, 1988, p. 507) which can best be accomplished with a GIS. Moreno and Siegel used a two step process to analyze possible routes for a highway in Arizona. In a first phase they identified a few alternative routes through a suitability analysis. The suitability analysis considered five issues of concern.

1. Sensitive habitats: biological resources of concern ...
2. Cultural resources: reflects legal protection given to archeological and historic resources.
3. Visual resources: includes aesthetic impacts and the Forest Service's Visual Quality Objectives.
4. Community impacts: reflects the public's concern for highway traffic, land use, noise, and air quality.
5. Construction/engineering: represents concern for geotechnical and design constraints. (Moreno and Siegel, 1988, p. 509)

These five issues were analyzed by use of weighted composite suitability mapping techniques and a small number of suitable corridors was identified. In the second phase of the study each of the preselected corridors was analyzed in more detail and with more emphasis to the cost and engineering aspects.

Environmental planning in general deals with a large number of variables that are spatially distributed. Since a GIS is an ideal tool for the storage and analysis of these data, it is of immediate utility to the environmental planner. Environmental planners will want to use GIS for tasks like preparing an EIS, monitoring environmental deterioration, modeling the effects of urban growth, or mapping the locations of the sightings of an endangered species. It can be expected that environmental planners will soon become major users of GIS.

5. TRANSPORTATION PLANNING

Transportation planning involves the estimation of current and future travel demand. Based on the travel demand estimates, the transportation planner determines inadequacies in the current transportation network. Future needs for expansions of transportation facilities are determined and recommendations are made accordingly.

Travel demand studies involve four basic steps. These steps are (1) estimating trip generation, (2) estimating trip distribution, (3) estimating the modal split (car or public transit), and (4) trip assignment (Levy, 1988, pp. 195-197). These studies rely heavily on mathematical modeling for their estimates and analyses. The models generally rely on demographic, economic, and land use data to predict the number and distribution of trips in an urban area (Levy, 1988, pp. 191-192; Amer, 1989, p. 120-123).

Although transportation planning is already a heavy user of computer equipment the use of GIS is likely to help in the transportation planning process as well. Increased availability of land use and census information will improve the efficiency of transportation planning. In general, Ferguson and Drummond (1989), maintain that

Geographic information systems will aid in the expansion and improvement of activity location models by making separate and distinct data bases compatible for simultaneous evaluation through a variety of simple and/or complex interpolation procedures. Translations from one spatially-oriented data base to another will serve to increase the availability and decrease the cost of

spatially-oriented data input for activity allocation modeling purposes (p. 3).

Moreover, the GIS's ability to aggregate and disaggregate these data based on varying areal units is of importance to transportation studies (Ferguson and Drummond, 1989 p. 4). The GIS also improves the accuracy of the areal data aggregations. According to Ferguson and Drummond (1989, p. 8) GIS technology will make it possible to improve transportation modeling by using adjustment procedures that have been frequently suggested but were until now too data intensive to perform.

The availability of the DIME and TIGER files from the U.S. Census Bureau allow the building of low cost GISs that are adequate for transportation modeling. Jackson (1988) reports the implementation of such a system for the Pikes Peak Area Council of Governments in Colorado.

Amer (1989) suggests the use of expert systems for transportation planning. Trip generation estimation techniques involve the use of regression models. These models require adjustment to certain situations and specific areas. This adjustment is a subjective process that relies on the expertise of the transportation planner. Amer sees this as a possible area for the application of an expert system. The expert system would help the planner in the adjustment of the model (Amer, 1989, pp. 122-123). An expert system would give more consistency and objectivity to

the adjustment process and provide a way to transfer and accumulate expertise.

Kiel and Berry (1986) describe the use of a low cost GIS for traffic monitoring in Johnson City, Tennessee. This GIS aided in the creation of a database of the transportation features in the area. The database contains attribute information like street names, street lengths, intersections, traffic counts, and roadway geometrics. The database was used to create and maintain up-to-date base maps of the street network. The system was also used for the implementation of a regular traffic counting schedule. A traffic accident inventory was created and analyzed on a monthly basis. Accident maps and reports are made frequently to analyze accident trends. Traffic counts and accident information are also used to identify locations of inadequate or missing signalization. Kiel and Berry (1986, p. 98) write, that with the help of the GIS, the need for "improvements to signalization, as well as to signs, pavement markings, and roadway widths, can now be more specifically identified and targeted." Some of the base maps and traffic count maps were compiled into an atlas that was subsequently published. Kiel and Berry expect to expand the use of the system to traffic modeling in the future.

There is a great potential for the application of GIS to transportation planning. GIS will improve the availability of traffic and land use data and thereby help

the transportation planner with traffic modeling. Traffic monitoring will also be made easier by GIS.

CHAPTER V

SYSTEM DESCRIPTIONS

The following system descriptions are based on the responses to the questionnaire. Just like the questionnaire responses, the system descriptions vary in their coverage and level of detail.

The system descriptions serve an illustrative purpose and are not meant to provide explanations. The system descriptions are included to give the reader a broader and more integrated view of the use of GIS in local government that could not be provided in the applications review. It is hoped that this broader view aids the reader in gaining an understanding of GIS's functioning within local government.

1. TOWN OF NEW SHOREHAM, RHODE ISLAND⁶

The Town of Shoreham in Rhode Island started its mini-computer based GIS in 1987. The GIS was developed in cooperation with the University of Rhode Island's Department of Community Planning. Graduate students of this department

⁶ This installation was not included in the judgmented sample. The questionnaire was returned to the author as a response to a request for information distributed by electronic mail. The PLANET (Planners Network) was used by the author to distribute the questionnaire and to invite responses. This installation was the only one that responded to this request.

are assigned to it and all the software and hardware are kept at the university. The Town of Shoreham's GIS is considered fully operational but an expansion is currently under consideration. This expansion would involve the relocation of the system to the Town of New Shoreham and the creation of a position for a full-time GIS coordinator, so far the GIS is run by students on part-time basis.

The GIS supports the operations of the planning board, the town council, the zoning board, the tax assessor, and others. Currently the system is used for parcel mapping. The parcel database has been successfully integrated with a preexisting computerized tax information system. The parcel maps will be used in the upcoming reappraisal process. The parcel maps are also used for comprehensive planning. Special purpose maps of natural and cultural features, such as wetlands, slope, vegetation, endangered species siting, and archeological sites have been prepared. Furthermore, the GIS has been used for a septic tank suitability study.

One of the applications that are currently in the development stage are a build-out analysis using parcel data, zoning, and natural feature overlays to estimate the environmental impacts assuming maximum development under current land use regulations. New Shoreham is also working on keeping the zoning layer up-to-date and intends to use the GIS for the support of zoning enforcement. The system will also help with the production of wetlands, open space,

and recreational facilities inventories and maps.

Previously a student has successfully used the GIS for a research project on the fiscal impacts of changes in buffer widths around wetland areas. Several similar fiscal impact studies are currently in progress.

In the more distant future it is hoped that the system could be expanded to include deed tracking capabilities, the automatization of the subdivision review process, support for capital improvement planning, growth management, ground water quality monitoring and protection, and the management of the local harbor facilities.

None of the so far attempted applications are considered to have failed.

2. JOHNSON CITY, TENNESSEE

Johnson City's GIS was started as a low budget project in 1984. From 1984 to 1989 it used the MOSS GIS software originally developed by the Bureau of Land Management. In 1989 the system was expanded and converted to the ARC/INFO (Trade Mark of Environmental Systems Research Institute, Inc.) package. The minicomputer based system contains a large number of data layers and is considered fully operational.

The main users of the system are the planning, water/sewer, transit, engineering, building inspection, public works, police, and transportation departments. East

Tennessee State University in Johnson City and the near by City of Bristol also have some access to the system. The GIS functions as a data center. It answers requests for information from all divisions of local government.

The parcel based system contains data layers on roads, railroads, rivers, streams, lakes, pipelines, power lines, airports, sidewalks, street names, street address ranges, soils types, hazardous materials locations, flood zones, digital elevation models, police patrol zones, historical land use data (1982 and 1983), zoning, city limits, annexations, census blocks and tracks, school locations and school zones, school bus routes, public transit routes, water lines, water hydrants, valves, fire zones, traffic zones, dilapidated structures, and city-owned properties.

The major current projects of the GIS staff are the compilation of a 1990 land use coverage, the integration of the new TIGER files into the system, the updating of traffic data, traffic modeling, and the preparation of a Johnson City area resource atlas.

Planned projects include the creation of inventories of street lights, traffic signs, billboards, the drainage infrastructure, city owned parking lots, historic sites, and wooded areas. The following data layers will be added to the GIS: sewer lines, hospital locations, cemetery locations, property easements, two feet contour lines, bicycle routes, and voting precincts. The following

applications are also planned: transit system ridership analysis, pavement management inventory, crime analysis, and fire alarm call monitoring. Another major project is the integration of the economic and demographic data from the 1990 census into the GIS.

In the more distant future the GIS staff wants to improve the geodetic control of their map base and try to link some of the existing non-GIS databases to their system.

The Johnson City GIS reports one failed application. In 1985 an attempt was made to link an existing pavement management database to the GIS. This failed because the technology to do so was not in place at the time. The Johnson City staff thinks that the link of the two databases would be possible today.

3. KNOXVILLE/KNOX COUNTY, TENNESSEE

The City of Knoxville and Knox County have developed a multi-institutional GIS under the leadership of the Metropolitan Planning Commission. The mainframe based system is networked and uses workstations and software from Intergraph, Inc. The system uses a parcel-based database. The planimetric and topographic land base for the entire area was converted from areal photography specifically made for this purpose. The system is fully functional but utility features and some miscellaneous data layers will still be added to the database.

Besides the Metropolitan Planning Commission, major system users are the Knoxville Utilities Board (KUB), the county tax assessor, the school board, the highway department, and the building inspectors of both the county and the city.

Currently the system is used to keep up-to-date parcel maps and ownership records. A current land use map for comprehensive planning efforts is being prepared. The systems database is used as a central source for geographical and topographical information. The Knoxville Utilities Board uses the system to produce site maps and work orders.

The systems administrators have a number of applications under development. They are in the process of automating the subdivision review process and integrating the recorded plats into the GIS. The zoning layer is currently under development. A building permit tracking system is planned. Water and gas facilities management applications will be developed. A revision and update of the planimetric and topographic database is also planned. In the more distant future the system is expected to also contain raster images of the deeds for, and linked to, the property parcels.

The Knoxville Utilities Board is in the process of uploading one of its non-GIS databases to the GIS. This database contains information about power outages. This

information will be used to identify which electric transmission facilities need to be replaced. KUB also plans to use GIS produced maps for the monitoring and managing of maintenance dispatch. Large maps showing where repairs on KUB's facilities are needed will be projected onto screens in the dispatching office. Small site maps will be sent to the repair trucks using fax machines. KUB also plans to scan and integrate into the GIS the existing engineering drawings of pumping stations, electrical substations, and other facilities.

None of the so far attempted applications have been considered a failure.

4. CITY OF DAYTON, OHIO

The City of Dayton started its GIS efforts in the early 1980s by creating a digital database of its territory using the Census Bureau's DIME files. The database was constructed by merging 78 DIME files. The files were merged, corrected, and updated with the help of a private consultant. The whole process of database construction is estimated to have cost only about \$200,000. In 1988 the city decided to buy the Landtrack GIS software to expand its use of her street centerline database.

This micro-computer based system is now used by the planning, water, transportation, police, and housing inspection departments. The system is used for address

matching, crime analysis, land use analysis, ownership listings, and various thematic mapping. Delinquent taxes and real estate sales have been mapped citywide. Building code enforcement is supported by the system. Real estate sales prices have been monitored by the system. Up-to-date listings of average prices by neighborhood and type of construction are made available as a service to the general public. The system could be used for traffic analysis and monitoring as well as network analyses, however, these applications have not been developed yet, mostly because of lack of sufficient staff.

The experience that the City of Dayton made with this low cost street centerline GIS have encouraged her to consider its expansion. A private consultant has been contracted to provide a complete analysis of the city's GIS needs and make suggestions about hardware and software products for a parcel based system. The city anticipates to add many new applications once the new system is in place, beyond the current applications. The city has plans for applications involving infrastructure management, land use planning, water quality monitoring, and crime analysis.

5. CITY OF LITTLE ROCK, ARKANSAS

The city of Little Rock in Arkansas is in the process of developing a large mainframe GIS using ARC/INFO (Trade Mark of Environmental Systems Research Institute, Inc.).

The hardware, including several graphics terminals, digitizers, plotters, and printers, is already in place. A database of 360 square miles of street centerline maps with address information is fully operational. A test database with planimetric features for a 6 square mile area is completed. All of the planimetric base map for the entire jurisdiction are scheduled to be ready in Summer 1991.

The system is currently supported by the planning, public works, traffic, code enforcement, and police departments of the city of Little Rock. The Little Rock Water Works have also joined in the effort of building the GIS. It is expected that the Pulaski County tax assessor, the City of North Little Rock, Arkansas Power & Light, and ARKLA Gas will be using the system in the future.

So far the system has not been used very much except for some limited data retrieval and map making. However, the database construction is making progress and a private consulting firm was hired to develop applications. These applications are described in the following paragraphs.

Incident Mapping. Address information of incidents (traffic accidents, emergency calls, etc.) will be imported into the system and is then geocoded and mapped.

Thematic Mapping Support. This involves the standardization of symbology for thematic mapping and the creation of routines that homogenize the format of map products.

Geographic Searches. Neighborhood and proximity analysis techniques between coverages will be automated. CAD/CAM Loading and Retrieval. Uploading and downloading of files between the GIS and an existing CAD/CAM system.

Utility Facilities Geographical Query and Display. The purpose of this application is to provide customized and standardized map and report output about utility facilities.

For the future development of the system the following applications are being considered.

Parcel Map Revision. This application should provide a controlled environment for the updating of the parcel coverage. Certain security controls and routine procedures would be developed. To increase the efficiency of updating, the system administrators are considering the standardization and automatization of input procedures.

Land Use Analysis. This involves the analysis of the demand that future growth will make on the varying types of land uses. Current supplies are compared with future demands.

Since so far none of the applications have matured beyond the development stage, their relative failure or success cannot yet be evaluated.

6. CLARK COUNTY, NEVADA

Clark County has a fully implemented GIS since 1982. The system is based on a mainframe computer that has disk

storage capacity of 900 megabytes. The GIS is mainly used by the planning department and the office of tax assessment. The parcel based system is used for land use planning and monitoring as well as land records management. An industrial lands inventory supports the economic development efforts. The system is also used for environmental planning. Clark County manages its land holdings using the GIS.

The GIS does not contain zoning information at this point. A zoning coverage is currently under development. The use of this system for tax assessment and the keeping of tax information will be expanded in the future. Further applications in transportation planning and social and economic analyses will be developed.

The county reports no failed applications. However, a few projects at the earlier phases of the development were aborted for lack of resources and staff.

7. CITY OF EUGENE, OREGON

The City of Eugene, Oregon started its mainframe based GIS project in 1985. Today the system is considered about one third operational. A number of microcomputers are used as stand alone workstations. Many data layers have been completed, but many more will be added. The parcel based system is kept and maintained by the Department of Public Works.

A new inventory of the sanitary and storm sewer systems was created using the GIS. The sewer maps are updated annually and compiled in a map book. The map book is distributed to several departments in local government and some interested outside parties. City-wide maps for the support of comprehensive planning are also being produced. In one application the sanitary sewer lines were color coded by age. The resulting map was used to plan the replacement of the oldest lines. An analysis of the storm sewer system was also performed with the help of a private consultant. This study had the purpose of determining areas in which additional storm sewer facilities were needed. Several land use maps of certain areas of the city have also been produced.

A street centerline and right-of-way survey project has been completed. The more accurate information generated by the surveys is used to improve the accuracy of the property parcel base map. The base map will be continuously updated and distributed to many departments. With a common accurate base map, departments will be able to exchange information more easily. The analysis of information on several layers of the database will be made easier.

A map of all the bike paths in the city is in progress. A sidewalk inventory is being created from field inspections. This inventory will support a sidewalk program that is intended to improve the safety of foot traffic,

especially near schools, and enforce existing sidewalk regulations. Fire hydrant locations will be mapped and better street maps than currently available will be provided to the fire department. The GIS staff is also working on a system that will make certain parts of their database available to the general public on what is called a 'public information counter.'

The GIS staff plans to integrate an existing pavement management database into their system which will for the first time make it possible to map the information contained in this database. With this information maps depicting pavement age and conditions will be prepared. A tree inventory for use by the park department will be developed, also using an already existing database. A map of all geodetic control and elevation points will be prepared for the city surveyor. A map of all trunk sewer levies will also be prepared to allow quick determination of whether a particular lot has been levied or not.

So far none of the tried applications have been categorized as failures.

CHAPTER VI

ENVISIONING FUTURE GIS APPLICATIONS IN PLANNING

What will the future bring in terms of the application of GIS technology to local government planning? From the system descriptions and the applications reviewed above one can conclude that the future will be different for different installations. Different systems have been developed to different degrees of 'sophistication.' What is the present for a few installations today, will be the future of many installations tomorrow. At present, it seems, GIS is mostly used to do the types of things that were done previously; and is not used to its full potential. Map making, data storage, and data retrieval are among the most common applications. Only a few installations, like Austin's Land Development Review System and Georgetown's IMAGE system, have gone a step further by using the unique capabilities of a GIS to do things that could not have been done otherwise. It seems that the future lies in the development of applications that make full use of the present capabilities of GIS. The capabilities of GIS that are not yet fully utilized by all systems are:

- the full integration of digital databases that are available in local government
- the automation of procedures, like the land use control review processes and permit tracking
- the use of advanced spatial analysis techniques

- the use of modeling
- the use of digital maps as legal documents.

The typical GIS in local government seems to be a relatively new operation. Many are just starting out. The major task at the beginning of the creation of a GIS is the construction of the database. The future of many GIS's lies in the expansion and refinement of their database. This is clearly apparent in the system descriptions (see for example Johnson City, Tennessee; Dayton, Ohio; and Eugene, Oregon). A significant part of the refinement of databases results from the **integration of existing databases into the GIS**. Pavement management inventories, 911-Emergency systems, and utility customer systems, are only a few examples of digital databases that are likely to exist in local government that could be integrated into a GIS. Furthermore, datasets created outside of the local government, like the digital census data and possibly marketing data from commercial sources will be integrated into the GIS. Once a database has been integrated into the GIS it should be updated. This could be done by entering the changes into the GIS as they occur or through periodic uploading. The first approach involves the transfer of the entire non-GIS system to the GIS. The second approach would merely involve the exchange of data.

The integration of these systems and datasets will, of course, increase the amount of digital information that is

centrally available and can be crossreferenced with other data layers. The profession of planning will be dramatically affected by this enlargement of the database. Planners will have more information about their local communities available and will be able to analyze and manipulate it more easily. As a result of this, it will become more and more important for planners to know how to manipulate information with a GIS. The skills required to obtain and process information, which are already of central importance to the planning professional, will become even more important. Moreover, the types of skills required will change and become even more computer oriented than they are today.

One of the potentials for further development of GIS in local government lies in the **automation of procedures that involve spatially referenced data**. For example, land use control review processes could be automated as described in Chapter IV of this thesis. It seems that these are more advanced uses of GIS that could become more widely used as systems mature. The emergence of commercial software supporting automatization of the land use review process is conceivable. Many other administrative procedures in local government might be automated. Under what conditions this is feasible and appropriate will have to be determined by further research and trial and error.

The automatization could also involve the integration

of systems discussed above. An algorithm could control the exchange of information between systems. This would make sure that information collected in the various different divisions of local government is made centrally available through the GIS. This would be an example of an advanced information management application that makes full use of a GIS's capabilities.

Another aspect of GIS that will probably gain more importance in the future are the many **spatial analysis techniques** that it makes possible. So far only very few planners have been trained on GIS equipment during their university education. Most planning schools still do not offer courses that teach spatial analysis techniques. Once planners get more exposure to these techniques they will find ways to apply them to their analytical problems. Their sophistication in the use of these techniques is likely to increase. We are still at the very beginning of the process of making use of these techniques. Judging from the information presented in Chapter V, spatial analysis techniques have so far been used only sparingly. Moreover, the techniques will probably become more refined and improved when they are used more often and receive more attention from the planning profession. Land suitability analyses will become standard techniques used in a great variety of planning tasks. Spatial queries will probably be used more often for complex siting tasks once databases

become more complete. The methodology applied in urban and regional analysis will incorporate the spatial analysis tools that GIS is likely to make widely available in just a few years. GIS will provide planners with very new ways to manipulate spatial information. In this context Dana Tomlin's Map Analysis Package and his work on 'cartographic modeling' can be said to provide a 'glimpse of the future' of urban and regional analysis (see Tomlin, 1990).

GIS lends itself to modeling. Today modeling is not as popular as it was in the 1970s. However, the emergence of GIS might change this. Planners will be able to use traffic models and models of urban growth on GIS's. The GIS will add very much improved graphic output capabilities to the type of modeling that has been done before. Moreover, map output will be easier to produce than before. The increased availability of digital information resulting from the proliferation of GIS will make modeling relatively easy to do. Modeling can aid in the comprehensive planning process. Modeling can also be used to estimate the future need for physical improvements. A great potential for extended use of modeling exists in the field of environmental planning. For example, the environmental planner will be able to rely on the GIS database and modeling capabilities to assess the environmental impacts of large projects or suburban growth.

Finally, there is also the option of using the GIS produced maps as legal documents. A GIS could produce

official zoning and long range land use plans in digital form. These GIS maps could become legal instruments like paper versions of the long range plan and the official zoning map are today. The GIS would allow easy updating and reproduction of such maps. Up-to-date zoning maps could be produced and reproduced daily. The coordination of zoning and the comprehensive long range plan could be facilitated by the GIS by making crossreferences between two legal documents easy and very accurate. Moreover, the GIS allows the monitoring of the correspondence between the adopted zoning designations and the comprehensive plan. A GIS may even allow very new forms of zoning. For example, a GIS could keep track of the number of dwelling units in a district. When maximum capacities, as designated by the comprehensive plan, are reached the GIS could indicate this on the zoning map and thereby alert the planners to advice against any rezoning proposal that would increase the number of dwelling units in this particular district. This is just one of the many ways in which GIS could revolutionize land use controls. The above described IMAGE system used in Georgetown, Texas (see Chapter IV) is an apparently successful attempt to use a GIS to handle land use controls in a new and innovative way. The amount of record keeping that IMAGE requires and the allocations of services to individual land parcels can only be accomplished by a GIS.

CHAPTER VII

CONCLUSION

This thesis explored a part of the technological future of the profession of planning. Its value lies in its descriptive and exploratory nature. It summarized and structured some of the available information on GIS in planning. It interpreted this information and presented it in terms of the local government planner's analytical needs. In addition, this thesis made an attempt to anticipate the directions of future developments of GIS applications in planning. Its value lies both in its presentation of factual information and providing of stimulating ideas on the subject of the application of GIS to local government planning.

GIS is an important technological innovation. Like many other important innovations it presents challenges and opportunities. Only if planners meet these challenges and take advantages of these opportunities can they make full and intelligent use of this new technology. This thesis is intended to be of help to planners who are determined to meet the challenges and take the opportunities that GIS presents to their profession.

There is clearly a need for further study on GIS applications in planning. Methods of analysis, like suitability mapping and other spatial analysis techniques,

need to be further explored and improved. Some methodological literature is still needed to help teach planners how to do planning using a GIS.

The issue of feasibility also needs further research. What types of GIS installations and applications are appropriate and feasible for what size of community? This is an important question of very practical significance to professional planners. The costs of GIS operation and the costs of manual operation should be estimated and compared. Additionally, institutional barriers and opportunities to the implementation of multi-agency GISs need further study.

Planning schools must respond to this new technology because the lack of well trained GIS experts is one of the greatest impediments to the development and implementation of this technology. All planners should get at least some training in GIS. More research about the application of GIS to urban and regional planning is desperately needed. A greater focus on GIS will also be essential to avoid displacement of planning professionals from local government positions that require a knowledge of GIS. Many more teachers with GIS backgrounds will be needed.

The planners's professional organization, the American Planning Association (APA), must also support training in this technology. Planning as a profession has to move towards GIS. GIS will not change the basic concerns or methods of planning, but it will change the tools of

information gathering and use and improve their efficiency and effectiveness. There are a lot of things that APA can do to promote the development of GIS and specifically its application in local government planning. Seminars for planning professionals, scholarships, special interest groups, and the publishing of GIS-related publications are initiatives the APA could take. However, at this point it seems most important that APA informs planners about the significance that this technological innovation has for the field of planning. Ultimately, the planning profession cannot say no to this technology - it has to come to terms with GIS.

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GLOSSARY

GLOSSARY

Attribute Data: Any non-spatial data relating to a spatial location or object.

Choropleth Map: A map showing areas of like value in the same color or pattern coding. A land use map is a choropleth map because it displays areas with the same land use in the same color or pattern.

Data Layer: A set of data grouped together within the overall structure of the database. For example, zoning districts may constitute one data layer and the road system another.

Digital Elevation Model (DEM): A digital representation of the topographic features of an area. Point measurements of elevation are used to represent the shape of a land surface. DEMs use interpolation algorithms to determine the shape of the land surface between data points.

Digitizer: A device for spatial data entry. It consists of a digitizing table and a cursor (or puck). A paper map is digitized by placing it on the digitizing table and following the map features (e.g. a stream) with the cursor. The cursor locations on the table are sent to the computer by pressing a button. A digital representation of the map feature is produced in this process.

DIME and TIGER Files: DIME stands for Dual Independent Map Encoding. DIME files are produced by the U.S. Census Bureau and made available to the general public. They contain linear features like streets, railroads, and streams. They also contain address ranges (see Carter, 1984, pp. 17-20). TIGER stands for Topologically Integrated Geographic Encoding and Referencing. TIGER files are an improved version of the DIME files and include basically the same information. However, errors that existed in the DIME files have been removed and the coverage of rural areas has been substantially improved. They are produced and distributed by the U.S. Census Bureau.

Expert System: An advanced computer program that simulates the decision making process of an expert in a given field of expertise. An expert system is fed with the knowledge of one or several experts in a knowledge acquisition process. After this process is completed the system can apply the accumulated expertise to new sets of problems or situations.

Form Environment: A mode of operation within a computer

software package in which the computer shows a form on the screen for the input and display of data. The blanks in the form are filled in with the appropriate information. A form environment improves the ease of data entry and reduces input errors.

Mainframe: A large computer system with many workstations and peripheral devices supporting many users at several different locations.

Microcomputer: A small computer supporting only one user at a time. Microcomputers are also called Personal Computers.

Minicomputer: A medium size computer, smaller than a mainframe but larger than a microcomputer. Minicomputers can support several workstations but are generally not as powerful as mainframes.

Parcel-based GIS: A GIS that uses the legal land parcel as its basic topological unit.

Plotter: A device used for graphic output on paper, mylar, or other material. Pen plotters use ink pens to draw a graphic or map. Hydrostatic plotters apply an electric charge to the paper that magnetically draws the ink onto the paper.

Thematic Map: A map displaying only selected spatial and attribute data relating to a specific theme.

URISA: Acronym for Urban and Regional Information Systems Association. URISA promotes the use of computerized information technology in local, state, and federal government.

View Shed Analysis: A computer analysis tool which defines the area that can be seen from a given geographical point or feature (scenic highway, river). The view shed analysis considers the shape of the topography for identifying the viewable area from a given point.

APPENDIX

John R. Lutz
Knoxville/Knox County GIS
City/County Building
Suite 651
Knoxville, TN 37902

May 25, 1990

Dear Mr. Lutz:

I am conducting research on GIS applications in local government, and particularly in local government planning. For this purpose, I am sending a mail survey to a number of GIS installations across the country. Your system is one of the GISs in my sample and I have selected you as my contact person.

In a couple of days you will receive a short questionnaire, which I will ask you to fill out. The questionnaire will ask to list the agencies in your municipality that are developing applications. It will ask for brief descriptions of the applications that you have already developed, are in the process of developing, and are planning to develop in the future. The questionnaire will also ask for applications that have been tried unsuccessfully.

This questionnaire is a part of my thesis research for a master's degree in Urban and Regional Planning from the Graduate School of Planning at the University of Tennessee in Knoxville.

Sincerely,

Jörg Land
Graduate Assistant

GIS
QUESTIONNAIRE

Please distribute copies of this
questionnaire to all agencies/divisions that are developing
GIS applications, or will do so in the future.

Return before June 15, 1990 to: Jörg Land
Graduate School of Planning
The University of Tennessee
1618 Cumberland Ave.
Knoxville, Tennessee 37996

Name:.....

Phone:.....

Function/Title:.....

Department/Agency/Division:.....

Name of the GIS:.....

Year of Project Start:19.. Population of Community

City:..... County(ies):.....

USE ADDITIONAL SHEETS AS NEEDED!

System Description

- 1) Briefly describe the hardware and software configuration of your GIS.

System Status

- 2) How far are you with implementing your GIS? To what extent is your GIS operational? If partially operational, use fractions to describe the status of your system (e.g., 2/3 operational).

Users

- 3) Who is, or will be, using your GIS? (List all agencies and/or divisions!)

- Application Developers**
- 4) Who is, or will be, actively developing GIS applications for your system? Please distribute copies of this questionnaire to all agencies/divisions that are developing applications, or will do so in the future.

Instructions for Questions 5 - 9:

Describe applications in terms of

- the problem that they are addressing or tasks that they are accomplishing,
- the input (data) that they require,
- the analytical techniques they use to analyze and manipulate the input,
- the products or output they generate,
- and, if they have already been used, how successful they are.

If necessary for the understanding of the applications also describe hardware/software requirements and database designs.

Include long term or ongoing applications as well as short term or single purpose applications.

Current Applications

- 5) How are you currently using your GIS? Briefly describe the applications that you have already implemented.

Applications Currently Under Development

- 6) Describe the applications that you have currently under development.

Planned Applications

- 7) Describe the applications that you are planning to develop soon.

Future Applications

- 8) Which applications do you expect to develop in the future? Describe all applications that are not yet in the planning stage, no matter how vague your idea of them is.

Unsuccessful Applications

- 9) Describe all applications which you/your agency have attempted to develop but failed. Try to identify the reasons for the failure of these applications.

VITA

Jörg Land, a native of the Federal Republic of Germany, was born on January 1, 1962. He attended elementary and secondary schools in his hometown of Gelsenkirchen, Germany and graduated with the Abitur in 1981. He received a Vordiplom in Sociology and Economic History from the Universität Hamburg in 1983. In 1987 he completed a Bachelor of Arts degree in Liberal Arts at the New School for Social Research in New York. He has completed the coursework for a Master of Arts degree in Sociology at Southern Illinois University at Carbondale. He began his studies at The University of Tennessee's Graduate School of Planning in the fall of 1988. In December 1990 he was awarded the Master of Science in Planning degree at The University of Tennessee, Knoxville.

Mr. Land has held graduate assistantships at both Southern Illinois University and The University of Tennessee. In the summer of 1989 he also worked as an intern for the consulting firm PlanGraphics, Inc. in Frankfort, Kentucky.

He was a Eugene Lang Scholar at the New School in 1986 and has received several New School Grants. He was awarded the Graduate School of Planning's Outstanding First Year Student Award in 1989 and its Academic Achievement Award in 1990. In 1990 Mr. Land was also awarded the American

Institute of Certified Planners Planning Student Award. He, furthermore, received the American Society for Photogrammetry and Remote Sensing Mid South Division's Student Award in 1989. Mr. Land is a member of Phi Kappa Phi, the American Planning Association, the Urban and Regional Information Systems Association, and the American Society for Photogrammetry and Remote Sensing.