**ORGANISATIONAL ISSUES IN THE IMPLEMENTATION OF MUNICIPAL GEOGRAPHIC INFORMATION SYSTEMS**

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## ABSTRACT

GIS represents new ways of collecting, storing, managing, analysing and presenting spatial information related to urban planning. Manual procedures that took hours or even days to complete can now be undertaken in often a fraction of the time. As well, GIS offers planners the opportunity to ask questions and investigate spatial phenomena in ways unheard of in the past.

Many of the benefits that GIS holds for the planning field have been recognised. These include the ability to query spatial databases and overlay different types of cartographic information. On a broader scale, GIS allows planners to share information, resulting in reduced duplication, waste and redundancy. These are only a few of the advantages that GIS represents for planners. Ironically, the adoption and acceptance of such systems by planning agencies has not always been wholehearted. Because the technological issues behind the operation of GIS are often quite complex, its functions and capabilities are seldom correctly perceived. Many misunderstandings persist among planners and municipal officials about the capabilities of GIS. There are a great many obstacles to the proper implementation and adoption of a municipal GIS. Technical problems can exist throughout the process, but can usually be surmounted given proper equipment and effective technical support. Still, a vast array of managerial and personnel issues have the capacity to affect the success of a GIS implementation scheme: lack of management commitment, ineffective user training, lack of expertise and awareness of GIS capabilities, and an unmotivated staff. The fact that planning processes operate on a level that tends to be less concrete and dichotomous than GIS can also affect its use and acceptance among planners.

This thesis examines some of the key issues raised by the obstacles to GIS implementation, and seeks to underscore the critical nature of those obstacles that are organisational in nature. The main findings of this research can be summarised by three categories of critical issues: (1) organisational issues--solving organisational challenges requires a deeper understanding of how the introduction of technological innovations will affect workflow processes, departmental relations and organisational hierarchy; (2) educational issues--end users and managers require a heightened awareness of geography and the true capabilities of GIS in order to use these systems to their fullest potential; (3) political issues--GIS challenges existing organisational structures by empowering those who can operate GISs and allowing them access to a multitude of information.

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## 1.0 INTRODUCTION

Effective decision making for planning depends on the availability of dependable, timely and accurate information. Over the past twenty years, the way in which information relevant to planning functions has been collected, stored, retrieved and eventually interpreted has evolved from largely manual systems to those that are automated. Information management technology for planning has made significant advances over this period. Unfortunately, the rate of system implementation success has not always kept pace with advances in technology. "While substantial progress has been made in the development of geographic information systems (GIS) hardware and software...the pace of development of information systems and the *integration* of information systems has not been as rapid" (Worall 1991, 1-2) [italics mine].

### 1.1 PROJECT OBJECTIVES

The topic of this thesis is as much, if not more, about managing people as it is about technology and how it is applied to the task of planning. While the technology or physical tools needed to confront planning challenges may be readily available, it is in the implementation, management and operation of the technology where even greater challenges arise.

There are many pitfalls, impediments and obstacles to the successful implementation and operation of a municipal GIS. Although these obstacles cover a diversity of areas, they can be divided roughly into two types: technical and managerial. It is the contention of this thesis that the managerial challenges posed by the immense task of implementing a GIS are often more compelling than the technical challenges. "Planners must understand that GIS is a socially constructed technology, including not just hardware and software, but also the practices, laws, organisations and knowledge that are necessary for its use" (Innes and Simpson undated, 1).

The use of GISs has recently attained a very high level of popularity in both the public and private sectors. Due to this recent popularity, adoption of many systems has been too quick, hasty and wrought with carelessness. "A 20 year history of efforts to develop large-scale computing systems for planning is littered with failed attempts and massive expenditures, often with little to show as a result" (Innes and Simpson undated, 1). This leads to some fundamental questions surrounding not only the technical ability to operate a GIS, but also the ability to effectively manage its operation. Do organisations interested in GIS know what they require of a municipal information system? Are their expectations too high or unrealistic? Are they prepared for the managerial upheavals and conflicts that can often be characteristic of a GIS implementation program?

Although the technical challenges in setting up a GIS are as great as they are diverse, the issues responsible for implementation failures are almost always related to people. More specifically, these are problems related to how planners and other municipal employees' occupations undergo a redefinition as a result of GIS implementation. For example, information flow, control and sharing is altered. Centres of power and knowledge change when centralised information sources are created. "The implementation of a GIS is where people and technology meet" (Aronoff 1989, 249).

Much of the past as well as present literature places emphasis on the technical considerations involved in GIS implementation. As Obermeyer and Pinto (1994) point out, this comes as no surprise since GIS is a relatively new field. Most of the writing on new technologies would naturally be concerned with technical or technological aspects because the wider effects on organisations and institutions have yet to be felt. As well, these wider effects are harder to define, understand and quantify in any meaningful way. Only after the technology has had a chance to evolve, diffuse and gradually permeate the workings of the institutions that choose to adopt it, may we begin to see the emergence of commentary on its wider societal influences.

> While GIS as a technology has been around for a quarter of a century, the widespread implementation of the technology is much more recent. One would not...expect literature on the theoretical aspects of implementing GIS to appear early in the development of this or any technology. Informed expectation would recognise that the development of technology and the growth of research...would follow a pattern that begins with technological problems, proceeds through financial aspects, continues with institutional issues and culminates with societal effects. (Obermeyer and Pinto 1994, viii).

GIS technology has now reached the stage where it has the capacity to impact on entire organisational structures. It is therefore time that research be focused on what these effects are, what aspects of GIS technology are responsible for these effects, and to what extent they can change the way public or private institutions conduct their affairs.

One of the themes of this thesis is that people, not technology, are responsible for driving change. "Technology offers possibilities and potential, but it is up to people to determine if, for better or for worse, that potential will be realised" (Smith 1994, 44). Whether it be the steam engine that was treated as a mere toy by its ancient Greek inventors, or automated Jacquard looms that were systematically destroyed by traditional hand-weavers, technological innovations have been impeded by a diversity of obstacles. For instance, Smith (1994) points out that the ancient Greeks developed the steam engine 1700 years before it was put to any extensive use during the industrial revolution. Similarly, the Jacquard loom, "which revolutionised the European textile industry, was not widely used for nearly a century after its prototype was developed, because weavers rioted and smashed the looms when they were introduced" (Smith 1994, 44).

GIS is undergoing similar treatment in many cases. For instance, there are many areas where threats are perceived. First, less technically-oriented planners may feel threatened by the new technology and fear losing their jobs. Second, alteration of a very comfortable *status quo* which acts to keep the hierarchy of an organisation in place may come into play. And third, "standard operating procedures" (Obermeyer and Pinto 1994, 76), the rationalising force and backbone behind many organisational bureaucracies, are threatened as new procedures are devised in order to accommodate new information management technology.

In many ways, GIS is to planning and geography what the spreadsheet was to accountancy and financial analysis. The introduction of the spreadsheet did not replace accountants and financial analysts. It simply helped them to do their jobs more quickly and efficiently. GIS cannot hope to, and never will, replace the planner as the interpreter of spatial information. Often, many planners and planning directors mistake GIS for a *solution* to planning problems instead of a *tool* to be used in the decision-making processes related to planning.

Spreadsheets cannot solve all problems and answer all questions that deal with mathematical, statistical or computational dilemmas. Like spreadsheets, GIS is a tool that can help in two very important areas. It can help planners, geographers and others who work with spatial data answer the questions *they already have* in a more efficient manner. But it can also help them to ask questions that, perhaps, were never thought of beforehand.

Comparable to the spreadsheet, GIS is often also seen as a way to increase productivity. Still, the assumption that new technology alone can increase productivity can be a false one. The widespread introduction of computers into the everyday workplace some twenty years ago created the presumption that productivity would skyrocket given the ability of computers to perform a greater number of tasks more quickly. But one cannot simply throw computers at a problem and expect it to go away. Nor can one assume that the use of computers will allow tasks to be accomplished within a reduced time frame. "The user organisation is also part of the equation...it is hard to integrate information technology into a changing organisation until the organisation itself is designed to accommodate change" (Loveman in Smith 1994, 45). Until this occurs, a GIS can only become as effective as the organisation that chooses to adopt it.

## 1.2 Limits And Scope

The comment quoted earlier by Obermeyer and Pinto (1994) on the evolution of research on GIS is certainly correct in suggesting that GIS has now attained the stage where larger societal influences are on the horizon. Managerial and organisational issues are not the only areas where the impacts of GIS technology are being felt. For instance, now that a great deal of municipal information is available in a format that allows for quick and efficient data search and retrieval, the implications for the eventual use and/or abuse of this information are great. Furthermore, the sale and distribution of such information by municipalities and other information gatherers, such as credit agencies or federal statistics bureaus, has raised concerns regarding the confidentiality of personal information.

It is impossible to review all the controversial issues that arise from an examination of the effects of GIS technology diffusion. Still, some discussion will be devoted to these issues. This thesis will focus fundamentally on why municipalities are adopting GISs and what internal administrative changes and difficulties they are undergoing as a result of adoption of this new technology.

### 1.3 A Definition Of Implementation

While the field of GIS is still relatively new, the development of GIS implementation theory is still newer. Obermeyer and Pinto's (1994) study represents one of the more recent commentaries on the subject. In their book, the authors comment on the relative scarcity of material on implementation theory that deals specifically with GIS in a social science context. Only four works are mentioned: (Wellar 1988a, 1988b ; Wiggins and French, 1991; Onsrud and Pinto, 1992). They find that theories of implementation that deal with more generic cases of technology adoption are far more abundant than those that are concerned specifically with GIS.

Still, because this thesis deals with the implementation of GIS technology and its effects on the organisations that adopt it, an attempt must be made to clarify and define what is meant by the terms *implementation* and *implementation success*. We must not only ask what it means to implement a specific policy or innovation, but also what factors define a successful implementation process.

One common and quite erroneous misconception made is that by the very fact that a technological innovation has been adopted, it is automatically accepted. "Past implementation studies in other fields frequently presumed that upon confirmation of the acquisition of a technological capability, the innovation was successfully implemented. That is to say, adoption and success were considered synonymous" (Obermeyer and Pinto 1994, 22). As one can only lead the proverbial horse to water, the same can be said for organisational attitudes toward the adoption of new, and perhaps revolutionary, technologies. System acquisition is only one step, and certainly far from the last step in the GIS implementation process. The concept of implementation success can only gain meaning after a system is put in place, put to use and evaluated based on its usefulness and acceptability to those charged with its operation.

Many authors have attempted to define implementation success. This is quite a challenging task given the fact that success means different things to different people. While some GIS managers stress cost-benefit ratios, others may use more qualitative criteria. Often, success is also measured differently in the private sector than it is in the public sector. Below is a short compilation of some of the major factors many authors hold to be important in defining implementation success.

- A GIS that is integrated within the managerial decision making process
- A system, that in a technical sense, "really works"
- A system that is cost effective.
- System performance expectations that are consistent with reality
- A system that has obtained sufficient management support throughout the implementation process and which is operated by staff that are properly trained, comfortable and enthusiastic.
- GIS software applications that are designed around user needs

There are many types of theories that can be applied to the study of GIS implementation. Below is a short list broken out into broad groupings or types. These include:

- Content vs. process models (Obermeyer and Pinto 1994)
- Multi-step or procedural models (Flagg 1993)
- Short-Road Approaches (Ballard 1993)
- Implementation Scenarios and Trade-Offs (Dangermond and Smith 1980)

The above is meant only to provide a short definitional context for implementation theory. A more in-depth discussion of the different types of implementation theories mentioned above will be covered in chapter four.

## 1.4 Research Methods

Because the study of GIS implementation theory is rather new, only a small body of written work exists compared to the amount of literature on the technical aspects of GIS. Those sources that did exist on implementation theory were consulted. As well, many articles were compiled from conference proceedings and trade journals that highlighted many real-world situations where the challenges of implementing GIS in a municipal planning context were covered.

Very limited primary research was conducted through an informal personal interview with planning assistants at the City of New Westminster. While opinions were sought on many issues ranging from technical obstacles to managerial and political problems involved in setting up a GIS, limited information was collected. This was due, more than likely, to the newness of the staff as well as the sensitivity of some of the subject matter.

## 1.5 Overview And Summary

This thesis is organised into six chapters, including an introductory statement and a conclusion.

Chapter one introduces the thesis and provides its statement of purpose and rationale. It also outlines its scope of analysis and the tools used in order to carry out the research. A short section on the basic definitions of implementation is also provided in order to set the stage for subsequent, more detailed discussion in the chapters to follow.

Chapter two provides a detailed definitional background and technical orientation to the subject of GIS. The content is quite lengthy owing to the complexity of technical issues required to understand GIS technology. The historical evolution of GIS and the various components and tools included in a generic system are covered. It also explains how a GIS works and the way in which geographic information is stored and organised.

Chapter three bridges the gap between the technical side of GIS and the managerial side -- conducting the business of municipal government. The characteristics of municipal information databases are discussed. Finally, end user applications are suggested as well as areas where GIS can be "misapplied," misused, or even abused.

Chapter four looks at the GIS implementation process. Once an organisation decides that it wishes to pursue the acquisition of a GIS, what steps are usually involved? A discussion of the various GIS implementation models will also be covered.

Chapter five takes implementation theory one step further by investigating the obstacles that are often responsible for GIS implementation failures. Both technical issues and personnel management issues will be covered. As well, an investigation into the gap that divides user expectations of GIS from reality will also be undertaken.

Chapter six will conclude the thesis by summarising the research findings and providing an overview of what can be learned from the issues covered in the main chapters.

# 2.0 BACKGROUND AND TECHNICAL INFORMATION

This chapter will introduce GIS concepts from a detailed technical standpoint in order to familiarise the reader with the information necessary to understand how a system operates. It will also provide an introduction to how GIS relates to the urban planning field, and some of the areas where conflict exists between the two.

## 2.1 DEFINITION AND EVOLUTION OF GIS

"All geographic information systems integrate a *mapping function*, which displays maps or geographic features (such as polygons, lines or points) with a *database manager*, which organises the attribute data tied to the various map features" (Levine and Landis 1989, 209-210).

Many definitions containing differing emphases have come to describe geographic information systems. For instance, a GIS is a computerised system for the 1) input and storage, 2) management, 3) manipulation and analysis and, 4) output of information that is spatially referenced (Obermeyer and Pinto 1994). This definition is most conventional as it stresses the four main elements of a generic GIS. Taylor (1991, 5), instead, believes that "there is no universally accepted definition of a GIS," because of the sheer diversity in terminology used in geography, planning and the many other fields that can make use of GIS. These include: "land information systems (LIS), urban information systems (URIS), environmental information systems (ERIS), and cadastral information systems (CAIS)." The diversity of the discipline then becomes one of the key issues when attempting to define GISs. For instance, Burrough (1986, 6) believes that "all these disciplines are attempting the same sort of operation - namely to develop a powerful set of tools for collecting, sorting, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes."

Essentially, GIS means different things to different people. For hardware technicians, it is the hardware needed in order to run the system. For those who design GIS programs, it is the software. Still, others see it as some combination of the two. One common misconception is that GIS is seen as nothing more than "a pretty mapmaker" (Smith 1994, 46). Still, Taylor (1991, 5) believes that "there is general agreement that a GIS involves much more than automated map making and that a true GIS includes the ability to analyse data." This difference is what truly distinguishes a GIS from a simple graphic display system.

The most basic GIS can actually be thought of as a paper map. In this case, the "analysis" module is the map user. All analysis and interpretation of cartographic features, which are supposed to be symbolic of spatial reality, are undertaken in a manual fashion by the map user. While not automated, a paper map contains the information necessary to establish relations between spatially referenced objects. In other words, it helps us to locate ourselves in relation to other objects on the surface of the earth and draw conclusions about those relations. A map is quite an efficient store of spatial information, but in comparison to an automated GIS, a paper map may be considered primitive for the following three reasons:

- Although paper maps are quite an efficient store of information, they cannot be changed or updated quickly and easily.
- The amount of space required to store large amounts of geographic data in paper map form can soon become unmanageable.
- Performing a manual search on a map for features meeting a certain criteria can be inefficient as well as time consuming.

This is not to say that the paper map does not perform its job adequately. "The fact that millions of people use Rand McNally's Road Atlas to take them from sea to shining sea in North America is a testimonial to the ease of analysis that a map represents" (Obermeyer and Pinto 1994, 5). For the average user, a paper map gets the job done. But in many cases where simple way-finding is not sufficient, more sophisticated tools are required.

Automated systems designed to handle geographic data have actually existed for over twenty years. But it is only during the past ten years that the technology has become portable, accessible and cheap enough for the average municipal planning technician or researcher to have a system on his or her desk. GISs have truly come a long way from the days when they resided only on large mainframe and mini-computers, useable only by those possessing the intricate knowledge required in order to operate them. While it is still true that many GISs still operate under a mainframe or workstation environment and are still relatively more complex and difficult to learn than the average software package, the desktop GISs of today enable users to perform a great variety of geographic analyses unheard of in the past.

> At the outset, GISs evolved out of a diversity of needs related to simple spatial analysis. Their development has been shaped by certain perceived needs for their capabilities, technological opportunity, methodological and institutional constraints. Their invention stemmed from the growing involvement of governments in land use planning, the resulting need to handle location-specific data in a timely manner, and the fortuitous technological opportunity offered by the development of computers...as information processors rather than as calculating devices. (Tomlinson 1984 in Pequet and Marble 1990, 18).

Maguire (1989, 173) offers four main factors behind the demand for GIS, and its subsequent development. These are:

- The great proliferation of environmental data in digital format.
- Advances in geographic theory and techniques which have far outgrown the capabilities of manual spatial analysis or primitive computer systems.

- Both the multidimensional and voluminous nature of geographic and planning related data.
- The practical/commercial applications of GIS in many situations where analysis of spatial data is required.

During the 1960s, Canada developed the world's first GIS, *The Canadian Geographic Information System* (CGIS). It was created at a time when the federal government was able to devote considerable financial resources toward GIS development. The main impetus for developing a GIS stemmed from the realisation that Canada's natural resources were far from limitless and that "there was increasing competition among the potential uses of land within commercially accessible land zones" (Tomlinson 1984 in Pequet and Marble 1990, 19). In the federal government's opinion it became critical to devise a method for recording, tracking and monitoring land use change within the overall framework of land use management, planning and the utilisation of natural resources.

"It was not until the 1970's that the phrase *geographic information systems* was first used to name a set of tools for creating, maintaining, analysing and displaying maps and data for use in public agencies" (Huxhold 1991, xiv). Still, the costs of purchasing hardware, software and converting data into digital format were so prohibitive that the technology was diffused only within a small circle of agencies that could afford such an enormous financial sacrifice. More often than not, government agencies were the only ones capable of supporting such costs. Consider the following examples given by Tomlinson (1984, in Pequet and Marble 1990,20-21) outlining the costs of GIS hardware and their capabilities at their particular period of development.

In 1960, an IBM Mainframe with 16K of base memory could process 1,000 instructions per second. It cost $600,000 ($2 million in 1984 dollars) and weighed more than 8,000 pounds. In 1964, the first mainframe computer with 512K of base memory was introduced. It was able to process 400 times the amount of information per second than its predecessor, but it cost $3,500,000 ($12 million in 1984 dollars) and weighed 10,000 pounds. In 1967, display monitors capable of showing graphics as well as text were priced at $90,000 and offered poor graphic capability at that. Digitisers, devices for tracing and converting paper maps into digital format were priced at $70,000 in 1984 dollars. In 1984, a system capable of accomplishing what the old mainframes of the 60's were capable of, cost about $600 and weighed less than one pound. Today, if such low end systems were still available, their price in relative terms would be minuscule. During the 1970s and into the 1980s, hardware prices decreased sharply with the rapid development of ever smaller and faster microprocessors. The result was the elimination of hardware as a major limiting factor in the advancement and adoption of GISs.

While the costs of acquiring the tools needed to build a GIS have decreased significantly, the capabilities of GISs have also increased dramatically over the past twenty years. GISs have evolved from simple spatial information display systems to systems that today incorporate sophisticated spatial analysis and modelling routines in their software. Numerous example applications include:

- Routing ambulances, police cars and fire trucks from origin to destination through the shortest route.
- Planning and maintenance of municipal infrastructure such as hydro lines, sewers and roads.
- Evaluating commercial cannibalisation when new store locations are planned.
- Summarising and aggregating property tax or other numeric information by user-defined zones.

- Selecting parcels based on a particular criteria and printing out a list of pertinent information relating to the chosen parcels.

While technology has grown in terms of power and capability, the role of computer mapping systems has gone from one of just generating cartographic maps to one of aiding in decision analysis based upon thematic mapping. In conjunction with these changes, the cost of mapping systems has fallen from millions of dollars to thousands of dollars which in turn has enabled a broader group of individuals to take advantage of the technology (Nappi in Scholten and Stillwell 1990, 24-25). McLauglin (1988) outlines some of these trends in table 1.

**Table 1: GIS Trends in Pricing and Capabilities**

| | 1976 | 1981 | 1986 | 1991 |
|---|---|---|---|---|
| *System Architecture* | Mainframe | 16-Bit Mini | 32-Bit Mini | 32-Bit Micro |
| *Processing Environment* | Central Data Processing Department | Dedicated Processor | Professional Workstation: Host-Based Network | Personal Workstation Distributed Network |
| *Primary Emphasis* | Map Production | Mapping and Attribute Data | Geographic Modelling | Decision Analysis |
| *Software Cost* | Non-commercial software | $100K-$200K | $100K-$200K | < $100K |
| *Hardware Cost (Central Processor, Storage, Input, Output)* | Approx. $450 K for Mainframe Alone | Approx. $150K-$300 K PDP-Based System | Approx. $100 K-$ 200 K VAX-Based System | < $ 50K |

## 2.2 GIS AND THE PLANNING FIELD

The above section highlighted the technical considerations in the advancement of GIS technology. Decreasing prices coupled with smaller and more efficient processing electronics helped make GIS tools more accessible. But there still remain several factors which tend to impede the adoption of GIS, especially in the planning field. Sauberer (1987 in Scholten and Stillwell 1990, 19) recounts conflicts between the designers of GIS hardware and software and the planners and researchers charged with using these systems. The main reasons for conflict were cited as:

1. The reluctance to adopt an objective-analytical approach in planning.
2. The necessity to use large amounts of data, which could not be handled adequately by first generation computers.
3. The impossibility of these computers to process graphical map information.
4. The lack of training of planners and researchers in the field of automated information processing.
5. The large investments and operational cost of hardware and software.

The problems outlined in points 2,3 and 5, already discussed in the previous section, have been virtually eliminated due to advancements in technology and decreases in system acquisition costs. Points 1 and 4, however, are of specific concern to the planning field and still remain to be rectified.

Point 1 highlights the long-standing conflict between the objective-analytical and the more social/subjective approaches to planning theory and practise. The quantitative revolution of the 1960s spawned *planning-by-numbers* or *blueprint planning*. This was a planning culture that was soundly rejected after its results produced solutions to problems that were often more destructive than the environments they were supposed to replace. These included monstrous, sterile housing projects and expressway construction projects that razed entire neighbourhoods.

Point 4 stresses the need to educate planners and researchers in the technical domain of operating a GIS. What Sauberer omits is the importance of educating planners on the organisational and management side as well. "Educating GIS course participants to agents of change has to encompass rising awareness of non-technical factors pertaining to information systems as socio-psychological and organisational issues. In practice, the introduction of information systems fails because these factors are ignored" (Linden in Scholten and Stillwell 1990, 200).

Breheny (1987, in Scholten and Stilwell 1990, 20) lists many other reasons for the failure of GIS to make inroads into the planning profession. Breheny's reasons will be covered in greater detail in chapter five, on obstacles to implementation. Below is a short summary of the five obstacles.

- GIS tends to be concrete and absolute, while planning is more social, abstract and subjective in nature.
- Planning activities are non-routine, often irrational and inherently political. This requires a certain flexibility most information systems are not yet capable of accomplishing.
- Planning involves much more than automated information processing.
- The challenge of extracting planning and policy information for *decentralised* processing from a *centralised* GIS database. Information control and territoriality often inhibits information sharing across departmental boundaries.
- How to bring to the forefront the importance of the costs involved in training, support, customising and maintaining the central database. These costs are, unfortunately, often ignored in project estimates.

## 2.3 GIS Components

A generic GIS is made up of roughly four components. These are data input, management, analysis, and output. Together, these elements act as a system that allows the user to enter geographic and non-geographic data, store it for later use, analyse and change the data, and eventually output it for interpretation and use.

### 2.3.1 Input

Input refers to the hardware and software tools necessary for the entry of spatial and non-spatial information into a GIS. This consists of transforming spatial and attribute data into digital format. Input devices may consist of a standard keyboard for the entry of non-graphic database information, and a mouse, digitiser or scanner for graphic information entry.

A digitiser is a device used for converting analog or paper map information into digital format. It consists of a magnetic tablet and a pointing device, known as a puck (similar to a mouse) which is used to trace the features from a paper map into a graphic database. Digitisers are used for entering *vector* type graphic data into a GIS. A scanner, on the other hand can be compared to a large electronic eye or video camera, that scans a paper image and breaks it up into small, regularly shaped cell-like pieces. The type of information read into a GIS by means of a scanner is referred to as *raster*-type data. These two ways of organising geographic data will be expanded upon in the section on geographic data models.

### 2.3.2 Data Management

"Geographic information systems are first and foremost, information management systems" (Huxhold 1991, 36). Therefore, the central component of any GIS is its information or database management system. "A database is a collection of information about things and their relationships to each other" (Aronoff 1989, 151). In the case of a GIS, these *things* are geographic features, and the relations that are critical to any analysis where GIS is concerned are those that are spatial in nature. A simple database consists of columns and rows. In almost all cases, the observations or cases of each variable are located in rows. Each row is referred to as a *record*. The characteristics of each observation are located in columns. Each column is referred to as a *field* or a *variable*. For example, a municipal parcel database may contain one record for each parcel and as many columns or fields for each record as there are characteristics of a particular parcel.

Once the geographic features or data are entered into the GIS, they must be stored for future analysis and retrieval. This is what makes the database central to any GIS. The database is where information integration takes place. It is also where information that is common to many sources can be examined and compared. Information needs in a municipal context often do cross functional areas. Huxhold (1991, 37) cites several examples. These include fire and taxation, taxation and building inspection, sanitation and taxation, utilities and public works.

In order for a GIS to operate effectively, at least in technical terms, its system of ordering and storing both geographic and attribute information must be efficient. As will be seen in the section on data models, different database management models have both their advantages as well as disadvantages concerning storage, organisation and data retrieval.

The task of the database management system is to organise geographic information in such a way that the user is able to establish and make sense of spatial patterns by manipulating data in various ways. The next section, on data analysis, shows how the manipulation of data is made possible through various GIS functions. For example, manipulation may involve overlaying different types of data in order to see where they intersect spatially. It may also involve comparing several databases in order to establish patterns of commonality.

### 2.3.3 Data Analysis and Manipulation

Data analysis is at the heart of a GIS, and distinguishes it from other spatial information or spatial display systems. In the context of a GIS, data analysis can be more accurately referred to as *spatial analysis*, because the data being handled is invariably spatial in nature. There are many types of spatial analysis functions with diverse purposes. They can be roughly broken down into two types: technical maintenance or *housekeeping* functions, and information generation functions. Housekeeping functions are those that deal with the internal maintenance and manipulation of geographic files. Information generation functions deal with the integration of attribute and geographic data in order to produce new information.

#### 2.3.3.a Housekeeping Functions

Some examples of housekeeping information include map editing, generalisation, rubber sheeting and co-ordinate transformation. What all these functions have in common is that they deal exclusively with geographic entities themselves, and not with any attribute or descriptive information associated with the geographic entities.

For instance, map editing may include moving vertices of a polygon in order to correct digitising mistakes. Generalisation involves deleting unneeded vertices from a line or polygon where an inordinate amount of detail may not be required. This also helps to cut down on file size and storage requirements. Rubber sheeting involves stretching and distorting one map sheet relative to another in order to register or match both layers properly so that they line up. Finally, co-ordinate transformation entails projecting an image of the earth's surface from a spherical surface to a flat one. It is impossible to represent the shape of the round earth perfectly as a flat image without distorting or warping one or more parts of that image. Different projections have been devised that distort various areas of the earth.

#### 2.3.3.b Information Generation Functions

Information generation functions, on the other hand, involve combining and integrating geographic and attribute data in order to derive and generate new information from data that already exists. A simple spreadsheet or database allows one to choose items based on several criteria, but it does not permit any spatial analysis of the data. Only when the geographic characteristics of the data are revealed and paired up with corresponding attribute data are we able to ask questions relating to the spatial relations between geographic entities. Some examples of the integration of geographic and attribute data resulting in new information include optimal path routing, point-in-polygon analysis, data aggregation, redistricting and location information transfer through overlays.

Optimal path routing uses linear geographic data, representing a road network, for example, and information on traffic flow volumes, as attribute information. Used together, an optimal routing algorithm considers alternative scenarios through the network until it finds the quickest path between two points established by the user.

Point-in-polygon analysis refers to processing point-based data that is contained within a bounded area. For instance, the city may want to count the number of delinquent property owners within a particular ward, sum together the total amount owing for that area, and then print a report summarising the new data generated.

Data aggregation is the more general case of a point-in-polygon analysis, because it refers to all cases where the data associated with geographic features are aggregated based on their relation to some other spatially coincident or neighbouring geographic feature. For example, one might sum all data from census tracts inside a particular electoral district to arrive at a new total for the whole area, or sum the number of lots measuring over 5000 square feet within a particular area.

Redistricting, or load balancing, involves dividing up a geographic area into units with roughly equal values of a particular attribute. For example, a city may choose to divide the city into electoral wards or districts with roughly equal population counts.

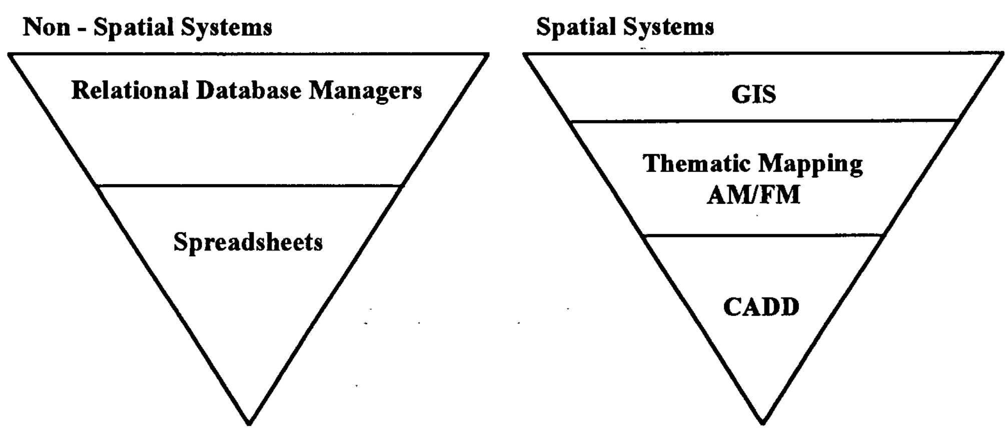
### 2.3.4 Information Output

Information output may consist of reports, spreadsheets, charts, graphs, tables and, of course, paper maps. Digital output products may also be made available through the preparation of electronic boundary files. These are files that contain information needed to display cartographic information on a computer. Output is made possible through a variety of output devices and peripherals. These may consist of graphics monitors, printers and plotters.

## 2.4 A Hierarchy Of Systems

There is a great wealth of geographic information handling systems[1] that presently exist. These diverse systems have the capability of storing and processing information in many ways. But the extent to which the spatial aspect of the information can be utilised depends on the system in question. A hierarchy can be devised describing the extent to which these systems allow the user to extract meaningful geographic information and establish spatial relationships between features. The hierarchy, illustrated in figure 1, is based on the degree to which each system recognises and makes use of the spatial dimension of the data being handled.

**Figure 1: A Hierarchy of Geographic Information Handling Systems**




### 2.4.1 Non-Spatial Systems

A spreadsheet is essentially a large electronic calculator organised into columns and rows, allowing the user to enter or import data from other applications and perform a wide array of mathematical computations. For most applications where performing basic non-spatial calculations is necessary, a spreadsheet is sufficient. Unfortunately, spreadsheets were not

[1] *Geographic information handling systems* is used here as a general term to describe any automated information organising system that handles geographic data regardless of its sophistication.

designed to allow the user to visualise the relations among data items that are spatially referenced. Spatially referenced data are tied to specific locations in space.

What differentiates even the simplest GIS from a spreadsheet lies in its capability to handle and display spatially referenced data. A spreadsheet may contain columns with the latitude-longitude co-ordinates of particular "point location," incidents for instance, but it is incapable of displaying them in any way other than symbolically or numerically. A GIS on the other hand enables the user to visualise in two-dimensional space exactly where these records are located in relation to each other as well as to other geographic phenomena. In terms of linear or polygon based data, a spreadsheet may contain only an identification code for a particular land parcel and a list of all its characteristics, but we have no way of knowing where the land parcel is located in space and know nothing of its relation to other land parcels as well as other types of features.

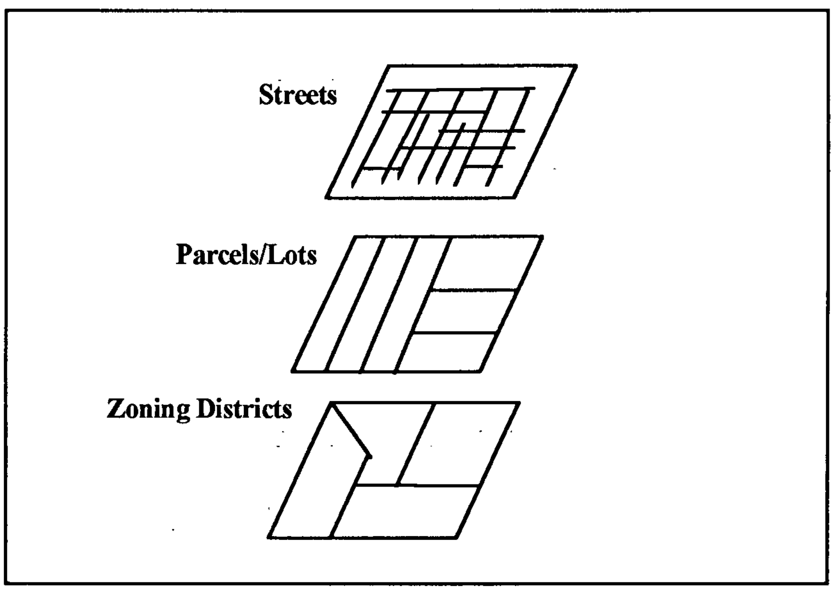
### 2.4.2 Spatial Information Systems

Early GISs did not possess the functionality and capabilities they possess today. The evolution of these systems demonstrates how some of the first GISs were not really GISs at all, at least in terms of the way we define them today. They were simply spatial information *display* systems, limited in their analytical and computational capabilities. They were able to display spatially referenced information, but unable to perform any sophisticated mathematical calculations or spatial analysis. This branch of the hierarchy deals with geographic information handling systems that are capable at the very least of displaying geographic data in two dimensions. In this way, at a minimum, the user is able to view spatial elements as they may actually appear on the ground.

### 2.4.2.a. CADD systems: Computer Aided Drafting and Design

The first category of spatially referenced drawing or mapping systems falls into the category of CADDs or computer aided drafting systems. These systems help to automate the drafting and printing of charts, maps and diagrams, and are used primarily by architects and engineers. CADDs are similar to GISs in that they separate different types of information into what are termed *levels* or *layers*. But with a CADD system, "there exists no relation between items existing on different layers other than visual relation" (Wiggins and French 1991, 5). A true GIS allows the user to transfer information between layers and calculate the areas that intersect between different layers, among other more sophisticated functions.

**Figure 2: Geographic Information Organised Into Layers**




Another feature that differentiates CADDs from true GISs is that there exists no attribute information associated with the different graphic elements in a CADD system. "In particular, it is difficult to link attributes in a database to specific geographical entities and then assign symbology on the basis of user defined criteria" (Cowen *et al.* 1986 in Peuquet and Marble 1990, 55). For example, a road segment drawn in a CADD system may be called or known as "Main Street," but the only way to store this information is to draw the text "Main Street" directly onto the map display somewhere next to the road segment.

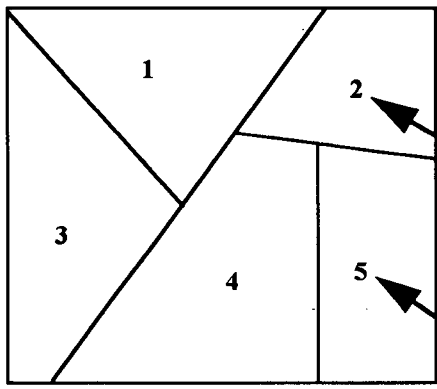
A similar problem arises when thematic information is introduced. For example, the user can shade land parcels with a particular pattern manually or arbitrarily in a CADD system. But a CADD cannot shade these areas automatically based on the values in an adjoining attribute table. In other words, a CADD cannot establish the link or connection between information about a particular feature, and the geographic feature itself. In essence, there is no way to attach characteristics that are intrinsic to map features in a CADD system. Returning to the previous example, the system is not aware that the road segment and the words "Main Street" are interconnected in any meaningful way any more than it is aware that a particular hatch pattern signifies the value of a particular variable.

#### 2.4.2.b. AM/FM systems: Automated Mapping and Facilities Management

AM/FM systems take CADDs one step further by combining automated drafting and layering capabilities with some rudimentary aspects of database functionality. AM/FM systems are most commonly used to manage data from utilities such as gas and hydro companies. Unlike CADD systems, AM/FM systems *are* capable of handling simple attribute information. Similar to a full-fledged GIS, two databases are present in an AM/FM system; a non-graphic database and a graphic database. This characteristic represents the first genuine similarity with a true GIS. The two databases are linked together by means of a unique identifier common to both databases.

**Figure 3: Linking Spatial and Attribute Information**

**Map**

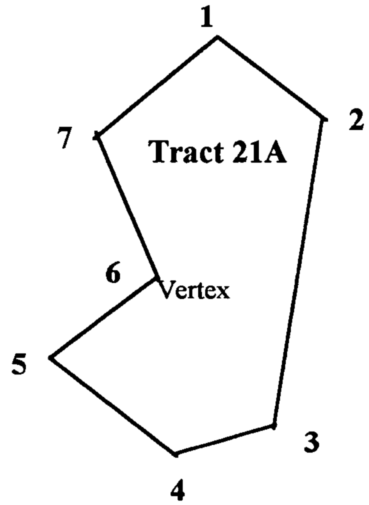



**Attribute Table**

| ID | Tract | Zoning |
|---|---|---|
| 1 | 21A | R1 |
| 2 | 2H | C2 |
| 3 | 3C | M4 |
| 4 | 7 | R1 |
| 5 | 5A | R2 |

The non-graphic database contains all the information *about* the graphic elements, their characteristics and attributes. For example, the non-graphic database describing a land parcel may contain information on its dimensions, ownership, address location, tax roll number and so on. The graphic database contains the graphic or geographic information inherent to the feature in question. In other words, it contains the specific locational information such as the co-ordinates and projection information needed to show the shapes, lines and points as the user sees them on a screen or map sheet. This twin database concept is a necessary but not a sufficient condition in meeting the requirements of a full fledged GIS. What is lacking is a concept referred to as topology. Topology relates the positions of all graphic features in a spatial database. This will be discussed in more detail in section 2.4.2.d.

**Figure 4: Geographic & Attribute Databases**




***Geographic Database Information***
Latitude-Longitude co-ordinates describing the location of each vertex and information about the shape and location of Tract 21A

| | |
|---|---|
| "Tract 21A" | 7 vertices |
| 1) 49.3424 | -122.9883 |
| 2) 49.7363 | -123.0933 |
| 3) 49.9192 | -123.0933 |
| 4) 49.8733 | -122.0873 |
| 5) 49.9823 | -123.0983 |
| 6) 49.9764 | -122.9907 |
| 7) 49.7362 | -122.9384 |
| 1) 49.3424 | -122.9883 |

***Attribute Database Information***
Information about the characteristics of Tract 21A

| Tract # | Population | Households |
|---|---|---|
| 21A | 7786 | 2390 |

2.4.2.c. Thematic Mapping Packages

Thematic mapping packages were some of the first commonly available geographic information handling systems on the market. They could be acquired for relatively little money and their capabilities were considered quite impressive. These packages display or shade geographic units automatically based on the value of a particular variable. Unlike CADDs which cannot take information from a table of attributes and transfer it symbolically over to geography, thematic mapping packages are capable of establishing this linkage.

For example, various city neighbourhoods or other spatial units such as census tracts or voting districts might be shaded differently according to the number of households, or average household income in each area; lighter shading for lower class intervals, more intense shading for higher class intervals. More sophisticated thematic packages can perform bivariate mapping where two variables can be displayed simultaneously. A bivariate map may show income level by colour, and number of households by shading intensity of a particular colour. These types of packages became extremely popular as PC-based systems because of their ease of use, simplicity, and the relatively low cost of acquiring the hardware and software needed to run them. Their application to many planning and business oriented functions can also be readily seen.

### 2.4.2.d. Geographic Information Systems

A true GIS combines the automation and layering capabilities of CADD, the attribute handling of AM/FM, thematic mapping capabilities, and adds a fourth essential element: topology. Topology is what makes the spatial analysis requirement of GIS possible. Topology is a branch of geometrical mathematics which is concerned with order, contiguity, and relative position rather than with linear dimensions and goes beyond merely describing location and geometry (Korte 1994). Topology is what differentiates GIS from all the other geographic information handling systems described above.

In a GIS, the spatial relations between all graphic data elements must be explicitly defined. Essentially, topology is concerned with the all-encompassing spatial characteristics of cartographic entities. "Topological data structures...tell the computer which cartographic objects are connected to each other logically" (Huxhold 1991, 137). Simplified spatial data structures that describe features in a CADD or an AM/FM system may include information on length, perimeter or area, along with the necessary co-ordinate data so that features can be located in space. But what is missing is information that describes the spatial relationships *between* all features. For example, a CADD or AM/FM system cannot tell which census tracts lie on either side of a road segment, or that two points on different line segments sharing the same set of co-ordinates constitute a road intersection. Rather, it views these entities in isolation from each other.

Computers cannot *see* maps the way humans do. When someone observes features on a map, the relations between the different cartographic elements are readily ascertainable. We are able to make sense of a vast array of information without realising its complexity. But a computer cannot perceive and make sense of map data in the same manner. Because of this, the spatial relationships between map elements must be made obvious or explicit. In figure 5 notice how points, lines and areas are all inter-related.

## Figure 5: Topological Data Structures

**Point Table:**

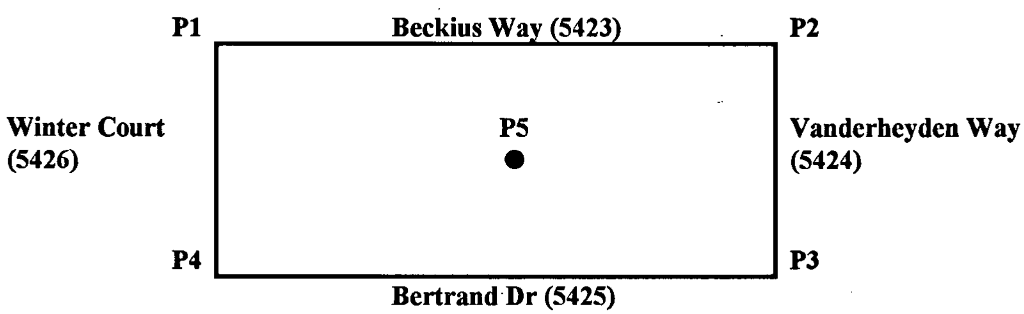
| **ID** | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| **Feature** | Intersection | Intersection | Intersection | Intersection | Block Centroid |
| **Feature Name** | Winter Ct & Beckius Way | Beckius Way & Vanderheyeden Way | Vanderheyden Way & Bertrand Dr | Bertrand Dr & Winter Ct | Block #1 |
| **x,y coordinates** | 23,25 | 35,35 | 34,24 | 23,24 | 29,29.5 |

**Line Table:**

| **ID** | 5423 | 5424 | 5425 | 5426 |
|---|---|---|---|---|
| **Feature** | Street Segment | Street Segment | Street Segment | Street Segment |
| **Feature Name** | Beckius Way | Vanderheyden Way | Bertrand Dr | Winter Ct |
| **Left Polygon** | - | - | - | - |
| **Right Polygon** | 1 | 1 | 1 | 1 |
| **Beginning Point** | P1 | P2 | P3 | P4 |
| **Ending Point** | P2 | P3 | P4 | P1 |

**Polygon Table:**

| **ID** | 1 |
|---|---|
| **Feature** | Block |
| **Feature Name** | Block #1 |
| **Centroid** | P5 |
| **Boundaries** | 5423,5424,5425,5426 |




Source: Huxhold 1991, 138-139.

## 2.5 GIS Data Models (Attribute And Spatial)

A GIS attempts to replicate geographic reality by means of a *data model*. "A data model may be defined as a general description of *specific sets of entities* and the relationships between these sets of entities" (Peuquet and Marble 1990, 252). "The purpose of any data model, relational or otherwise, is to provide a formal means of representing information and a means of manipulating such a representation" (Date 1983, in Peuquet and Marble 1990, 252).

A geographic data model is simply a way of representing the real geographic world in conceptual form. In GIS terms, two types of data are relevant, non-spatial and spatial. As already outlined above, the first type of data describes geographic entities in terms of their non-spatial characteristics or attributes. The second type describes the spatial characteristics of the entities themselves. Spatial data models are used to describe the geographic entities, while non-spatial or attribute data models are used to describe the characteristics of geographic entities.

### 2.5.1. Attribute (Non-spatial) Data Models

As outlined in section 2.2, the information contained in an attribute data model or data structure can be organised in many different ways. These vary in the structure of data files, ease of use, information sorting, and retrieval and linkage with other files in order to combine information from various sources. Three basic attribute data models will be discussed here. These are the hierarchical, network and the relational database models.

### 2.5.1.a. Hierarchical Data Structures

The hierarchical data structure represents one of the earliest forms of storing and organising data in a database management system. The main distinguishing characteristic of hierarchical file structure is the existence of more than one type of record in the database. Data items (records) and their characteristics (variables) are arranged in a hierarchical structure similar to the branches of a tree. "Lower orders of data are subordinate to higher orders as in the series: state, county, municipality, ward, block, and parcel. The hierarchy can be enlarged by adding links in the series (metropolitan areas or school districts) or, for example, by increasing the number of blocks or parcels resulting from urban expansion" (Wellar in Castle 1993, 13). This data structure is synonymous to what is often called a *one-to-many* relations because the many detail records, often referred to as *children,* can be linked ultimately to only one master or *parent* record (figure 6).

The method for retrieving and accessing data is also highly structured. Records can only be accessed by first passing through the parent, or highest order record. In other words, queries must originate with the parent record and must "proceed along a path that must be fully defined and followed for connections to be made among the links and to retrieve the desired data." (Wellar in Castle 1993, 13).

### 2.5.1.b. Network Data Structures

What distinguishes network from hierarchical data structures are the relations between the data records. Instead of a *one-to-one* relationship between data records, a *many-to-many* relationship exists. This means that multiple links can be established between records residing in several different files. Detail, or lower order records can be associated with more than one parent record. For example, a land parcel can be owned by more than one person, but a single person can also own more than one parcel (figure 7).

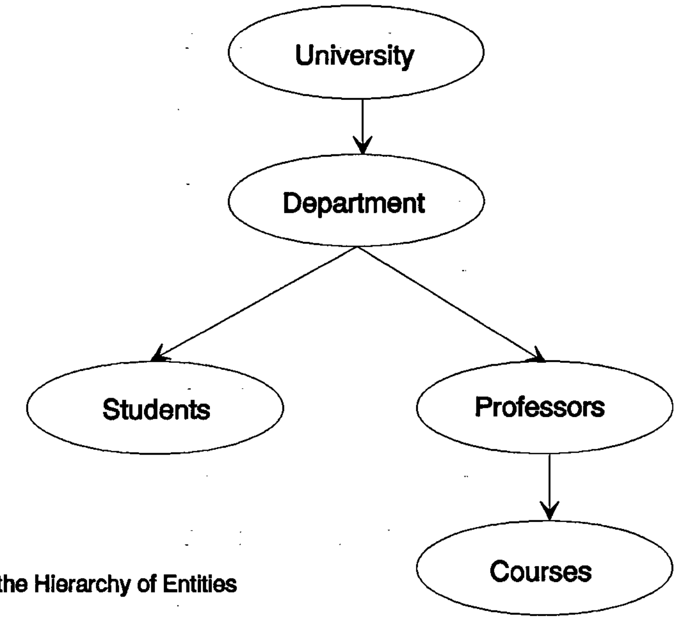
2.5.1.c. Relational Databases

The two previous data structures use database pointers to establish conceptual links between common information in several database files. As the amount of information in databases increases, the number of linkages that must be created and maintained also increases. Pointer file storage requirements can even surpass those of the database files themselves as the complexity of the relations between files increases.

The main advantage of the relational database model is that it does not use pointers to maintain links between information common to multiple databases. "This reduces the complexity of the network by allowing the logical linkages of the data values in common fields among files to form the associations" (Huxhold 1991, 44). Thus, a relational data structure consists of several *tables* or *relations* linked by information common between at least two files. The linkages are, in a sense, direct. The data items themselves provide the link instead of using pointers.

The relational structure also permits users to join tables based on data common to both files. For instance, a file of information about owners and a file of information about parcels can be combined into a single file if there is a column of data common to both files, perhaps the name of the owner (figure 8).

# Figure 6: Hierarchical Data Structure




a) Organisation of the Hierarchy of Entities

University Record

| University Name |
|---|
| University of California |

Department Record

| Dept. Name | Number of Profs. | Number of Support Staff | Number of Grad Students |
|---|---|---|---|
| Biology | 17 | 7 | 23 |

Student Record

| Student ID | Last Name | First Name | Yr | GPA |
|---|---|---|---|---|
| 692214 | Smith | John | 3 | 3.5 |

Professor Record

| Employee ID | Last Name | First Name | Teaching Years |
|---|---|---|---|
| 790 | Newman | Elaine | 5 |

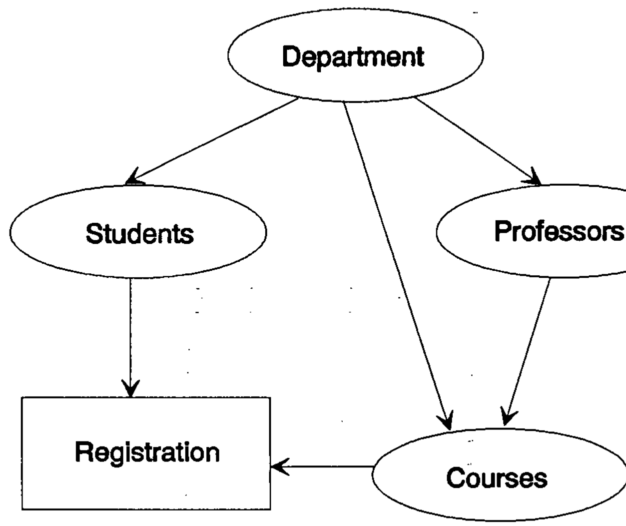
Course Record

| Course ID | Course Name | Hours/ Week |
|---|---|---|
| 12-247A | Zoology | 3 |

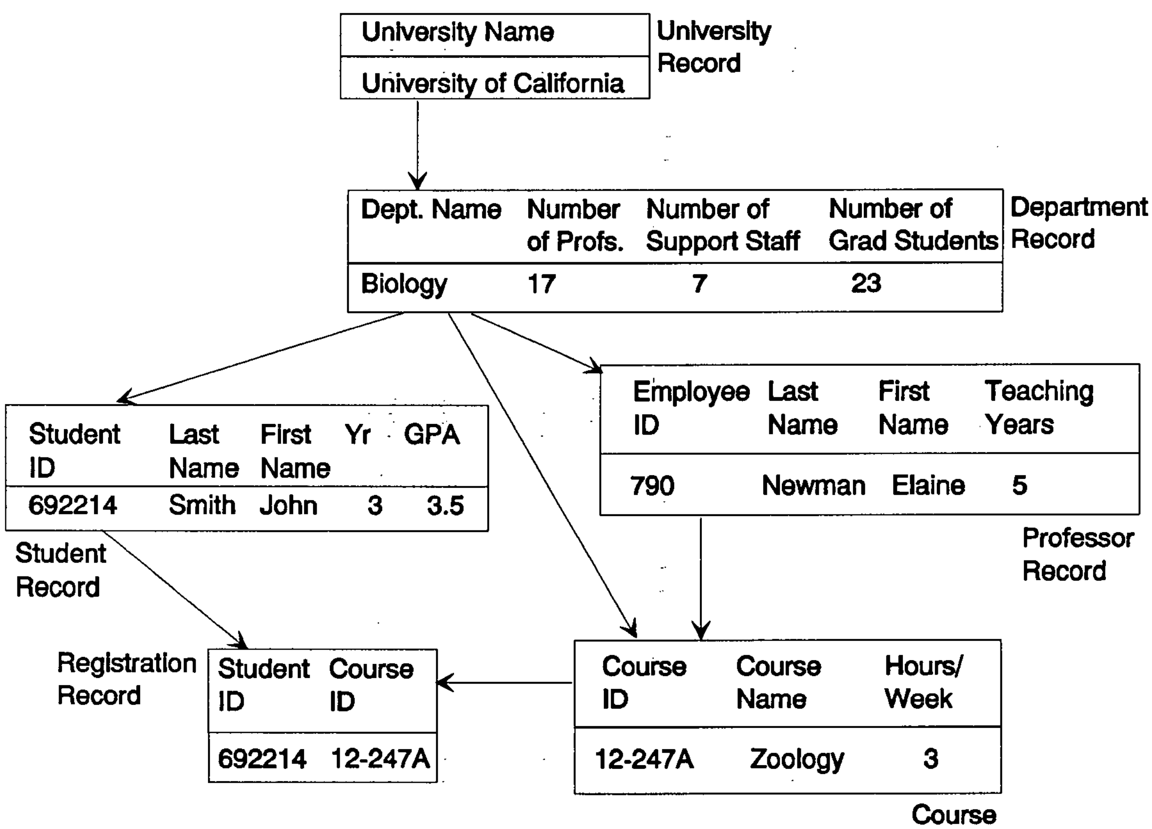
b) Organisation of the Data Records

Source: Aronoff 1989, 156.

# Figure 7: Network Data Structure




a) Organisation of the Entity Relations




b) Organisation of the Data Records

Source: Aronoff 1989, 158.

# Figure 8: Relational Data Structure

Professor Information

| Prof ID | Dept | Name | Hours | Course ID |
|---|---|---|---|---|
| 790 | Bio | Zoology | 3 | 12-247A |
| 745 | Chem | Organic | 4 | 14-200A |
| 807 | Chem | Organic | 4 | 14-200B |
| 642 | Chem | Biochem | 5 | 14-280A |
| 689 | Engl | Medieval | 3 | 17-340A |

Registration Information

| Course ID | Student ID |
|---|---|
| 12-247A | 692214 |
| 14-200B | 692214 |
| 17-340A | 692214 |
| 12-247A | 728437 |
| 17-340A | 728437 |
| 14-280A | 728437 |
| 14-200B | 745870 |

Student Information

| Student ID | Last Name | First Name | Yr | GPA | Dept |
|---|---|---|---|---|---|
| 692214 | Smith | John | 3 | 3.5 | Biology |
| 728437 | Green | John | 2 | 2.4 | English |
| 745870 | Thomas | Randy | 4 | 3.7 | Physics |

Result of a Database "Join" Operation Linking All 3 Tables

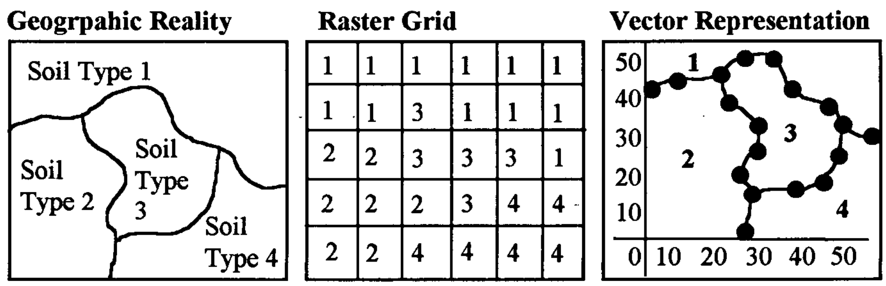
| Course ID | Course Dept | Course Name | Student Last Name | Student First Name | Student ID |
|---|---|---|---|---|---|
| 14-200B | Chem | Organic | Smith | John | 692214 |
| 14-200B | Chem | Organic | Thomas | Randy | 745870 |

Source: Aronoff 1989, 159.

### 2.5.2. Geographic (Spatial) Data Models

There are two basic approaches to the representation and organisation of spatial information. These are the raster model and the vector model. Each model lends itself to representing a certain type of geographic data. For instance *raster*, or grid cell representation, is used commonly in the analysis and interpretation of remote sensing imagery. *Vector* or point, line and polygon representation, is used more commonly in municipal planning, utilities and marketing applications.

**Figure 9: Raster vs. Vector Representation**




### 2.5.2.a. Raster Model

In the raster model, space is divided into regularly distributed cells. All information within a cell is assumed to be homogeneous and cannot be subdivided. In other words, information is "spread" over the entire surface of the cell. The finer the grid of cells, the more geographically specific the information. The larger the cell, the less detailed the information becomes. The size of the cell then defines the resolution of the analysis. If, for instance, a particular image is "divided into 10m by 10m cells, then the position of an object can only be recorded to the nearest 10m by 10m area" (Aronoff 1989, 165).

Satellite and other remote sensing imagery is almost always stored using the raster model. Cells assigned the same value are said to share the same characteristics. For example, three different types of forest cover may be coded as 1,2 or 3, with these numerals assigned to grid cells depending on the type of forest cover. When cells become quite large, the risk that the information contained within that cell becoming too heterogeneous increases. It then becomes difficult to assign values to cells without compromising detail and accuracy.

While the raster graphic data model provides for a fixed level of resolution across an entire grid cell, there do exist variations. The quadtree model, while still based on the concept of the grid cell, uses different sizes of cells depending on where more detail is required. "In this way, a higher level of resolution is provided only where it is needed" (Aronoff 1989, 169). For instance, a large homogeneous area is represented just as well with small grid cells as it is with large ones. But it is far more efficient in terms of data storage to record large homogeneous areas using a single large cell since the entire area contains little or no spatial variation. Conversely, in areas where there is increased spatial change, many smaller cells may be used to account for the increased level of detail required for accurate representation.

### 2.5.2.b. Vector Model

In the vector model the level of precision is limited not by the size or number of grid cells, but instead by the number of points used to define the precise shape of a given feature. The more points used to represent the shape, the more accurate the representation. The vector model treats geographic entities as either points, lines or polygons. Each of these concepts is defined below in the section on the functional elements of a GIS.

Compared with the cell representation used in raster coding, vector coding is far more precise. "The map area is assumed to be a continuous co-ordinate space where a position can be defined as precisely as desired. The vector model assumes that position co-ordinates are mathematically exact" (Aronoff 1989, 172). The positions of geographic features are recorded as *x,y* co-ordinate pairs. Points are represented by a single pair. Lines are represented by as many pairs as needed to define or locate any curves, bends or intersections accurately. Polygons are defined in a fashion similar to lines, only that they are defined as a closed shape or loop.

## 2.6 The Functional Elements Of A GIS

This section outlines the essential elements and functions that are basic to a GIS. As described above, a GIS combines many aspects of less sophisticated systems while using topology to clarify in an explicit manner, the exact spatial relations that exist between different cartographic features. The functional elements or characteristics of a typical GIS can be broken down into two groups or levels. The first level is characterised by the actual physical elements or the *nuts and bolts* of how a system classifies and organises information. The second level looks at a GIS as a set of tools or functions that makes use of the above elements in order to perform spatial analysis functions.

### 2.6.1. Classifying and Organising Geographic Information: Layering

In a GIS, different types of spatial information are organised into layers. A layer is simply a way of organising logically related or homogeneous geographic features in electronic form. Imagine several transparencies, each containing a different type of map feature stacked on top of each other. One can add or subtract layers and overlay them in different ways in order to view how various types of features interact spatially. In the case of municipal data, layers might contain information on sewer lines, land parcels, bus routes, fire hydrants, locations of criminal incidents or fires, rivers, census tracts and school districts, not to mention hundreds of other possible characteristics of a municipal database. By viewing different types of information simultaneously, one can uncover spatial patterns that may have been previously impossible to derive by simply inspecting a spreadsheet with only the attribute information present. Only when these spatially referenced features are displayed visually in relation to other features in the database can we begin to further investigate the spatial relations between them.

### 2.6.2. Feature Types

As outlined above, vector representation is almost always used in the treatment of municipal information. While a geographic database can contain hundreds of layers, owing to the wide diversity of objects to be considered, they can be further classified by type. All geographic information can be organised into a hierarchy of feature types. Across many layers, information can be organised into either points, lines or polygons. Point features simply indicate the location of a site or incident. Linear features are represented by a series of points linked together to form a line, while polygons are simply linear features that are closed about their ends, encompassing a defined area.

#### 2.6.2.a Points

Points represent the lowest level of feature hierarchy and can be treated as the basic building block upon which higher order features are derived. Points possess only location, and by themselves say nothing about the magnitude of the phenomena they are supposed to represent. For example, a dot on a map representing the location of a particular city may have a certain size on the actual map sheet, but its printed size should not be measured in comparison to the map scale. The data attached to a particular point may describe the size or other characteristics of that point, but in geographic reality it has zero dimensions. For example, a dot map showing the distribution of delinquent property tax locations indicates just that: locations. The size of the dot may indicate the amount in arrears to be paid, but its size only exists to demonstrate the concept of dollar amount *thematically*. Dot size cannot be measured against the map scale and compared to other features on the map sheet.

### 2.6.2.b. Lines

Lines are one dimensional features that possess length. For example, linear features could represent the location of a river, streamline, bus routes, roads, contour lines, hydro lines or any feature that has a predominantly linear characteristic. While it is true that rivers, streams and roads do possess width, which would make them two dimensional or polygonal features, lines are often chosen to represent these features. The choice depends on the objective of the mapping exercise. If the object of the exercise is to perform a hydrologic or floodplain study where stream or river width is important in measuring flow intensity, for instance, then these features should be entered in the database as two dimensional and treated as polygons. This is so because stream length as well as width is critical to the outcome of the study.

An alternative approach would be to enter stream width as an attribute in the non-graphic database. Width can then be shown in a variety of ways using the proportional or thematic mapping tools that GISs offer. These include the use of varying line widths or colours depending on the level of the variable in question.

On the other hand, if only the location or path of the feature is important, so that it can be viewed in relation to the position of other features, then a stylised representation such as a simple line segment may suffice. For example, a transit map does not need to represent bus routes using true street widths, or subway lines showing the width of the tunnel, because this type of information may be completely irrelevant to the map user.

#### 2.6.2.c. Polygons

Polygons are two dimensional features that possess both length, or perimeter (because they are closed), as well as area. Polygons can represent lakes, land mass, artificially created districts such as counties, census tracts or provinces. Lines are used to form polygon boundaries, but they must be described topologically as lines that enclose an area in order for the shape to be defined as closed.

### 2.6.3. GIS Functions and Spatial Analysis

The above concepts described the ways in which geographic information is stored and organised. The following provides a summary of the basic tools and GIS functions that are made possible given the presence of topological data structures.

One of the main features that differentiates a GIS from other software lies in its capability to perform spatial querying. Spatial querying is the process of asking questions of a spatial database. In non-spatial databases, a typical query may involve asking the database to select all records that meet a certain criteria such as "all customers that have an account balance over $12,000" for instance. This is a rather simple task that involves comparing each data record to a set value and performing a logical (true/false) test on each record in sequence.

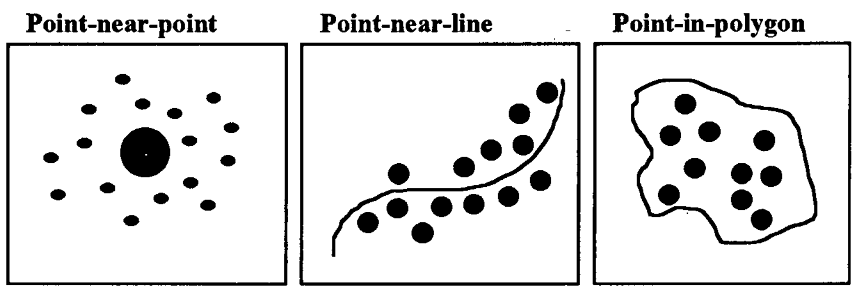
While a user can ask logical questions of a database or spreadsheet, spatial information cannot be retrieved without knowledge of where features are located in relation to each other. Let us add a spatial dimension to illustrate. A typical spatial query may ask: how many customers from The Bank of Nova Scotia fall *inside* this census tract, or how many registered voters are there within a three kilometre radius of city hall? One can also combine the two types of queries to create spatial/logical criteria. For example, locate all land parcels measuring over 2000 square feet in area, that fall within a 2 kilometre radius of the geographic centroid of the municipal dump.

There are several types of spatial queries or searches that are made possible given topological information.

### 2.6.3.a. Point Analysis

*Point-near-point* analysis is used to locate points that fall within a certain distance of a set location. For example, one may want to count the number of armed robberies within a set distance of a police station. *Point-near-line* analysis seeks to locate points that fall within a certain distance of a linear feature; for example, all residential structures within ten metres of a river bank susceptible to flooding. *Point-in-polygon* analysis is by far one of the most utilised basic spatial analysis functions. This type of spatial query locates points that fall within the bounds of a polygon. Because so much information in both the public and private sector deals with both people (points) and the areas in which they live and work (polygons), this function had a wide range of applications. For instance, one may want to locate those residences that meet a certain criteria within the bounds of a particular area and send out a notification. The city may want to locate all lot centroids that have delinquent property tax payments inside four particular census tracts, for instance. Polygons are often represented, not by a polygon, but by a geographically representative centre point or centroid instead.

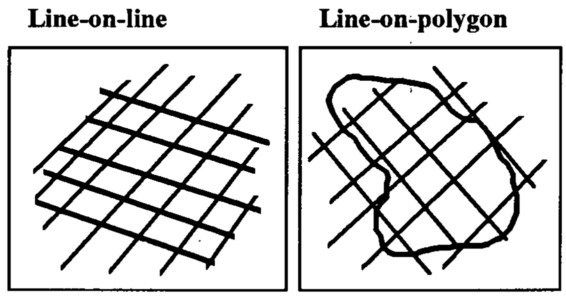
**Figure 10: GIS Analysis Functions - Points**




2.6.3.b. Line Analysis

*Line-on-line* analysis is concerned with how line segments intersect. One may want to know which streets intersect a particular arterial street or which streets meet at a given intersection. Similar to point-in-polygon analysis, *line-in/on-polygon* analysis finds lines that are inside a polygon. This function would be used to locate streets that fall within a census tract, or rivers that fall inside a specific watershed polygon.

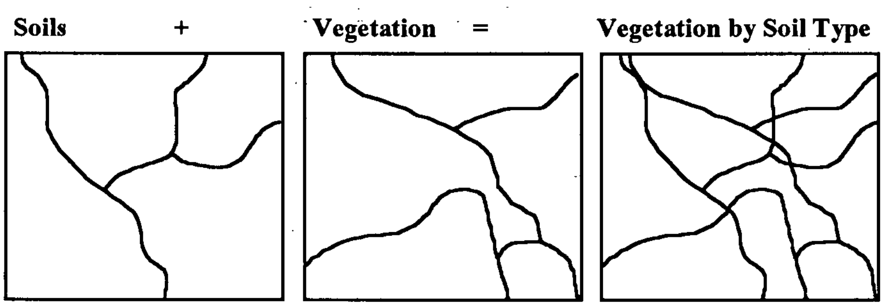
**Figure 11: GIS Analysis Functions - Lines**




2.6.3.c. Polygon Analysis

*Polygon in/on polygon* analysis is concerned with how two dimensional features intersect. This a particularly popular function, especially in the natural resource field. For example, one layer in a natural resource based GIS may contain soil polygons, while another may contain vegetation. By overlaying and then "splitting" each layer through superimposition, one can determine what kinds of vegetation is present under differing soil conditions.

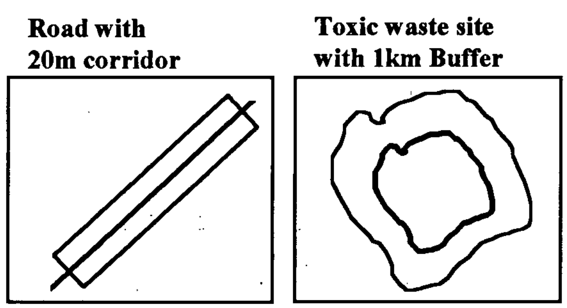
**Figure 12: Polygon Overlay Function**




2.6.3.d. Buffer and Corridor Analysis

Buffers and corridors are polygon features that are created around either points, lines or polygons. They are used in special types of spatial queries where one wishes to select or perform calculations on features inside a particular geographic field of influence. For instance, a point buffer takes the form of a circle, where the point represents the centroid of the buffer. Each point along the circumference of the buffer is located an equal distance from the centre. Circular buffers may represent the extent of a radio transmission range, or the trade area of a supermarket. Buffers are most commonly used in point-in-polygon analysis in order to select smaller polygons or point features that fall within the sphere of influence of a central point. A linear buffer zone is conventionally called a corridor. A corridor could represent a high risk area surrounding a damaged gas line or a flood zone around a rising river. Polygon buffers can be thought of as polygons that have roughly the same shape as the figure on which they are based only that the buffer feature is larger in area and has a smoother outline.

**Figure 13: Corridors and Buffers**




## 2.7 Chapter Summary

This chapter has covered a wide variety of subjects: an introduction to the history of GIS, the role of GIS in planning, definitions of implementation, as well as a significant amount of technical background.

GISs have evolved from being accessible only to those with highly sophisticated equipment, technical expertise and financial resources, to tools that are used by a diversity of professionals in an ever growing number of application areas. The dramatic decrease in the cost of acquiring GIS technology over the past 25 years is certainly a contributing factor in its diffusion.

The planning profession is one domain where the application of GIS technology can be beneficial. The spatial nature of planning research and inquiry lends itself well to analysis undertaken using GIS. This is true, but only up to a point. The planning field and GIS technology have not always been well-matched. To clarify, the concrete and dichotomous world of GIS often finds itself at odds with the more subjective and haphazard realm of the planning process. Still, GIS can play an effective role in the information processing, spatial analysis and decision support tasks of planning.

With reference to technical background, which formed the bulk of this chapter, the summaries on GIS components and functions described some of the many questions that can be asked of a spatially-referenced database. From these simple descriptions one can readily begin to ascertain how easy it becomes to perform searches that may have been unthinkable beforehand, given the amount of time and effort needed to manually process the geographic dimension of information. Chapter 3 will outline why and how municipalities use GIS, given the tools described above.

# 3.0 GEOGRAPHIC INFORMATION IN A MUNICIPAL CONTEXT

The great majority of data housed in municipal governments is geo-referenced. This means that the data possess characteristics that tie them to specific locations in space. For example, information dealing with land parcels and taxation, emergency service provision, demographic and health data, transportation and utilities, all have a geographic element about them.

This chapter will look at some of the different types of geographic data that are used in building a database, justification for collecting the data, and how these data are used in various GIS applications. How GIS can sometimes be misapplied, misused, or abused will also be discussed.

## 3.1 GIS In Municipal Government

Worall (1991) remarks that interest in the new opportunities that arise from spatial information are quite recent. This lack of attention existed despite the fact that geographic data has always represented an integral part of a municipality's arsenal of information resources.

Studies have shown that spatially referenced information is of fundamental importance to government. For instance, "not only is 80% of the information used in local government in the UK spatial, but 80% of that information is of direct use to other governmental organisations and utility companies" (Worall 1991, 1). "Outside of financial accounting and purchasing information systems, it is difficult to think of urban information systems that *do not* process data that are location-related" (Huxhold 1991, 22).

Huxhold also makes reference to two additional examples that stress the importance of spatial data to municipal governments. A committee organised by Wisconsin governor Tony Earl, during the years 1985-1987, was charged with studying local, county, state and private land-related information needs in Wisconsin. Their findings indicated that "of all information collected and maintained by all levels of government, the percentage that is land-related is so large that it is difficult to imagine a data set whose value would not be enhanced by a geographic or locational reference" (Wisconsin Land Records Committee in Huxhold 1991, 22).

Huxhold's second example refers to a brochure released in 1986 by the Municipality of Burnaby, British Columbia. "It reported the results of a needs analysis for an urban geographic information system in that municipality: eighty to ninety percent of all the information collected and used was related to geography" (Municipality of Burnaby in Huxhold 1991, 23).

The above statements may lead one to believe that municipal government is a prime candidate for the adoption and use of a GIS. After all, with this wealth of spatially referenced information, would a system that allows one to use and analyse this information in a more efficient manner not be a welcome addition?

Though computer use is now rather commonplace in municipal planning, Aronoff (1991) points out that the rate of take up of GISs by municipalities has been rather slow. Worall (1991,1-2) similarly points out that "while substantial progress has been made in the development of GIS hardware and software...the pace of development of information systems and the integration of information systems has not been as rapid." Why is this so? Often, the monetary and non-monetary costs associated with administrative changes that occur as a result of GIS implementation are so great that GIS projects get sidelined. Still, many municipalities have adopted systems, some successfully and some unsuccessfully.

Regardless of subsequent success or failure, the reasons why municipalities have considered the adoption of a GIS are numerous. While the list below outlines many of the perceived benefits of adopting a GIS, some of these same benefits may also have possible negative consequences, as noted.

- A more integrated approach to computerised data, and to geo-referenced data, specifically.
- The reduction in redundancy and duplication of maps and tabular data that can be shared among departments through access to a centralised database. This can also cause conflict because of disagreements over which individuals/departments control or even have access to the centralised database, including certain critical layers.
- Ease of updating map and tabular information which may have existed in multiple locations previously.
- The ability to perform sophisticated spatial analysis and querying functions too tedious and time-consuming to perform manually. The relative ease of automated database querying opens up a whole new area where abuse of information becomes possible.
- The ability to display municipal data cartographically in order to establish spatial patterns. Spatial and descriptive data are now linked, making forward/backward data display possible.
- Standardisation and consistency of data.
- Charges for new products or services, including public access to GIS data for residents or businesses, bring in new revenues.
- The ability to provide a greater array of information products to decision makers. With these new methods of querying, displaying, and adding value to information, we must ask whether *more* information is necessarily *better* information (Public Technology Inc. 1991, 8).

The subject of whether more information is better information is really a case of context. For instance, under what conditions was the information collected and analysed, and what conclusions were drawn from the analysis? Regardless of the amount of information collected or produced, incorrect conclusions can still be drawn as the result of erroneous analysis conducted by unskilled users of geographic information. More information is only of benefit if the users of that information know how to make proper use of it, and the technological tools used in the process.

### 3.2 THE COLLECTION OF GEOGRAPHIC DATA AND ITS JUSTIFICATION

As stated earlier, the data held in municipal databases, whether in electronic or in paper format, contains information that can be expressed cartographically. This adds an incredible amount of value to the information possessed by municipalities. The following two tables indicate the types of information collected and contained in a typical GIS. Table 2 is adapted from an 1986 ESRI (Environmental Systems Research Institute) study of a proposed GIS for San Diego. Table 3 is a list of the map layers contained in the City of Victoria's GIS.

**Table 2: Data Sets Typically Held in a Municipal GIS**

| Data Category | Example Map Layers |
|---|---|
| **Area Data** | Demographic Areas<br>Tax Rate Areas<br>School Districts<br>Emergency Service Areas |
| **Base Map Data** | Control Points<br>Topographic Contours<br>Building Footprints |
| **Environmental Data** | Soils Map<br>Floodplain Map<br>Noise Level Map<br>Streams and Waterbodies |
| **Land Records Data** | Lot Boundaries<br>Land Parcel Boundaries<br>Easements and Right-of-Ways |
| **Network Facilities Data** | Sewer System<br>Electrical Cabling<br>Telecommunications |
| **Street Network Data** | Road Centrelines<br>Road Intersections<br>Street Lights<br>Street Trees |

(Adapted from ESRI 1986, in Aronoff 1989).

**Table 3: City of Victoria Map Layers**

| Layer Group | Description | # of Layers |
|---|---|---|
| Municipal Boundary | To define City Limits | 2 |
| Property Lines-final | Final Cadastral Product | 20 |
| Property Lines-construction | Temporary Cadastral for projects | 6 |
| Survey Control | Integrated Survey Area Control Monuments | 2 |
| Highways | Curbs, sidewalks, roads, paint lines | 9 |
| Utilities-municipal | Sewer, drain, water, lighting, signals-above & below ground, telecommunications, gas electric, cable TV, | 39 |
| Geographic | Contours, rock outcrops, banks, shoreline | 3 |
| Miscellaneous | Retaining walls, fences, ponds, etc. | 3 |
| Trees | Trees and foliage in public areas | 1 |
| Buildings | Building roofs & walls | 4 |

(Adapted from Mallett and Paterson 1992, 4)

The types of data held in municipal databases are quite varied, as both tables indicate. As diverse are the types of data collected are the reasons for collection in the first place. The justification for the collection of geographic information varies from agency to agency. This justification also depends largely on whether the agency is involved in the private or public sector. Aronoff (1989) makes the following distinction between the justifications used by both types of agencies.

In the private sector, cost-benefit analysis almost always enters into the equation. This is because the financial bottom line in the private sector often differs from that of a public agency. For private industry, information is a commodity like any other product that is bought and sold. On the other hand, municipalities and other public agencies treat geographic information as a social commodity. In fact, in many jurisdictions, GIS implementation programs are actually legislated and mandated. "There is a trend for government agencies to be required to provide more accurate, more detailed, and more current geographic information" (Aronoff 1989, 261). As a result, one of the only ways public information provision requirements can be satisfied is through the adoption of the tools that GIS can offer. This may help to explain why cost-benefit arguments often play a less significant role in GIS acquisition plans for municipal government.

## 3.3 Applications, Misapplications & Ethical Issues in the Use of GIS Technology (Use, Misuse and Abuse)

This section will place the uses of GIS on a continuum: how GIS can be applied, misapplied, and in extreme cases, abused.

Many tasks performed manually by municipal government employees can be automated in some way by the adoption of GIS technology. Still, there may be other tasks that do not merit the time, effort or financial sacrifice. While GIS can certainly help automate or quicken many procedures such as manual searches and look-ups, there may be others that are just as well left alone. This is often the case where the municipality is so small that automating every procedure tends to be excessive.

Quite commonly, GIS is sold as the prime solution to many municipal planning challenges. "GIS is a highly attractive technology and suffers from the problems of all such technologies. It has been wrongly sold as a solution in response to needs which were poorly defined or not defined at all, and to clients who did not really understand its capabilities or limitations" (Tomlinson in Peuquet and Marble 1991, 156).

> A GIS is not a panacea, and the *GIS solution* should be evaluated carefully to see whether it forms part of the jurisdiction's long-term goals and overall information master plan. A GIS should help to manage the collection and flow of information, to improve decision making and operations on a daily and long-term basis. Although it can be an extremely important part of government planning and problem solving, it is not the total solution to managing either information or infrastructure. Implementing a GIS does not automatically create better decisions or organisational harmony (Public Technology Inc. 1991, 17).

At one end of the continuum are GIS *applications*. These can be defined as the positive or *ethical* uses to which a GIS is put. While the GIS itself is merely a technical tool, applications represent the different ways GIS can be put to work. Examples include automating manual records searches, thematic mapping, point or incident mapping, and geographic searches. In other words, applications are some of the ways GIS can be used in a positive way to help planners do their jobs more efficiently and effectively.

In the middle of the use continuum are GIS misapplications. Misapplications can also be classified into two categories. The first and more general category concerns the use of technology to solve problems that can often be solved as efficiently using manual methods: for example, using GIS to solve a problem that may not require a GIS at all. The second category deals more specifically with how GIS tools are improperly implemented, used, or how resulting information products can be misinterpreted. The old adage: *garbage in-garbage out* definitely applies in these types of cases. In some instances an organisation may decide to implement and adopt a GIS and then end up not making use of it. Sometimes GIS is also used as a solution to a problem for which it was never intended (Obermeyer and Pinto 1994).

At the extreme end of the continuum are the unethical uses to which GIS is sometimes put. Abuses or unethical uses can be defined as those that do not necessarily have a positive or honourable purpose. This is not to say that zoning, or property searches are *honourable* or intentionally *ethical* uses. It is to say that the end to performing these tasks does not necessarily entail breaking the law, infringing on the privacy rights of individuals, or stirring up controversy. For instance, new centralised methods of record keeping permit the collection and maintenance of massive amounts of personal information in electronic files. Access to information is made easier for those few powerful and skilled individuals who have access to it. These same people hold the enormous responsibility for maintaining the privacy of those individuals' personal records.

### 3.3.1 APPLICATIONS

According to Levine and Landis (1989, 210-11), GIS applications for municipal planning can be separated into three broad categories; *forward data mapping, backward data capture* and *interactive data modelling*. Below is a table summarising their classification:

**Table 4: Planning Applications of GIS**

| Major Functions | Sub-Applications | Descriptions |
|---|---|---|
| **[1] Forward Data Mapping** *This application stresses graphic data display for symbolic representation purposes.* | a) Data Display | - Symbolic representation of objects/events using thematic or point/pin maps to enhance reports and presentations.<br>- Also used to aid in human analysis of the spatial distribution of socio-economic phenomena. |
| **[2] Backward Data Capture** *This application uses information already in the system, or information input on an ongoing basis for criteria-based searches.* | a) Land Info Storage/Retrieval | - Used as a filing and updating system for geo. information (ownership, uses, assessment).<br>- Perform queries (searches) on parcels. |
| | b) District/Zone Management | - Maintain and update zoning info. |
| | c) Notification | - Determine parcels affected using proximity analysis and send out notices. |
| | d) Permit tracking/Growth Management | - Ongoing analysis of parcel development and permit status |
| **[3] Interactive Data Modelling** *This application is used for "what-if?"- type scenario analysis. Different scenarios are modelled using different inputs in order to predict various possible outcomes.* | a) Site Selection | - Selection criteria (graphic and/or tabular) set up in order to identify potential sites. |
| | b) Environmental Impact Assessment | - Identify impacts that are influenced by geographic location: flooding, noise, toxic waste dumps, etc. |
| | c) Development/land suitability modelling | - Using indices derived from many factors (soil condition, drainage, slopes) rank sites for development suitability. |

(Adapted from Levine and Landis 1989).

Levine and Landis (1989) classified applications based on the way GIS data is used and modelled (table 4). Each level in the table describes GIS capabilities and functions that become progressively more complex and sophisticated as one moves through the three levels.

Public Technology Inc. (1991) also breaks GIS applications down into a hierarchy, based on the associated costs of performing analysis at each level of detail.

> The uses to which a GIS are put are called "applications," and occur on three levels: wide-area planning; dispatching and locational analysis; and facilities management, tax mapping, and engineering design. Wide-area planning usually involves small data systems oriented toward census tracts, traffic zones, or neighbourhoods, at a cost of under $10 000. Dispatching and locational analysis require larger amounts of data and greater detail. The cost of this type of system varies according to the volume of data. The third-level GIS requires even greater detail and is much more expensive (Public Technology Inc. 1991, 8).

Although the above examples do mention some concrete GIS application areas, they could be considered more as taxonomies. They use a framework to classify applications into different categories based on a set of given criteria. In other words, they stress the type of classification tools used instead of concentrating on describing the applications themselves. The following is a more detailed discussion of application areas independent of classification scheme.

Huxhold (1991, 65-74), for instance, devotes considerable space to outlining the many areas where GIS can be applied to real-world planning tasks. These include: map updating and zoning changes, reapportionment of electoral districts, facility inspection and workload balancing, waste collection routing, housing and health policy, licenses, and library or other public facilities planning.

*Mapping*

Land use and zoning map updating becomes necessary when legal descriptions of properties undergo changes, when new subdivisions are created, when physical changes to streets such as widening are undertaken, when parcels are rezoned, or when an annexation takes place. Because these changes may occur at different times and under different situations, manual updating each time a change takes place can be quite tedious, labour intensive and time consuming. The combination of the sheer number and variety of map types maintained by a municipality coupled with the frequency of changes can greatly affect the amount of manual work that is necessary. The number of duplicate map sheets maintained by many municipal departments also highlights potential problems with map consistency.

The availability of a digital land base eliminates the need to completely redraw erroneous or outdated map sheets. Changes need only be made where required. Redundancy in the recording of identical information across different departments can also be alleviated by recording shared data once for all parties concerned. While this is a good theoretical solution to the problem of information redundancy, its effectiveness in a practical sense remains to be seen. This is so because of the conflicts that can develop as a result of centralised information control by a single department or even a single individual.

*Reapportionment, Redistricting and Workload Balancing*

Reapportionment is the process of redrawing electoral boundaries in order to achieve districts that contain relatively equal populations. This is largely a trial-and-error *or what-if* type of analysis because there are virtually hundreds of ways to carve up a city into roughly balanced districts. Performing this task manually would again require a significant investment in time.

Reapportionment or redistricting GIS software is designed to perform these types of *what-if* scenarios, providing different solutions to varying redistricting permutations.

Workload balancing is a similar application that uses redistricting. Application areas include garbage collection routes, building inspection, permit and licensing territories. In these cases, district updating is required on an ongoing basis. This is because the volume of changes in the domain of physical infrastructure occur at a more rapid pace. For instance, Huxhold (1991) cites an example where the number of buildings to be inspected in one district changed so dramatically that a particular inspector had three times as many inspections to conduct as another.

*Housing*

In terms of housing policy, the example of Milwaukee's *dirty-dozen* list is a relevant instance of a GIS being used to analyse and keep track of trends in building code violations and delinquent property tax payments. This project was undertaken in order to combat continued neighbourhood decay. "Since 1985, one alderman has led a crusade against the top building code violators in the city" (Huxhold 1991, 95). Using the municipal GIS, locations of boarded-up buildings or those which were in dire need of renovation were located. These locations were then matched to ownership records, identifying the delinquent owners. Patterns were quickly established relating to repeat offences, offenders, and to the geographic concentration of properties with multiple violations.

*Licensing and Permit Tracking*

Deciding where to approve new liquor licenses was also an application area where a municipal GIS was helpful. The review and approval of tavern licenses can be a potentially sensitive area for municipal politicians. This is especially the case where a district already contains many establishments. Before approving licenses, a visual inspection of the distribution of already existing taverns may help, but a quantitative analysis of the density of establishments can only be provided by some of the point-in-polygon processing capabilities of a GIS (Huxhold 1991).

Density calculations can be derived for any level of geography: aldermanic districts, square mile grids, census tracts or whatever level of analysis is required to come up with a fair approval decision. Evidently there are other variables involved in approving liquor licenses, such as availability of parking, previous problems relating to disturbances and noise. These characteristics can also be attached to the tavern location database for further spatial analysis.

*Public Facility Location*

Locating public facilities such as swimming pools, recreation centres, schools and libraries, requires an up to date picture of population growth trends in the neighbourhoods concerned. Assuming that the municipal GIS is kept current, it can help to assess the need for additional facilities. For instance, knowledge of the minimum population serviced by a library can help determine if additional facilities are required. Using buffer analysis to measure population counts within a reasonable radius of existing facilities can help officials decide if existing population centres are being adequately served and if new facilities are required.

### 3.3.2 MISAPPLICATIONS

In the introduction to this chapter a distinction was drawn between the two types of misapplication areas: general misapplication of GIS technology to the entire work process (deciding to implement an unneeded GIS), and the inadvertent misuse of the technology once it has been implemented (using an already implemented GIS in the wrong fashion). This section will discuss these two interpretations of GIS misapplications. Theoretical background as well as some concrete examples will be provided.

While GIS technology is used for many applications, there do exist cases where the expenditure in time and money does not justify its adoption. Often, this is merely an issue of scale. For many smaller municipalities with a more modest population and land base, a PC-based GIS may be ideal since the amount of information to be input into the system is minimal and manageable. Even the use of networked GIS workstations, which are quite commonplace, may be overstepping the bounds of what is realistic and necessary.

In fact, many municipalities commit the error of being sold on a system with *bells and whistles* that are seldom if never needed. A combination of overzealous marketers and naive municipal officials failing to do their homework has often resulted in monumental GIS projects that either never get off the ground, get sidelined, or suffer from major setbacks. Often, a significant proportion of the funds allocated to a GIS implementation program are devoted toward hardware, leaving little or no financial resources left for training or data conversion.

While GIS could very well represent the wrong solution to a particular planning problem, there are cases where GIS may prove to be a viable route to take, but it is applied in the wrong fashion, or utilised to solve problems for which it was never intended. Unfortunately, few GIS managers or those responsible for implementation or operation of GIS would be willing to admit that their system was misapplied to a particular problem, that it failed to operate as planned, or that the wrong kind of system was purchased for a particular type of task. Trade shows, conferences and other events for the planning and/or GIS community stress the successful applications and certainly not those that had gone wrong. This emphasis comes with no surprise as the following two examples point out:

> Some of the published case-study research involves the reporting of the GIS implementation process by a single individual (usually the manager responsible for the implementation). Obviously, there is a strong temptation for these individuals to report the implementation experiences in the best possible light, even if they are somewhat inaccurate (Obermeyer and Pinto 1994, 21).
>
> Successful institutionalisation of large-scale computing agencies has been the exception rather than the rule, as managers of the systems amply testify in conference presentations and informal discussion. These failures are very little documented or explained, however. System managers understandably prefer to publish success stories (Innes and Simpson undated, 1-2).

The above helps to explain the relative difficulty in finding examples of documented misapplications of GIS technology. While written evidence of GIS misapplications is rare, there are theoretical attempts at classifying the differing conditions that would have to exist in order for a misapplication of GIS technology to occur. Schultz, Slevin and Pinto (1987) have developed a matrix that classifies implementation **strategies** (planning or initiation activities) and **tactics** (action or implementation-oriented efforts) into four quadrants (figure 14). These quadrants represent the four different combinations of low/high effectiveness in terms of planning strategy/tactical action.

*Strategy* refers to the processes that take place before implementation. These can be thought of as planning for the implementation, or devising how the implementation process is to take place. *Tactics*, on the other hand, refers to the implementation process itself and whether its results were successful in terms of user acceptance of the system.

**Figure 14: Strategy/tactics effectiveness matrix**

| Effectiveness of Tactics | | Low | High |
|---|---|---|---|
| | **High** | **Quadrant IV**<br>Probability of Type II and Type III errors<br>High Acceptance, misuse | **Quadrant I**<br>High probability of implementation success |
| | **Low** | **Quadrant III**<br>High probability of implementation failure | **Quadrant II**<br>Probability of Type I and Type IV errors<br>Low acceptance, low use |

**Effectiveness of Strategy**

(Adapted from Schultz, Slevin and Pinto 1987).

In order to more fully comprehend situations where the quality of strategy and tactics are not consistent (hi/low or low/hi), an understanding of the different types of strategic implementation errors, or pitfalls, may be helpful. To summarise briefly, the four basic types of implementation errors are:

- Type I: Action should have been taken, but was not
- Type II: Taking an action when none should have been taken
- Type III: Taking the wrong action (solving the wrong problem) - similar to type II
- Type IV: A solution is discovered, but it is not used - similar to type I

In quadrant 1 (top right), implementation efforts are successful given an effective set of planning strategies. Quadrant 3 (bottom left), representing the inverse of quadrant 1, indicates low effectiveness in both planning strategy and tactical implementation. Implementation efforts would be expected to fail in this case. The situations in the remaining two quadrants are unfortunately not as cut-and-dry.

In quadrant 4 (top left), type II and III errors would be quite common. In the case of Type II error, "a poorly conceived or unnecessary system that has received no initial buy-in from potential users, may not be needed or will not be used" (Obermeyer and Pinto 1994, 32).

Type III error, on the other hand can be characterised by a system that has been adopted and accepted, but the wrong action has been taken in attempting to solve a problem. A need has been identified, but owing to a badly performed strategic sequence, the wrong problem was isolated and the subsequently implemented GIS has little value in that it does not address the target for which it was intended (Obermeyer and Pinto 1994).

Quadrant 2 (bottom right) represents effective planning strategies with good intentions, but subsequent tactical action is either not effective or even non-existent. Type I and IV errors are common here. These include not taking an action when it has been determined that action is needed, or simply not using the new system. Low user acceptance is characteristic here, as any attempt to match the system to the needs of the organisation inevitably fails (Obermeyer and Pinto 1994).

The above quadrant scheme represents a general classification of the different ways GIS technology can be applied or misapplied. There are, however, specific ways in which the technology can be unintentionally misused or its output misinterpreted. The following is a discussion of specific examples of GIS misapplications. But before embarking on any further discussion, an important distinction must be drawn between the unintentional misapplication of GIS tools and intentional misuse or abuse.

The unintentional variety of misuse often arises from the sheer incompetence of the user. Examples include ignorance of geographic theories and fallacies and a failure to understand the art and science of proper map production and map interpretation. The intentional variety of misuse, to be discussed in the next section of this chapter, is usually committed by skilled individuals with specific political agendas. These individuals know how to manipulate geographic information to their advantage. They also posses the knowledge required to operate the technological tools that can facilitate access to a vast array of spatial and non-spatial information products.

These tools also enable one to combine spatial information in ways unheard of in the past. By combining diverse data sets, new conclusions can be drawn and new patterns established. Still, not all conclusions may be error-free. While GIS creates the opportunity to gain access to a wider variety of data, it also increases the probability of drowning in it. This can lead to improper processing, combining, and misrepresentation of the data.

Some specific examples of geographic information misrepresentation include *ecological fallacy, the modifiable areal unit problem* and *absolute versus relative measures of magnitude*. An ecological fallacy is encountered when assumptions are made about data at a more detailed level when only data at a less detailed level is available. For instance, one cannot fairly draw conclusions about each individual inside a census tract based solely on average data used to describe that census tract. The converse is also true, where conclusions cannot be drawn about groups characteristics based solely on knowledge about individual behaviour.

Similar to ecological fallacy, the modifiable areal unit problem also occurs when looking at variables at different geographic scales. In this case, carving up a territory into two different types of districts (census tracts versus postal areas, for instance) may produce differing relations between the variables examined. Monmonier (1993) provides an entire chapter on this type of mapping fallacy. One hypothetical example involved the correlation between the number of children per household and the number of televisions per household. By analysing the data at different scales, markedly different patterns emerged. Similar differences occurred when looking simply at the number of televisions per household, when town-level data was aggregated to the county level.

Finally, using absolute instead of relative measures (or vice versa) can be quite deceptive. Saying that a certain census tract is responsible for the largest sales volume may be fair, but if that tract also has the highest population, the expenditure per unit of population can shrink considerably. The figures can be misleading if absolute and relative measures of the same phenomenon are examined in isolation from each other.

Finally, GIS can be misapplied by inputting and using information that is erroneous or incomplete right from the outset. For instance, certain variables already resident inside a municipality's database may be used to conduct an analysis, even though that set of variables may not be entirely appropriate. Most projects are subject to financial constraints as well as time lines. This makes the collection of accurate and timely data all the more difficult. "Thus the tendency is for agencies to use whatever information is currently on file regardless of its quality. The information may not be up to date, or the most suitable for the project. The accuracy of the data may also be insufficient" (Madziya 1990, 312).

### 3.3.3 Ethical Issues and the Potential Abuses of GIS

One of the more controversial issues arising as a result of the emergence of GIS on the municipal planning scene is the issue of responsibility. "The mere conversion of information to digital form can have dramatic implications" (Aronoff 1989, 250). What Aronoff is attempting to convey is that information stored in paper files cannot be searched as rapidly and efficiently as can be done with electronic files and a database management system. Not only are searches faster in the generic sense, but complex criteria-based searches are now considered quite commonplace.

This enables the selection and analysis of records, properties or individuals with distinct characteristics. This coveted information is desired by all sorts of enterprises: direct marketers, appraisers, lawyers, a variety of salespeople and real estate companies, to name but a few. The fact that more complex queries can be conducted more rapidly is not the ethical issue. What is done with the information by these organisations certainly is.

Aronoff (1989) cites four extremely topical and relevant examples of how the new storage and retrieval mechanisms made possible through GIS require us to rethink some very important issues related to responsibility:

- Data security
- Individual confidentiality
- Public access to information
- Accuracy of context

Aronoff's first example highlights the issues of the public's right to information as well as individual confidentiality. A New Hampshire university economics professor wished to acquire a tape containing information on 35 000 city properties in order to conduct a tax study. While the city argued that the acquisition of the tape represented a threat to the confidentiality of every citizen on file, the State Supreme Court ruled that the information was not confidential because the same information could be gathered from a simple visual inspection of each property.

What the Supreme Court did not take into consideration was that records in digital format could be used to generate information on property owners that would be completely impractical to determine otherwise. Whereas a search to find the top ten largest property owners would prove to be unrealistic using a manual search, a computerised search would be fast and inexpensive (Aronoff 1989).

In a second case, Aronoff tells of a somewhat shabbily dressed man who appeared at a zoning counter of a municipality and demanded a list of the names and addresses of all single women living in a specific area of the city. After claiming to be doing some sort of research, the clerk promptly generated the list using the GISs geographic querying functions. As the clerk was about to hand out the listing, his supervisor came by interested to know how the system was being used. After looking at the report *and the customer*, the supervisor decided to veto the release of the information. The supervisor felt that the customer would use this information inappropriately--to target these women (Aronoff 1989).

The third example demonstrates how the production of a simple map dealing with a seemingly non-controversial issue evolved into much more serious case. A GIS manager in a municipality decided to produce a simple map in order to show some of the capabilities of the newly acquired system. The map showed the distribution of a potentially vicious breed of dogs.

The information was simply imported from the dog license file. When the distribution of these licenses was mapped, it was discovered that a few areas of the city contained an unusually high density of potentially vicious dogs.

> While the results were interesting and potentially useful, the manager recognised that the map was potentially damaging to the landowners in these areas. If this information were made public, the desirability of these areas might be reduced, causing a fall in property values. As a result, the information was deemed to be confidential (Aronoff 1989, 269).

Aronoff's next example takes the issue of sensitive information one step further. This fourth case is concerned more with the presentation of sensitive information that may be open to misinterpretation in addition to issues of overt abuse. Accuracy of context refers to the accuracy of new information that is created when data from two sources are overlain. Although Aronoff's example is hypothetical, unlike the previous three, it demonstrates how the information on a simple map can be made to mislead the reader or cause him or her to reach an unwanted or incorrect conclusion.

Consider a map showing the locations of three PCB sites, and the locations of three schools, which appear to be quite close to these PCB sites. If one were to take a closer look at the map scale, then one would realise that the schools and PCB sites were actually separated by about 70 kilometres. The point Aronoff is trying to make in using this example is not that geographic information must be presented at an appropriate scale, but that if the information is presented in such a way that the user could reasonably draw an incorrect conclusion, then the information product should be seriously re-evaluated (Aronoff 1989).

There are many other ways to "lie with maps" (Monmonier 1993), misuse or *twist* information in map form. Make no mistake--such "errors" are not always as unintentional. Many competing groups within organisations have varying political agendas, and will often skew information to further their cause.

The act of retrieving information by means of a GIS is not unethical in itself. GIS only facilitates or increases the potential for committing activities that may be unethical or for uncovering spatial patterns that may cause controversy. As in the case of the dot distribution map of vicious dogs, a fair amount of soul searching must have had to take place before deciding whether to release such information. In the case of the questionable individual asking for the list of women's names, the decision was probably a lot easier.

## 3.4 Chapter Summary

This chapter covered a diversity of issues concerned with the information collected and used by municipalities; what is collected, how it is used, applied, misapplied and even misused.

The capability to store and retrieve a vast array of data with relative ease holds enormous implications for issues of privacy, confidentiality and the proper utilisation of such powerful systems. Still, GISs are only as powerful and effective as the individuals who use them. And depending on the user, effectiveness can be construed in either ethical or unethical terms. Whether GISs will be used to do good or bad, or to simply stir up controversy, will be determined by the individual user's level of competence, political agenda and his or her position within the organisational hierarchy.

## 4.0 IMPLEMENTATION: THE GIS ROAD BEGINS

"Ultimately, the success of a GIS site will depend on the people who implement it" (Aronoff 1989, 265).

While technical considerations are critical to the implementation process of any GIS, it is truly the organisational structure, attitudes, commitment of management and staff, and financial backing that will determine whether the process is a successful one. Above all, managing organisational change in response to technical changes is one of the greatest challenges to the process. This chapter will explore some of the procedures and methods followed when implementing a GIS, and examine why human factors are critical in its success.

### 4.1 GENERIC STEPS IN IMPLEMENTING A GIS

Studies conducted by many authors and across several municipalities have identified several generic implementation steps (Public Technology 1991, Aronoff 1989, Flagg 1993, Ballard 1993, Korte 1994). A summary of these generic steps will be outlined in this section.

One would usually start the implementation process by initiating awareness and interest in acquiring a system based on a perceived need. Next, carrying out a user needs assessment identifies application areas for GIS data and classifies existing resources such as paper maps and data sets. It also identifies organisational goals and priorities, and creates the framework around which the GIS implementation process takes shape.

Justification through cost-benefit analysis then seeks to determine whether the significant investment required will eventually pay off. Return on investment, or benefits, can be divided into two types: tangible and intangible benefits. Tangible returns are simple enough to define, and are usually financial in nature, because monetary concepts are inherently quantifiable. For instance, how much will a GIS cost, and will its monetary benefits outweigh the monetary costs of initial investment? Intangible benefits such as "improved decision making" (Public Technology Inc. 1991, 10), "increased efficiency, better communication and improved morale" (Aronoff 1989, 260-261), are more difficult to quantify and therefore, make the end result of the cost-benefit equation uncertain at best.

Next, requests for proposals are sent out to potential GIS suppliers, a choice is made and system installation takes place. Data conversion follows, and may take several months or even years, as this is often the most expensive, labour intensive and time consuming step of the implementation process. Data conversion involves creating the layers of base maps to be input into the GIS. Usually this involves manually digitising or scanning paper map sheets into the GIS and entering, translating and linking already existing non-graphics data for use in the new system. Before the system can be used in any capacity, staff must be hired and/or trained.

Finally, system maintenance from a technical and managerial standpoint ensures that the GIS becomes an integral part of the organisation. Successful integration takes place when the GIS becomes accepted as part of the everyday operation of the organisation.

While the above paragraphs outline a simplified, generic implementation model compiled and boiled down from many different theoretical frameworks, various authors have envisioned specific ways of carrying out the GIS implementation process, each with their own emphases. Four basic types of models will be outlined in section 4.2 of this chapter.

1) Temporal model: The Short Road Approach (Ballard 1993)

2) Content vs. Process models (Obermeyer and Pinto 1994)

3) Procedural or Stepwise models (Flagg 1993)

4) Implementation Scenarios and Trade-Offs (Dangermond and Smith 1980)

Before embarking on a discussion of specific models, it is important to provide more detail on some of the basic or generic steps involved in implementing any GIS.

### 4.1.1 Raising Awareness and Gaining Management Support

A GIS implementation process is seldom a short term effort. Many projects can take as long as five years to become fully operational. And even then, the task of constantly keeping the system up to date with current data, relevant applications and the latest software/hardware configurations is an ongoing process. In order to assure continued support and funding for such initiatives, it is crucial that the support of high level management be obtained and maintained throughout the implementation process.

If management is not wholly convinced of the long term benefits of GIS, the initial implementation process risks being delayed. For instance, only portions of the land records may become automated, or only portions of the system may become implemented (Korte 1994). While a partially implemented GIS may serve as a great pilot project, it does no good in the long run where the true benefits of the system have the potential to make themselves evident.

Before the support of management is sought, all affected members of an organisation must be made aware of what GIS is, what it can, and more importantly, cannot do, how it works, and what effects it may have on the way work is carried out in the future. Raising awareness is, first and foremost, the most important step to be undertaken before any other in the implementation process. Raising awareness may take the form of educational seminars or informal vendor demonstrations, for instance.

While information about new technology can enter into the organisation at any level, it will be viewed differently by members of that organisation depending on who acts as the messenger (Aronoff 1989). New ideas will almost certainly be treated differently when presented by a senior manager or planner as opposed to a planning technician. As a result, new ideas must always be sold if presented from a bottom-up perspective. If the need for a GIS is started from the management level, other types of challenges may arise. Management is seldom well-versed in the technical realm of GIS technology. This may result in inflated expectations that are dismissed by more technically oriented experts at lower levels of the organisation. Resistance from staff may also enter into play.

Once the idea of embarking on a GIS implementation program is sold, the project implementation team must investigate the various costs and benefits associated with taking the "GIS leap." As will be covered in the next section, no matter how sophisticated the cost-benefit analysis, GIS is still often regarded as a leap-of-faith initiative because of the unquantifiable outcomes, unforeseen circumstances and unpredictable events on both technical and organisational fronts.

### 4.1.2 Cost-Benefit Considerations

Although an entire thesis could be written on cost-benefit considerations with reference to GIS implementation, only a short discussion will be undertaken here owing to space constraints. As previously discussed in chapter 3, cost-benefit considerations in GIS implementation have lost ground to other factors deemed more critical to implementation success. In fact, in most technology adoption studies to date, the economic value of innovations such as GIS appear to play a relatively minor role in the decision to embrace the technology (Obermeyer and Pinto 1994). This tends to be especially true of GIS installations in the public sector.

Implementing a GIS is a costly and often long term undertaking. For this reason, some degree of cost-benefit analysis *is* usually warranted. But compared to many other capital projects, cost-benefit analysis in the context of GIS tends to be more complex. Even with the use of sophisticated models, the decision to proceed still remains a judgement call. There appears to be truly no unbiased, objective analysis method. The number of unforeseen unknowns, variables and risks in a process as lengthy and complex as the above adds to its complication (Aronoff 1989).

One reason why a lack of objectivity and a significant amount of difficulty persists in using cost-benefit analysis is the existence of intangibles. Intangibles are hard-to-quantify concepts that represent both the inputs (costs) and outputs (benefits) of a GIS implementation process. Figure 15 illustrates both tangible and intangible costs and benefits.

The ongoing dilemma lies in the measurement of these concepts. Which variables should be chosen to compose the cost-benefit equation, and once chosen, how do we quantify them? “In fact, there is a debate in the GIS community as to whether a rigorous cost-benefit analysis of these systems is even possible" (Wiggins and French 1991, 16).

A second reason for the lessening of cost-benefit considerations in public sector GIS specifically, is the unique mandate these types of agencies hold with respect to their public service role. Still, it is generally true that a municipality would not consider a GIS if it was unreasonably untenable in a fiscal sense.

**Figure 15: Tangible, Intangible Costs and Benefits**

| | Costs | Benefits |
|---|---|---|
| **Tangible** | • Hardware<br>• Software<br>• Training courses for users<br>• Consultants' fees | • Time/$ savings from increased efficiency, measured by cost of producing maps and reports<br>• Time savings from automation of routine manual procedures<br>• Reduction in redundancy, measured by the number of duplicate maps that need not be reproduced<br>• Benefits of new marketable products and services (maps/other info. products sold as revenue for the city) |
| **(Hard to Estimate) Intangible** | • Cost of operating new system<br>• Custom programming (contingent on choice of applications, complexity, etc.)<br>• Rate of system depreciation<br>• Cost of not implementing GIS in the first place | • Improved decision making<br>• Increased morale<br>• Better communication within the organisation<br>• Better public image<br>• Benefit of new non-marketable products and services (internally used products - impressively formatted reports/graphics. |

(Sources: Aronoff 1989, French and Wiggins 1991, Public Technology 1991).

> Any institution considering investment in an innovation must first cross the threshold of having enough slack in its resources to be able to make some initial investment in it. However, presuming slack is available, factors other than immediate economic advantage typically are shown to be far more crucial in the actual decision to adopt (Obermeyer and Pinto 1994, 28).

In the case of public sector institutions such as municipalities, serving the *public need* is the prime directive. While *public need* is a vague term at best, it does suggest some more concrete concepts. For instance, many municipalities and regional governments in the United States have specific mandates to implement GISs as part of growth management strategies and legislation. For instance, "Vermont was the first state in the United States to legislate the development of a multipurpose state-wide GIS for all levels of government. Act 200, Vermont's growth management law passed in 1988, provides funding for local and regional plans for growth management. The law requires that information at all levels of government be compatible with the state-wide GIS" (Public Technology 1991, 35).

In short, information is treated as a social commodity by municipalities. Its value is seen less as a source of revenue than as a tool to serve the public. Still, if it appears that growth management plans and other types of planning-related legislation seem far removed from the concept of directly serving the public, consider the following two examples which can hopefully bring the concepts of GIS and serving the public closer together. Improved productivity in providing public information appears to be the main benefit in:

- providing immediate zoning counter support for citizens with basic parcel questions.
- improving the public notice system. This entails identifying parcels within a project area and notifying affected citizens. This task is accomplished using the point-in-polygon functions described in chapter two.

While the public service role of municipalities tends to encourage the treatment of information as a social commodity, this role is gradually changing. While not entirely straying from this view, information has recently taken on a dual role. Many municipalities are recovering the costs of GIS implementation by selling data in digital format to individuals and organisations that are willing to pay for it. This, of course, raises many of the same issues brought to light in chapter three's discussion of ethics and the release and/or sale of data to various individuals and organisations. The overall social benefit of providing this information to the public may be hard to measure, but the democratic process dictates that the benefits of public access outweigh its costs or negative effects (Aronoff 1989).

### 4.1.3 Information Needs Assessments

Conducting an information needs assessment (INA) is important because it identifies the needs of the users of the system. The functional requirements identified in INAs are based on what information is needed to make decisions in the organisation and what information they will require in order to carry out their work (Wiggins and French 1991). This concept is crucial to any information management process. Unfortunately, many organisations omit or avoid conducting this type of study (Dangermond in Scholten and Stillwell 1990). Without this information, an organisation may be poorly equipped to enter the database design stage, where decisions must be made regarding what types of information to eventually input into the GIS.

INAs are usually composed of two phases. These are: an inventory of existing resources, and an analysis of resource deficiencies and gaps that could be filled by GIS (Public Technology 1991). First, one starts with an inventory of existing information products whether they be in paper or digital format. This enables the assessment team to gauge what kinds of information products are presently available. This will eventually be used to calculate the cost of converting existing paper based data into digital format.

Ultimately, all resources should be covered. These may include a wide array of areas: existing information systems, present soft/hardware technology, personnel, cartographic products and manual processes. This analysis is done across all municipal departments in order to assess which ones make use of what kinds of products and processes. It may also identify what kinds of data various departments may wish to access and/or share in the future once the GIS is established, up and running.

The inventory is best conceptualised in the form a matrix, where map or information products are listed across the side, and municipal departments across the top. Rows correspond to maps or databases, and columns to the users or producers of these products. Each cell can then show whether a department makes use of a particular information product. More sophisticated matrices may also show whether a particular department creates, uses or changes certain types of information, the importance of the information and how often it undergoes changes. The matrix then immediately enables the assessment team to identify areas of:

- potential data sharing
- redundancy, if different copies of the same information are kept by more than one department
- possible inconsistencies among the same data collected by multiple departments
- priority, where specific data/cartographic products are critical to more than one department

**Figure 16: Example Information Needs Assessment Matrix**

| **Departments→** <br><br> **Maps↓** | **Building & Zoning** | **Planning** | **Highways & Engineering** | **Water** | **Inspections** |
|---|---|---|---|---|---|
| **Land Use** <br> Commercial | (created by B&Z) <br> ✓ | ✓ | | | ✓ |
| Industrial | ✓ | ✓ | | | ✓ |
| Residential | ✓ | ✓ | | | ✓ |
| **Parcels & Lots** | ✓ | ✓ | | | |
| **Political Boundaries** | | ✓ | | | |
| **Roads** <br> Centerlines | | | (created by Eng.) <br> ✓ | | |
| Traffic Signals | | | ✓ | | |
| **Service Districts** <br> Parks and Recreation | | ✓ | | | |
| Law Enforcement | | ✓ | | | |
| Garbage Collection | | ✓ | | | |
| Building Inspection | | ✓ | | | ✓ |
| School Districts | | ✓ | | | |
| Water Districts | | ✓ | ✓ | ✓ | |

(Adapted from Public Technology 1991, Wiggins and French 1991).

INAs also identify how frequently decisions are made, what data is used to carry them out, and the kinds of techniques that are used to assess these decisions. By answering these questions, INAs attempt to match the needs and budget of the organisation, with a system of appropriate size, power and capability (Wiggins and French 1991).

### 4.1.4 Requests for Proposals (RFPs)

One of the final steps in the GIS procurement process is the sending out of RFPs. An RFP is used to solicit competitive bids for the desired system. After conducting a needs assessment, decisions are made regarding the different components of the desired system. This *wish-list* of components, made up of hardware, the core GIS software, and additional applications software, is sent out to potential suppliers. Ultimately, the company holding the successful bid will prove that its offer best meets the needs of the organisation (Public Technology 1991).

Preparing an RFP usually takes one of two routes. RFPs can either emphasise the specific functions desired in a system, or they can list exact system specifications. For example, desired functions may include the capability of performing certain tasks such as optimal or shortest path routing. Desired functions tend to be general in nature, expressing the overall desire for the system to possess that function. Expressing the desire for a specific function (no matter how specific) is still more general in nature than a list of detailed system specifications. It is for this reason that functional RFPs usually take longer to prepare owing to their vagueness, relative to specifications-driven RFPs.

RFPs that emphasise technical specifications "tend to have lengthy lists of features, mandatory or desirable, to be provided by the vendor" (Public Technology 1991, 52). This clarifies the expectations of the purchaser as well as the exact types of features to be included in the system. Below is an example of some of the mandatory database requirements listed in the RFP prepared by the City of Palo Alto, California.

> In particular, the system's database characteristics must meet the following specifications:
>
> A. Support point, line polygon features, raster, text graphics, and attributes.
>
> B. Define locations of cartographic features using an arc/node data structure which combines sequences of x,y coordinates or x,y,z coordinates with full topological encoding.
>
> C. Support up to 256 000 points per polygon, up to 512 000 map features per map, and at least 512 attributes per map feature, files of virtually unlimited size and up to 2 048 files in a single database.
>
> D. Provide a minimum of 32 000 layers per map data file (Public Technology 1991, Appendix F).

The specifications listed above certainly give potential suppliers a more detailed idea of what is desired than a simple list of functional requirements such as optimal path routing or redistricting, which are, at best, loaded terms that only provide a surficial idea of what kind of system is truly being requested.

This section has provided a basic outline of some of the steps that are normally carried out during the pre-acquisition phase of GIS implementation. The next section will cover some of the different approaches that are used to classify how different theorists have envisioned the GIS implementation process.

### 4.2 IMPLEMENTATION MODELS

The previous sections of this chapter described some of the generic elements of a GIS implementation model. Implementation models describe how technology, information and people will be formed and moulded into an operating information system (Aronoff 1989). Most conventional models usually describe the implementation process as a set of procedures or steps to be followed from beginning to end. Still, there are other specific models that take different approaches.

Instead of concentrating on the individual steps or procedures, as does Flagg (1993), some models emphasise the time frame over which the implementation process takes place (Ballard 1993). Some models underscore the locus of power, such as centralised vs. decentralised implementation models, or substance versus process (Obermeyer and Pinto 1994). A more creative framework is suggested by Dangermond and Smith (1980) in Aronoff (1989) where *what-if* scenarios are derived based on a combination of implementation alternatives and user considerations. This section will describe and compare four general categories of GIS implementation models.

### 4.2.1 A Temporal Model: The Short Road Approach

This approach views the GIS implementation process in terms of the practical need to develop concrete applications quickly and efficiently. To illustrate, a case is drawn from the City of Augusta, Georgia, where a *Short Road to GIS* approach was taken (Ballard 1993). The *Short Road* approach is seen as valuable by Ballard because it stresses the need to produce tangible benefits from the GIS very soon after installation has taken place.

Producing immediate and tangible benefits is an important consideration, in the sense that it can help to get senior management on side. Seeing immediate results emerge from a project that requires significant financial sacrifices helps to put it in the best light. This is especially true for those at the top who a) are concerned with the bottom line and b) do not have an appreciation for the usual amount of time required for a GIS to start producing real benefits.

> Some GIS projects do not provide a return on investment until a lot of time and money have been spent. As these projects drag on, they tend to lose political support within the organisation as more urgent and visible problems take priority, particularly in the challenging environments faced by today's municipal governments (Ballard 1993, 20).

In the case of Augusta there was a push to "develop GIS applications quickly so we could point to positive results and ensure continued funding and support for the project" (Wittke in Ballard 1993, 20).

The practical aspect of the *Short Road* approach is the fact that a municipality can enter the process at whatever level its GIS data will support. *Short Road* uses a set of simple street centre line applications that include point incident mapping, vehicle routing, and thematic mapping. These applications seem to address some of the most basic or common needs of most municipalities.

> All pieces are designed in advance...The need to customise the basic system framework is also recognised, so functions that typically require tailoring are designed to be modified easily...Money is spent tailoring an existing, modular GIS, which was designed to be customised, rather than developing the system from scratch (Ballard 1993, 20).

User needs were carried out initially in order to gather data on system requirements. Interviews were carried out focusing on relevant application areas. Application designs were then reviewed by the various departments for validation. Data input was facilitated by scanning paper map sheets and later registering them to digital vector files and orthophotography. In order to get the implementation process underway, the US Census Bureau's TIGER digital street file was used as a starting point for many of the street-centerline-driven applications.

There are still other aspects of this approach that stress speed in expediting the implementation process. For instance, "all work was managed through one vendor, eliminating much of the contracting and negotiating overhead" (Ballard 1993, 22). As well, a project manager was used as the singular contact and focal point of communication for the city. The project manager was responsible for ensuring "that all system components met design specifications and any issues were resolved quickly" (Ballard 1993, 20).

While this implementation model does have it advantages, the main disadvantage of taking a *short road* approach is the risk of moving *too* quickly toward automation. Otawa and Lyons (1992) examination of the factors behind GIS implementation success and failure point out that the poor success rate of system implementation can be attributed to the lack of a comprehensive approach to designing and implementing GIS. "Primarily because of desires to quickly move towards automation, GISs are established merely with the acquisition of hardware and software" (Otawa and Lyons 1992, 2). Callina (in Public Technology 1991, 44) also points out that there are no real shortcuts that work well in automating a GIS and making it work."

### 4.2.2 A PROCEDURAL OR STEPWISE MODEL: FLAGG'S SEVEN STEPS

The model to be discussed in this section stresses the distinct steps or procedures followed in order to get from start to finish when implementing a GIS. Most GIS implementation models are inherently procedural in nature because one inevitably follows a path, no matter how convoluted, to implementing a GIS.

The procedural model to be discussed is Flagg's (1993) *7-Step Path.* This type of model tends to be quite popular because it divides up the complex GIS implementation process into bite-size phases. Procedural models are also popular because they follow a chronological step-by-step path. More complex procedural models choose to make use of complicated feedback loops and circular processes that are dependent on outcomes of other steps. These models may tend to confuse, if not intimidate, prospective GIS managers or management teams, especially if they are not familiar with the technology or the processes necessary for their proper implementation.

Flagg's model was designed to deal with the staggering number of decisions and amount of information that confront government agencies and private-sector organisations interested in establishing a GIS. Often, many potential GIS managers do not even know where to begin (Flagg 1993). This is certainly understandable as over seventy-five separate steps covering all areas of GIS procurement were condensed into seven general categories. The seven steps listed below are:

1. **Orientation of Decision-Makers and Staff:** A formal orientation and introduction to GIS.
2. **Organisational Assessment:** Identifying existing operations, funding sources, functions and missions.
3. **Functional Objectives and Implementation Plan:** Creating and documenting specific GIS objectives and functions.
4. **System Design:** Designing system specifications that will support an organisation's program and project goals.
5. **Project Requirements:** Selecting a pilot project and evaluating the data and funding required to complete it.
6. **Detailed Database Design:** Developing a structured information database to ensure that the agency and project goals are met.
7. **Application and Development:** Design, development and output of the application information.

### 4.2.3 Content vs. Process Implementation Models

One of the serious problems with past research on the implementation of innovations has been the use of either content or process models as the sole investigative mechanism (Obermeyer and Pinto 1994). The two models presented so far seem to focus on procedural matters rather than the substantive issues responsible for the successful implementation of a municipal GIS.

In order to identify and fully understand the key decision factors in the adoption of GIS technology, as well as the processes by which implementation occurs, both approaches must be considered. While each method is useful, neither offers a complete picture (Obermeyer and Pinto 1994). Content models stress the environmental, organisational and interpersonal factors that have the capacity to facilitate or inhibit the implementation process (Leonard-Barton 1987 in Obermeyer and Pinto 1994). Process models, on the other hand, are concerned more with the key steps involved in the diffusion of technological innovations.

Content models, as the name stresses, emphasise the substantive factors that can contribute to the potential success of a GIS site. From a synthesis of many GIS implementation studies containing a disposition toward the substantive, Obermeyer and Pinto (1994, 29) provide the following set of content factors deemed to be crucial in implementation success:

- Clearly defined goals
- Sufficient resource allocation
- Top-management support
- Implementation schedules
- Competent technical support
- Adequate communication channels
- Feedback capabilities
- Responsiveness to clients/end-users of the system

In addition to the above, there exist many other diverse content factors crucial to success. These include visible benefits, a reasonable learning curve, information sharing potential and the presence of a champion/GIS guru.

The authors note that while the above are factors that stress the substantive, the majority are organisational rather than technical in nature. "Implementation theorists and researchers have known for some time that problems associated with the diffusion and adoption of new technologies are often based on human issues rather than on technical difficulties or concerns" (Obermeyer and Pinto 1994, 29). This is not to say that technical adequacy is less of a concern, only that adequate technical support and functional equipment is only the starting point toward a successful GIS.

Content factors such as those listed above are important in the management of GIS implementation. Still, they are only a static representation of the implementation effort. In other words, content models do not focus on the significance of procedural matters. Since most models inevitably include some notion of change or " 'process of organisational change', implementation models in general also need to reflect the dynamic nature of new-system diffusion" (Obermeyer and Pinto 1994, 30).

Process models emphasise the key phases or steps involved in arriving at the adoption and eventual acceptance of a system. For instance, Schultz, Slevin and Pinto's (1987) model described in chapter 3 of this thesis is an example of a typical process model. Their quadrant scheme describes *initiation* activities as they relate to actual *implementation* activities. In other words, the awareness and *planning-for-the-implementation* stage is separated from the stage where the organisation actually engages in the *activities* necessary to put the innovation into practice (Obermeyer and Pinto 1994).

The model then allows one to evaluate the outcomes resulting from differing degrees of quality at each stage of the game; planning for implementation, as opposed to how the implementation process actually turned out.

### 4.2.4 Implementation Scenarios and Trade-Offs

Probably the most original or creative of the models to be discussed so far is Dangermond and Smith's (1980) *Alternative Approaches to Implementing a GIS*. Unlike any of the previous models, but similar to Schultz, Slevin and Pinto's (1987) quadrants, it provides hypothetical answers (outputs) to various implementation questions or scenarios (inputs).

**Table 5: Alternative Approaches to Implementation**

| | **IMPLEMENTATION ALTERNATIVES** | | | | |
|---|---|---|---|---|---|
| **CONSIDERATIONS** | **User Creates System** | **Buy Some Software** | **Buy Complete Software Package** | **Buy Complete Software & Hardware Package** | **Purchase GIS Services** |
| Dependence on supplier | Very Low | Low | High | Very High | Nearly Complete |
| Time until system functions | Long | Long to Moderate | Short | Very Short | Not a Problem |
| Initial cost | Low | Moderate | Moderate | High | High |
| Labour costs paid by user | High | Lower | Moderate | Moderate | Very Low |
| Risk and uncertainty | High | Lower | Low | Low | Low |
| Customising | Complete | Complete | Moderate | Moderate | Varies |
| Technical skill required of user | Extremely High | High | Moderate | Moderate | Quite Low |
| Use of existing resources | High | High | Moderate | Low | Very Low |

(Source: Dangermond and Smith 1980 in Aronoff 1989, 263)

We can see how different implementation alternatives are affected by various combinations of user considerations (table 5). Implementation alternatives range from a system entirely conceived, designed and built by the user, to a ready-to-use system that is purchased from a supplier. By considering different alternatives for each of the stages of the implementation process, the GIS project team can gauge the required effort and costs to be incurred at each step.

Costs incurred in order to have a supplier provide expertise and servicing differ from the costs associated with performing the same tasks in-house. For instance, it may be cheaper to do much of the initial start up work in-house, but the associated trade-offs may turn out to be more expensive. More sophisticated technical skills and background may be required, as well as personal time commitment and the willingness to wait a long time before the system is up and running.

## 4.3 Chapter Summary

This chapter outlined some of the generic steps that are usually followed in the GIS implementation process. These steps were derived from a variety of models. This was followed by a more thorough discussion of actual theoretical approaches undertaken by various authors. Four models were covered, each with their own specific emphases.

Certain models stressed the importance of time and the need to produce immediate results, while others broke the implementation process down into distinct phases. The issue of substantive versus procedural elements, and their role in implementation models was also discussed. For instance, is it more important to consider the substantive factors that can lead to implementation success, or are procedural issues more critical? The final model in the discussion included an analysis of the various trade-offs that are involved in considering different implementation scenarios.

While chapter 4 discussed the implementation process in a general sense, chapter five will focus on those specific aspects of the process that have the capacity to inhibit, or act as obstacles to the implementation, adoption, and acceptance of GIS by an organisation.

## 5.0 OBSTACLES TO SUCCESSFUL IMPLEMENTATION AND USAGE

Because of its technically complex and often socially controversial nature, implementation of GISs has often been met with significant opposition. Many reasons exist for this opposition: high costs, weak management commitment, intangible short term benefits, shifting responsibilities and information flows along with associated occupational upheavals.

This chapter seeks to investigate some of the obstacles encountered in implementing GIS technology with specific reference to a municipal planning context. Still, opposition is but one obstacle to implementation. There are many other forces that act to affect and impede the proper and effective implementation, adoption and eventual use of a municipal GIS. One significant obstacle is the perceptual gap that exists between system expectations and the realistic capabilities of a GIS. In addition, the perceived benefits of adopting a GIS can vary significantly among organisations and local authorities (Campbell and Masser 1992, Otawa and Lyons 1992).

System delivery and success is dependent on several factors. Some of these factors include: obtaining senior staff or management support, acquiring sufficient financial resources, undertaking a complete needs assessment, and encouraging the participation of those with technical as well as managerial experience and expertise. This chapter will begin with a discussion of the gap between perceptions/expectations and reality, leading to some brief suggestions on how to reconcile these differences. The chapter will then conclude with a discussion of the conditions that have the capacity to affect the likelihood of success or failure of GIS implementation. These are broken down into technical issues and organisational issues.

## 5.1 Expectations and Reality: Closing the Gap

The principal objective of this section is to explore some of the incongruencies between what potential users of GIS *believe* it is capable of accomplishing, and what a GIS *is actually* capable of accomplishing. The perceptions and misconceptions held by planners and politicians concerning the capabilities of GIS have the capacity to impact greatly on the degree to which a GIS implementation program is successful and accepted by those in the organisation charged with its use.

In the introduction to this thesis, two broad categories of obstacles were mentioned as responsible for the vast majority of GIS implementation failures. These were technical obstacles and managerial obstacles. On the technical side, issues of concern may include: choice of software, hardware, database design and data conversion.

While many believe that technical obstacles can be easily and quickly surmounted, given the proper equipment, equipment testing procedures and technical support, organisational or managerial obstacles are believed to be more complex in nature. To clarify its meaning in this paragraph, the term *management* is not meant to refer to the upper echelons of municipal government. *Management* is used here to refer to the broad domain of issues that affect the administration and direction of the organisation with specific reference to the human resource. For example, management issues may include resolving internal political conflicts, training, funding and financing the system, diverse political agendas, attitudes toward new technology and, specific to the planning profession, the different philosophical approaches taken in the planning process.

All the issues mentioned above have the capacity to affect the way GIS is perceived, accepted, adopted, and eventually used. Issues related to perception and expectation are the main focus of this section. There are several explanations for the chasm that exists between GIS expectations and GIS reality.

- **Lack of awareness, and the failure to consider the scope of GIS implementation.**

One of the more common reasons for the inconsistencies between expectations and reality is the lack of awareness of GIS by those in the planning and municipal management field. Awareness is defined not only as having heard of GIS and having some vague notion of its capabilities. It refers to the informed knowledge of the potential benefits that can accrue to an organisation (Aronoff 1989), as well as an awareness of what the limits of GIS are. As was pointed out in previous chapters, the role of GIS is often misconstrued as a total solution to problems and challenges, rather than as a tool to help in decision making for planning.

Related to a lack of awareness of the limits of GIS, is the failure to comprehend the sheer scope of the implementation process and the diversity of challenges, both technical and managerial, it poses for any organisation. In fact, it is quite common for organisations to misunderstand the full scope of a GIS project.

GIS represents a significant investment in time, money, organisational energy, and management credibility. Moreover, it represents a radically different way of managing land data. The technology is more complex and the workflow processes are much more complicated. Furthermore, most of the employees who will have to use the GIS begin with little or no knowledge of data processing systems, much less GIS (Korte 1994).

- **Lack of education and awareness of geographic concepts, map usage and interpretation.**

Many planners and other municipal employees who have not had an education in the geographical sciences may lack an understanding of some very basic and important concepts that govern the proper use and interpretation of geographic information. As stated in chapter three, it is quite easy to unintentionally misinterpret and/or misrepresent geographic information.

In Mark Monmonier's book, *How To Lie With Maps* (1993), he highlights the level of ignorance of this new breed of *fly-by-night* cartographers. The availability of personal computers has allowed mapmaking technology to be simplified to the point where many of the people who now assume the role of cartographer have not only been parachuted into that role, but have virtually no training (Obermeyer and Pinto 1994). "Map users can now easily lie to themselves - and be [completely] unaware of it" (Monmonier 1993,1).

Coupled with this lack of understanding is the overall lack of sophistication or level of use to which GISs are being put. In other words, these systems may not be used to their fullest potential, not because of technical flaws in software design, but because users are either a) not equipped with a sufficient background in geographic concepts or b) have not had the proper training, exposure or the very important hands-on experience that is necessary in order to fully understand and appreciate how a GIS uses and processes data. Campbell (1992) mentions the frustration felt by agencies with systems that operated well in a technical sense, but were being used in only very limited ways by professional staff, especially decision makers.

- **Vendor Problems and Overstating Benefits**

Vendor demonstrations of software to prospective GIS buyers can sometimes be misleading. This is not to say that most software demonstrators are dishonest, only that anyone responsible for the decision to commit significant financial and human resources to such a project must be prepared to ask the right questions. They should also be prepared to watch for clues that suggest that the vendor is misleading them. According to French and Wiggins (1991, 10) vendor demonstrations can mislead potential buyers in three different ways.

1. They make applications appear to run faster than they actually will.
2. They make sophisticated applications seem simple since all of the graphic and attribute data have been entered, cleaned and tested.
3. They are run by someone very familiar with the software.

In order to resolve some of these issues, one might suggest a system testing session using some data samples taken from the prospective buyer.

User friendliness of software is also a point of exaggeration among many vendors. There have been claims that many vendors mislead their clients into believing that their product does not require as much training and practice as it really does. In the context of vendor-supplied training courses, a balance must be struck between teaching general concepts and organisation-specific applications training. Croswell (1989) claims that vendors may not be adequately directed to the user's application environment in order to bring them to an operational status quickly.

Overstating the benefits of a GIS while not recognising its limitations can lead to grave consequences when undertaking actual project work. Stating both the pros and cons of all *candidate* GISs is key during the process of deciding which GIS to eventually purchase. This enables one to evaluate trade-offs between functions that are critical to the organisation versus those that are less commonly used.

- **Expectations of GIS software components/contents**

The vast majority of GIS software packages are *empty shells*. While some packages are bundled with sample data for introductory or tutorial purposes, most GISs are simply software without the data needed to perform the analysis they were meant to undertake. It is up to the users and managers of the system to provide the data either through purchase, if available, or through manual digitising, scanning or other data input methods. On the technical side, the data conversion step is often the most expensive and most critical step in the GIS implementation process.

To be fair as well as realistic, spatial data for the United States is quite commonly available bundled with GIS software. And even when it is not included, it is made available quite easily. The US Bureau of the Census' TIGER (Topologically Integrated Geographic Encoding and Referencing) files cover every county in the U.S., and include street address range coverage as well as major geographic and hydrographic features. Unlike its U.S. counterparts, Canadian data is much more difficult to come by, especially current data with such a wide geographic scope.

The Canadian equivalent of U.S. TIGER is Statistic's Canada's SNF (Street Network File). It includes coverage of major metropolitan areas with populations of 50 000 or more. The downfall of this system is that the vast majority of rural areas are excluded, and the accuracy and currency of the data is at the mercy of the municipality in question. SNF files are updated only as often as participant municipalities are willing to update their own files, and supply these updates to Statistics Canada. As well, different jurisdictions supply differing amounts of detail. While some municipalities supply only rudimentary information such as roads, highways, railways and shoreline, others may provide additional detail. These may include lakes, creeks, golf courses, park, airport and university boundaries, as well as point locations for shopping centres, schools, and churches.

Other software expectations include the presumption that GISs come pre-packaged with already developed applications. While a system designed entirely by an outside consultant tailored to the needs of a particular client may include specific applications software, many GISs are, as described above, empty shells. It is up to the implementation team to first conduct needs assessments in order to derive the set of application areas that are priority.

- **Productivity does not always increase with the introduction of new technology**

Productivity does have the capacity to increase with developments in new technology, but only up to a certain point. Steepness of the learning curve may have the effect of keeping productivity constant until users are properly trained. The motivation of individuals to learn and feel they are making progress, as well as contributing to the success of the organisation, is also a critical success factor.

Employees who feel threatened by the changes brought about by GIS may exist at all levels within the hierarchy. This includes managers as well as lower echelon employees. Regardless of position or pecking-order, no one enjoys unexpected massive changes in work methods and procedures.

As mentioned in the introduction, one can very easily throw technology at a problem and expect it to disappear. This ignores the human element in any problem solving situation. It ignores the fact that it is only the end-users of technology that are ultimately responsible for its effective and proper use. Chapter three pointed out situations where GIS was not always put to its best and highest uses.

- **Sold as a solution to poorly defined problems**

Poorly defined problems are often the result of an incomplete information needs assessment. Poorly defined problems can also be looked at in the context of the quadrant scheme from chapter three. Poorly defined problems would be attributable to Type III error: solving the wrong problem. In this case, GIS technology is implemented for a specific set of problems, but is not actually used for those purposes. This type of misuse can occur because of improperly trained or frustrated users who revert to previous methods.

For many years, too much attention was paid to the technical aspects of technology, while the management side of information systems was left to suffer. To further worsen the overemphasis on technical issues, some commercial vendors implied that all an organisation needed was a technical solution. " How often has a vendor expounded the technical details of his system and completely ignored the impact of that technology on your organisation?" (Madziya 1990, 312).

- **GIS automatically creates better decisions or organisational harmony**

The belief that the introduction of a GIS will create better decisions that are more satisfactory to all parties can be a false one. By its very nature GIS is subversive. GIS has the potential to disrupt organisational hierarchy and cause rifts between employees or departments that may have never had reason to disagree in the past. The centralisation of information that often comes with the arrival of a GIS directly opposes the decentralised information sharing needs of municipal government.

- **Information produced using a GIS is more accurate, trustworthy and impartial**

A common perception exists that places computer-generated information on a higher level than manually processed data. Decision makers and the public alike generally consider computer-generated information to be more accurate, credible and value-free, for the sole reason that a computer was in part responsible for its production. This belief is partially related to the complex technical jargon surrounding the preparation, processing and presentation of computer-generated data. Technical language is often assumed to be used by equally technical, and more importantly *objective* and non-political, technical experts.

In fact, computerised data and analysis techniques are subject to the same kinds of political bias and inaccuracies as other data. "The bias enters in the selection of the data to be included, the analytical methods to be used, and the way the results are presented" (Aronoff 1991, 250). Several examples of data misrepresentation highlighted in section 3.3.3 are the result of data that has been twisted and fitted to follow the agenda of the presenter.

### 5.1.1 Brief Case Studies: Expectations of GIS Benefits

The previous section listed some of the common perceptions GIS users have concerning the capabilities of a system as well as some of the potential benefits that can help an organisation. This section will highlight some cases of actual GIS installations, the experiences of users and their expectations and perceptions of what benefits GIS can bring to an organisation. The following cases were not selected using any especially stringent criteria. Chosen from conference proceedings and trade journals, these cases all possessed the following common themes: the GIS implementation experience, system expectations and perceived advantages of GIS among various types of planning agencies.

*Massachusetts and Vermont*

Campbell (1992) studied the implementation experiences of communities in these U.S. states by asking individuals whether they regarded improved information processing facilities, cost savings, or better decisions as the most important set of benefits to be derived from the adoption of GIS technology. "All respondents were in agreement that the main advantages to be gained from GIS adoption were in terms of enhanced information handling capabilities, including such facilities as data integration, more rapid output or new techniques for data manipulation" (Campbell 1992, 90).

*Great Britain*

A case study of the perceptions of GIS benefits and the resulting problems encountered is highlighted by Campbell and Masser (1992). Their study of 98 different local authorities throughout Great Britain revealed much about what municipalities expected of their systems and the problems they encountered during the implementation process. Their study found that "for those authorities presently implementing a GIS, the technology is expected to improve existing capabilities for information processing rather than enhance decision-making or help achieve savings" (Campbell and Masser 1992, 529). This could be attributed to a possible lack of knowledge of what a GIS can do.

*New Westminster, B.C.*

The above findings are consistent with an interview conducted in the Vancouver area. For instance, the City of New Westminster is currently implementing a GIS. During an interview conducted with two of the planning assistants, it was indicated that improvements in information retrieval and information integration were more important than improving the overall decision making process, and certainly more important than saving a few dollars. In the final analysis, serving the public more effectively was a main concern. While the notion of *better serving the public* is vague at best, the important point is that financial or decision-making considerations were not paramount.

*Louisville, Kentucky*

This example concerns the development of a land records database in Louisville, Kentucky. The City of Louisville formed the Land Management/Geoprocessing Task Force in 1982. Its purpose was to design and implement a comprehensive Land Record Database. Some of its objectives were to eliminate manual lookup, reduce data redundancy and to allow City agencies to share data used by many departments (Sampanis and Dant 1985).

Expectations and perceived advantages resulting from such an information system stressed the following elements:

- Assist police and fire in emergency situations.
- Help to market vacant properties in Louisville's Enterprise Zone.
- Improve the issuance of building permits.
- Help in the enforcement of the zoning bylaw.
- Provide information for economic development.

- Assist in housing revitalisation projects.
- Assist in the estimation of trash volumes.
- Alert property valuation to changes in zoning and/or additions of structures.
- Locate businesses for the levying of occupational taxes.

Above all, it was hoped that developers and their representatives would describe their needs to a single City agency. They would then receive information relating to those needs during that visit. The system would identify properties which meet the developer's unique location criteria including land area, zoning, type of structure, and its condition, the present owners and the property's valuation. A site analysis will then be generated in a matter of minutes (Sampanis and Dant 1985, 62).

In the above cases, the emphasis seems to be placed not on saving dollars or improved decision making, but instead on functional requirements and ease of data retrieval and integration in order to serve a public need.

*Queensland, Australia*

Otawa and Lyons (1992) conducted an extensive survey of government organisations using GIS in Queensland, Australia. When one analyses the results of the study, once again, cost savings were rated below detailed data analysis and the capability to respond to public inquiries. In addition, enhancement of inter-departmental communications was rated below both of the above perceived benefits of implementing a GIS.

In terms of obstacles to implementation, the insufficient level of knowledge and skills to operate GIS were rated as highest, along with data conversion issues. The second group of obstacles, rating slightly lower, were: a lack of interest in GIS implementation, the failure to recognise potential problems once implementation was initiated, and the threat of looming internal or inter-departmental political problems. Related to the data conversion issues highlighted above, it was perceived that a lack of available, ready-to-use digital databases coupled with the cost of purchasing those that exist could hamper implementation efforts.

A common thread running through many of the above experiences demonstrates an emphasis on the technical issues involved in data retrieval and integration in order to supply clients or citizens with information. This emphasis is understandable given the sense of urgency that organisations feel when confronted with adapting to new technological innovations. The first issues that come to mind may be more centred around the technical capabilities of the system in terms of information output and getting the system to "work" rather than how "interdepartmental co-ordination" could be improved, or how "data redundancy" through information sharing could be reduced.

## 5.2 Reconciling Perceptions with Reality

Some of the most critical factors in reconciling misconceptions about the true capabilities of GIS are increasing awareness, education, and hands-on experience. Several outcomes can result from a planning staff that is poorly informed and educated about what GIS can and cannot do. The GIS may be perceived as a threat by those employees who may not be as computer or geographically literate as others. The system may also sit idle because no one was properly trained or no one was made aware of what application areas GIS was well suited to handle. As a result, planning staff may be still using manual methods that require repetition, long search times, and the collection of data from differing physical locations.

The perceptual gaps outlined in the previous section are the result of many factors. These are a combination of lack of interest, motivation, computer literacy, and one factor that is often ignored, geographic literacy. The lack of understanding of basic geographic concepts among those who are charged with using spatial data on a regular basis is astounding (Obermeyer and Pinto 1994, Monmonier 1993). "Geography is not adequately taught in public schools, particularly in the U.S. The result is a group of future professionals who lack some fundamental skills in understanding and using GIS technology" (Croswell 1989, 30).

Some of the tactics municipal governments and other organisations can use to reconcile expectations with reality as well as heighten awareness of GIS are the following:

- Provide some introductory sessions on basic geography: theories, concepts and methods of conducting research and data interpretation.

- Encourage and fund attendance at GIS seminars, trade shows and conferences. Although many of these are geared at specific concerns, exposure to talks and exhibits can benefit potential users in making them aware of how GIS tools are actually used in government as well as private business.

- Use a consultant to come in and give introductory talks on GIS. Consultants and vendors may be willing to provide an introduction and orientation to GIS in order to familiarise potential users/clients with the technology.

- Motivate potential users to become involved in the implementation process early-on. Getting the users of GIS involved in decision making processes related to system acquisition may help to reduce anxieties. It will also help to familiarise them with GIS concepts and issues and prepare them for changes that may have been unexpected had their involvement not been solicited.

- User involvement is also important from *an implementation success* point of view as it provides the system designers with an accurate perspective on user requirements as well as encouraging a co-operative spirit and active support by the user community (Croswell 1989).

- Incongruencies between expectations and reality are not limited to system considerations. They may also crop up where issues such as job security are concerned. Employers must attempt to assure future job-security. Although some jobs may be lost in the long term owing to job redundancy, enthusiasm and a desire to learn can certainly do no harm, and can only contribute to the increased possibility of continued employment within the organisation.

## 5.3 GIS Implementation and Organisational Change: What Conditions Lead to Success or Failure?

The introduction of a GIS holds great potential for municipal government. What must be emphasised is that municipalities must learn to change and adapt in order for that potential to be realised. A positive implementation process requires the co-operation of all employees who will inevitably be affected by organisational change. The manner in which these changes are introduced can also greatly influence the degree to which they are accepted (Somers 1989).

It has been suggested in the literature on GIS implementation that success tends to be the exception rather than the rule. With the promise of rather sophisticated technological tools, why are there so few *bona fide* success stories? Perhaps, the technology has not yet fully matured, or system managers still fail to set the right priorities in GIS development (Croswell 1989).

Wellar (1989) has even gone to great lengths in insisting that the current state of informed knowledge on GIS is seriously lacking. He claims that we do not know very much about GIS that is founded in past experience that may be able to help us in the future. Much of what we do know "is far more anecdotal than analytical, that it is far more particular than general, and that little of what is known or is claimed to be known has been derived as a product of methodologically designed research process" (Wellar 1989, 2).

Many other authors have also offered a veritable litany of explanations as to why so many GIS installations never accomplish what they were set out to do (Croswell 1989, Somers 1989, Wellar 1988, Innes and Simpson undated). Croswell (1989), in particular, provides a rather complete summary of these issues in the following list adapted from a presentation given at the 1989 URISA (Urban and Regional Information Systems Association) Conference entitled *Facing Reality in GIS Implementation: Lessons Learned and Obstacles to be Overcome.*

**Apathy and the Fear of Change**
- Afraid of organisational change
- Too conservative in outlook/lack of innovation
- Previous failure in information system development

**Planning/Management Support**
- Lack of commitment from top managers
- Inadequate high-level support or mandate
- Lack of understanding by management
- Lack of or inadequate implementation plan

**Organisational Co-ordination and Conflicts**
- Inadequate communication among participants
- Conflicts with main data processing organisation
- Internal power struggles

**Training and Understanding of Technology**
- Poor system documentation
- Lack of trained staff/recruitment problems
- Lack of understanding of technology

**Staffing Availability/Recruitment**
- Insufficient staff for operation of system
- Insufficient staff for planning
- Staff availability or recruitment problems

**Software Complexity/Maturity of Technology**
- Software or hardware not suited to desired application
- Immaturity of technology

- Software too complex/training or documentation inadequate
- Volatility of the technology

**Data Communications and networking problems**

- Data communication and networking problems
- Hardware operation/communication problems

**Data and Software Standards/Data Integration**

- Data integration or inconsistency problems
- No accepted standards for procedures or data

**Miscellaneous**

- Contract performance problems with service vendors
- Internal hardware/software procurement policies too rigid

Although the list is taken from information presented six years ago, many of the above points are still applicable. It is important to bear in mind that although GIS technology has advanced significantly over the past six years, the same organisational concerns emerged then as they do today. This again highlights the significance, timelessness and critical nature of the role of organisational issues in GIS implementation.

Croswell's list is quite exhaustive in its coverage of the potential pitfalls that can cause the failure of a GIS implementation process. A selection of Croswell's points will be further expanded upon, in order to provide some discussion on these obstacles. Obstacles have been divided into technical and organisational issues.

### 5.3.1 Technical Issues

Although the purpose of this thesis is to highlight the importance of organisational issues, technical problems can also act to impede the implementation process. These include many issues. For example, the type and capabilities of the hardware or software chosen must be well matched to the needs of the organisation. The choice of applications to develop must also fit with this same set of needs. Data conversion, often the most expensive step on the technical side is also critical.

### 5.3.1.a Hardware and Software Integration Choices

While applications represent the conceptual framework around which a GIS is built, hardware and software form its concrete framework. Many difficulties in GIS implementation on the hardware side stem from bridging the gap between existing information processing equipment, and new hardware and software (Campbell and Masser 1992). Decisions must be made regarding whether to maintain and integrate existing equipment into a larger information processing scheme that includes additional GIS hardware, or to completely do away with existing information processing resources.

The choice of starting anew presents advantages as well as a few problems. While purchasing new equipment and software possess the advantage of currency, the task of getting everyone to adapt to a completely new work environment is a challenging one. Old, tried and often successful work processes die hard, and it is often difficult to get employees who were comfortable with existing equipment to start learning a whole new set of procedures using new equipment.

Integrating new equipment with existing resources may be more challenging from a technical point of view, given the issues of hardware and software compatibility. But from an organisational point of view this route may be a more desirable one to take in that it represents a more gradual transition process for employees.

### 5.3.1.b Database Design

Database design represents the core and foundation of the GIS, and forms the basis around which applications are selected and eventually designed. In terms of its simplest definition, database design encompasses the choice of map layers, or spatial data to be collected and input into the system. Application areas are then limited by the choice of variables to be included in the database. Database design choices may be governed not only by the kinds of map layers to include, but also as to what level of detail data should be collected.

There are two broad approaches to the database design process at either ends of a conceptual scale (Public Technology 1991). One approach is to embark on an extremely comprehensive planning and database design process in an attempt to accommodate all potential applications. This may result in an inordinate amount of time spent in the data collection and conversion process, which is very expensive. Trying to satisfy all user needs at the same time may result in spreading too thinly the attention required to develop priority applications properly.

The opposite to the above approach is to concentrate too heavily on a single application. Focusing too narrowly on what is usually the first project to be implemented using the GIS software, usually results in the neglect of other possible map layers that for instance, would be useful in the design of subsequent application areas.

### 5.3.1.c Data Conversion

Data conversion is the process of converting a wide variety of non-digital sources to digital format for use in a GIS. Non-digital sources include paper maps, charts, and aerial photographs.

Through processes such as digitising (tracing) or scanning, data describing artificial and natural features on the earth's surface are entered into the GIS's graphic database. This step is one of the most critical because it represents the actual preparation of the graphic foundation on which the GIS is entirely based. It is therefore important that the information entered into the system be accurate as well as current.

For obvious reasons, a large urban land base with a diversity of geographic features tends to be more expensive to convert than a similarly sized rural area. Thus, smaller municipalities may benefit from their sheer size as a factor in reducing the costs of data conversion. Still, there does come a point where a jurisdiction becomes so small that automating land records may not create any long term benefit, even in terms of serving the public need. In these cases, municipal data is probably as easily managed and retrieved using more manually oriented methods.

An alternative approach in the case of small jurisdictions would be to convert some of the more basic types of land data--parcels, zoning, roads, statistical/planning district boundaries--for use in a lower-end desktop or PC-based GIS such as Atlas*GIS, MapInfo, or even ArcView, which is a member of a family of much higher-end GIS tools that could be brought in at a later stage if ever needed.

Other factors that may have impact on the success of implementation have to do with the conversion costs of already existing digital data into a format that is readable by the newly acquired GIS. Often, data conversion may have taken place at an earlier stage for a previous system that may have been abandoned.

5.3.1.d Implementation Time Frame

As discussed previously in the section on implementation models, the time frame over which implementation takes place can affect greatly the degree to which it is successful. For instance, Ballard's (1993) *Short Road Approach*, covered in chapter 3, possesses both strengths as well as weak points. While the approach has merit in its need to produce immediate results in order to keep decision makers on side, it may also falter because its short time horizon concentrates too heavily on present requirements.

The selection of an implementation time frame inevitably involves the selection of a set of trade-offs illustrated in the matrix below.

**Figure 17: Time Frame Trade-Off Matrix**

| | **Quick** | **Slow** |
|---|---|---|
| **Positives** | Provides demonstrable results quickly | Measured/cautious approach |
| | Gains management support from the outset | Time to conduct proper needs assessment provided |
| | Keeps management support in order to assure future funding | |
| **Negatives** | Possibility of a hastily conducted needs assessment | Requirement that management wait for results |
| | Focus limited to applications needed in the short term | Possibility of no immediate results or financial pay-off |
| | | Uncertain commitment or support, financial, or otherwise, from management |

Trade-offs usually involve deciding between a quick approach that provides demonstrable results, which look positive in the eyes of management, and a slow but measured process that carefully examines all implementation alternatives and undertakes a proper needs assessment.

### 5.3.2 ORGANISATIONAL ISSUES

The importance of organisational issues forms the basis of the main arguments of this thesis. For many years the tools required to carry out sophisticated spatial analysis have existed in many forms: large mainframes, workstations, as well as a variety of PC-based systems. The number of products, vendors, as well as consultancy firms specialising in the resale, installation and provision of implementation planning advice, have literally exploded over the past ten years. The sophistication of the product has also risen to a level where many relatively inexperienced users are now able to easily conduct many types of geographic inquiry and analysis. Unfortunately, these capabilities are being harnessed by individuals regardless of their skill in geography.

The main problems concerned with system integration and implementation have consistently proven to be organisational ones--issues that deal with how people and technology interact, and how the introduction of new innovations causes changes in how people interact with each other. These are the issues that will be covered in the sections to follow.

#### 5.3.2.a Institutional and Political Issues

This category of obstacles can be subdivided further into two areas of concern. The GIS implementation process can be hampered by 1) natural resistance to change and by 2) political power struggles and clashes.

First, while there is natural resistance to change in any organisation, there are certain inherent characteristics of public sector organisations presenting additional constraints that can act to further impede the implementation process (Somers 1989, Campbell 1992).

These include:

- Rigid hierarchical organisational structures
- Emphasis on short-term goals driven by the annual budget process, limiting long term planning
- Low propensity for change and a resistance to new ideas
- Rigidly specified procedures controlled by legislation and habit, and a reliance on procedural, regulatory practices
- Civil service job characteristics, rigid job descriptions
- Few incentives for risk-taking
- Visibility and sensitivity to the public and the press, especially at the municipal level

Secondly, the practice of municipal planning is often a highly emotionally charged process. Personality clashes are naturally quite common when dealing with many types of controversial issues. These clashes and power struggles that occur among individuals with divergent points of view can even result in the reversal of seemingly logical decisions. "It is not that the decisions made by people lack logic, it is that the people involved have multiple objectives. The parties to a decision are commonly operating with several diverse agendas that can change abruptly. Wherever people interact, there are politics" (Aronoff 1989, 249).

The struggle for power in an organisation is one that is fought with whatever information or knowledge *weapons* available. Knowledge truly is power, and access to as much knowledge and information as possible tends to hold a most coveted position. It was mentioned previously that, by its very nature, GIS is a subversive tool. This is true in the sense that GIS presents challenges to organisational power structures. "It separates the *ability* to make a decision from the *authority* to make a decision" (Somers 1989, 45), and thereby poses real threats to the so-called *real* decision makers.

The effect all this has on the organisation has many outcomes. One of the more limiting ones happens to be its effect on the level of information sharing within the organisation. The benefits of sharing information are still highly theoretical in nature. This means that although the sharing of information across departmental boundaries is made possible through GIS, political realities and considerations often prevent this from occurring in a realistic sense. As an example, the theoretical advantages of shared data would tend to be viewed less positively by those who felt that it may lead to closer scrutiny of their activities (Campbell 1992).

For instance, one department may not want other departments to have access to its databases under a new information system's shared data arrangement. Technological imbalances among departments can lead to resentment and jealousies of those who have more sophisticated equipment. "At times, this leads some departments or municipalities to avoid participating in the development of systems or refuse to share data" (Madziya 1990, 311). Campbell (1992) again stresses the level of apprehension many organisations feel when faced with a proposal that implies a change in how data, that may have been previously jealously guarded, is now *up for grabs.*

The above pitfalls are not limited to disputes and other forms of "covert non-cooperation" (Campbell 1992, 91) within an organisation. Suspicion and animosity can grow between organisations and agencies that are now forced to share information under the umbrella of a centralised database. Campbell's (1992) GIS implementation study of Massachusetts and Vermont recounted some of the fierce battles and reactions provoked by computer-based systems holding information on individual properties which were essentially located and controlled within the state bureaucracy. In a similar study of GIS implementation in Vermont, Van Buren (1991 in Campbell 1992, 92) noted "the deep concern many municipalities had of the state and regional commissions obtaining access to town tax information." In this case, computerised mapping was likened to giving your neighbour access to your bank account.

### 5.3.2.b Management Support and Funding

"Where GIS implementation involves a number of agencies, jurisdictions and organisations, management involvement and understanding of major issues is critical (Public Technology 1991, 43).

Because GIS implementation has such a broad scope, one of the most important factors than can affect its success is the degree to which top management support is obtained. Coupled with this factor is the key presence of a strong individual that is dedicated and committed to the entire scheme. This project *champion* or *GIS guru* may be an individual at any level in the organisation, but is usually a more technically-oriented employee with a more corporate outlook that extends beyond the limits of their prescribed position. Enthusiasm, personal drive and commitment of this individual is then crucial in keeping management on-side. Campbell (1992), found that the enthusiasm and skill of key individuals in organisations for the securing of political commitment and resources was absolutely crucial.

A GIS implementation project also requires significant expenditures of time and money. This, more than any other factor related to management control, highlights the importance of approval by the top decision makers in an organisation. While project approval is necessary for many types of capital improvement projects, GIS is different because top management is seldom familiar with GIS technology. The presence of a strong-willed individual certainly helps, but there are still great challenges to be met in acquiring top-management support. Some managers may understand the basics of computer technology, but few would be comfortable with spatial concepts or even computer mapping in particular (Korte 1994).

Thus, while the involvement of upper management is critical, it is also problematic because of the complex technological issues involved. The challenge exists in bridging the gap between less technically oriented management and the need for an understanding of these issues in more detail.

### 5.3.2.c Training, Expertise, Hands-on Experience and Attitude

There is no doubt that the success of a GIS implementation program can only be improved with a healthy commitment from management. But without the commitment of the eventual users of the system, success can only be questionable.

In this sense, the attitude taken by the user in approaching the GIS learning experience is most critical. Even if proper training is provided, there is an enormous difference between an employee who comes away from the training experience following instructional steps blindly, as opposed to one that grasps the important concepts, and combines these concepts with the interest, motivation and desire to learn.

The problem with employees that simply follow steps and instructions blindly is that they are unable to cope with situations that may even deviate slightly from the norm, or from any examples they became accustomed to during the training process. Those who can apply a solid understanding of general concepts across many situations are often guaranteed more success.

Hands-on experience is an invaluable asset gained as part of learning how to use GIS. GIS skills can very rarely be learned by simply reading technical manuals, learning about theoretical aspects or simply listening to instructional lectures. The user must be fully immersed in the tools of the trade and must learn by trial and error, making mistakes along the way. GIS skills also start with a knowledge of ideas and concepts that are often not even spatial in nature. This entails a knowledge of how databases management systems work and are used to combine information from a variety of sources.

### 5.3.2.d Attitudes Toward Technology

Croswell's (1989) list of potential impediments to GIS implementation included an entry entitled *Apathy or Fear of Change*. Of all the categories, it is interesting to note that this one appears at the top of the list. As stated in the introduction, while technological tools may be present, it is ultimately up to GIS team leaders and project leaders to instil a positive sense of interest among end users. Related to issues of training and motivation, attitudes toward new innovations can alter the degree to which they are adopted and accepted.

### 5.3.2.e Approaches to the Planning Process

Chapter two highlighted some of the conflict areas between the urban planning process and the use of GIS technology in planning. Paramount among these conflicts is the fact that GIS operates in concrete, logical and dichotomous space. In comparison, planning processes tend to operate on a more analog, unpredictable or even irrational level. "Technology has a concrete existence. In principle, the capabilities of the technology can be rationally assessed by means of a physical test. The results can be expected to be repeatable. However, the decisions that people make are not nearly as predictable" (Aronoff 1989, 249).

Bridging the gap between expectations and reality concerning GIS capabilities is far from the only challenge in successful system implementation. In a planning context, the gap that exists between the seemingly black-and-white world of GIS and the haphazard, emotional and political realm of planning is as important. Breheny (1987, in Scholten and Stillwell 1990) highlights five points that define the conceptual chasm that persists between planning and GISs.

- **GIS deals with concrete and absolute space, whereas planning is concerned more with the subjective and abstract.**

Relative to GIS, there are no absolutes in planning. Planning operates at the intersection of social and physical space. GIS can deal quite well with concepts of physical space, but individual spatial behaviour, abstract, subjective and relative notions of space are more difficult to deal with. In addition, this type of information is hard to quantify which makes storage and analysis in a GIS all the more challenging.

- **Planning activities are often of a non-routine character and the policy-making process knows many irrational moments.**

In contrast, GIS is treated as a tool used for the rational understanding of spatial patterns and behaviour. As planning issues and priorities change over time with political parties and personalities, so do planning cultures and paradigms. GIS designers must conceive of systems that are more flexible in responding to these changes in the evolution of decision-making processes.

- **The costs of training, support, customisation and database creation are largely underestimated in project plans.**

The principal costs items given emphasis usually include hardware, software, applications development to the detriment of other items which are more critical over all stages of the implementation process. These items include education and training, technical support, creation of digital base maps, and the input of attribute information.

- **The challenge of providing planning and policy information for decentralised processing from a centralised information source.**

GIS operates under seemingly paradoxical conditions. While one of the purposes of GIS is to provide an efficient store of information that can be shared among members of different departments, this store of information often exists as an entity in a central location, controlled by a single knowledgeable individual or a very small group. It is this ironic characteristic of many GIS models that leads inevitably to power struggles between departments that don't trust others with access to their data.

- **Planning involves much more than automated information processing.**

Planning is a human act, only aided by technological tools. Planners rarely depend solely on GIS generated data in order to formulate recommendations to city council or other municipal officials. While GIS is supposed to make information more readily available to planners, one must bear in mind that there exists the danger of relying too heavily on computer generated data in order to reach a decision. In chapter 3, it was mentioned that computer generated data holds a certain objective mystique about it. While this is true to a certain extent, members of the public may be equally wary or suspicious of such data and may not always be convinced of its merit.

In fact, many planning decisions involve issues that cannot be solved with GIS alone. For example, the decision to locate a given public facility, to allow certain commercial enterprises into a community, or to change a zoning designation involves much more than assessing the suitability of the site to the proposed project. It involves assessing impacts on wider geographic and time scales, as well as input from the public. One should not be tempted to use the GIS simply because *it is there*.

The above is not meant to imply that GIS is unsuited to analyse data at broader spatial scales. The implication is that at any scale, many more issues, aside from those which are easily quantified, may come into play. For instance, it would be quite challenging to incorporate some notion of public opinion into a GIS analysis of site suitability. While the data used in a study may indicate that a particular site is suitable for a big-box retailer, for instance, public opinion and public perception about what is good for their community may differ from what the numbers say.

The common theme that links many of the above points is that the introduction of GIS into the realm of planning has somehow been problematic. While GIS is supposed to make the task of municipal planning more streamlined, its dichotomous nature sometimes fits uncomfortably within the more amorphous nature of the planning process. Certainly, this does not imply that GIS should not be used altogether, or that using GIS will automatically prevent planners or politicians from making irrational or politically-driven decisions. As was pointed out in chapter 3, the use of GIS may even abet such activity by providing the necessary information ammunition required to persuade or mislead political adversaries.

In summary, GIS does have its place in the planning process, but one must remember that it forms only one of many inputs. If used properly by adequately trained users, it can help to streamline the more repetitive or mundane procedures in the data processing and spatial analysis phases of examining a planning problem. GIS can also help to uncover spatial patterns and phenomena that may have been too difficult and time consuming to investigate in the past.

## 5.4 Chapter Summary

One of the major organisational obstacles to GIS implementation is the perceptual gap that exists between expectations and reality concerning the capabilities of GIS. This chapter outlined some of these differences and provided some solutions to rectify them. By preparing staff, involving them in needs assessments, and educating them about the implementation process, many misconceptions about GIS can hopefully be alleviated.

Some of the major obstacles to GIS implementation on both technical and organisational fronts were also covered. In terms of technical obstacles, hardware and software integration along with database design, data conversion and the proper implementation time frame can influence the success of a GIS.

But more importantly, organisational issues affect how the system is managed, accepted and eventually used. Regardless of technological quality, the GIS will fail if no structure exists to manage it properly. While technical obstacles do have the potential to cause setbacks in the implementation process, organisational and institutional factors tend to play a more critical role in influencing the success rate of many GIS implementation schemes.

## 6.0 CONCLUSION

> *It should be borne in mind that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain of its success, than to take the lead in the introduction of a new order of things... The innovator makes enemies of all those who prospered under the old order, and only lukewarm support is forthcoming from those who would prosper under the new. Their support is lukewarm partly from fear of their adversaries, who have the existing rules* [bureaucracy] *on their side, and partly because men are generally incredulous, never really trusting new things unless they have tested them by experience. In consequence, whenever those who oppose the changes can do so, they attack vigourously, and the defense made by others is only lukewarm... The populace is by nature fickle; it is easy to persuade them of something, but difficult to confirm them in that persuasion* (Machiavelli 1512, in Harding 1992,4).

Regardless of context, managing organisational change is seldom easy. Machiavelli's "Prince" demonstrates that this challenge is truly a timeless one. New methods, policies and tools will always be regarded with suspicion by those who hold power and are accustomed to their own ways and means of carrying out decisions. The slightest threat to existing political and bureaucratic structures and procedures is often viewed as subversive or even treacherous. The introduction of new innovations such as GIS is no exception.

For instance, the introduction of GIS holds great possibilities for the sharing of information resources within municipal government. While this is viewed as a benefit by those who are proponents of GIS and the new types of arrangements that are made possible though its adoption, many view data sharing as a threat to departmental sovereignty. Opponents are often suspicious of anyone outside their circle wishing access to their information. In terms of other areas of potential conflict, GIS allows planners and other municipal officials to access a wide variety of information and perform analyses that can potentially cause much controversy, as was outlined through the various examples in chapter 3.

To summarise, the GIS implementation process is a rather formidable one, in that it represents a departure from those challenges posed by the implementation of conventional management information systems. One can gain a clearer understanding of why GIS is different by recognising the following points. These points fall into three broad categories: the importance of organisational and managerial factors, the critical role of geography and the use of GIS in spatial/analytical exercises, and the political, paradoxical, subversive nature of GIS.

**Organisational**

- Two critical factors required in a successful GIS implementation process are "will and skill" (Obermeyer and Pinto 1994). *Will* refers to the political will to initiate and follow through with a GIS implementation plan. *Skill* refers to the skills on both managerial and technical fronts that are required in order for the plan to result in a successful outcome.

- GIS success does not solely involve a technical understanding of the technology, but also an understanding of how technology can affect the entire organisation.

- The GIS implementation process is often a long and arduous task that seldom produces immediate results or benefits. The task of keeping management support given these difficulties is critical.

- The GIS implementation challenge is different because management is seldom familiar with spatial or geographic concepts, much less how these concepts are used in the context of information systems.

This leads us to factors relating to why the "G" in GIS really matters.

**Geographical/Spatial**

- Traditional education in geography tends to emphasise aspects such as the "where, " instead of the "why"--**Why** are things where they are?

- Despite advanced technical capabilities, GISs are still not being used to their fullest potential. Most GIS users do not even begin to tap into the power of these systems. Most rely on GIS as a storage and map output tool. The current emphasis on GIS as a means to store spatial information undersells its value as an analytical tool (Obermeyer and Pinto 1994, 53).

- A lack of individuals properly trained in geography hampers the advanced use of GIS as an analytical tool.

- A lack of awareness of geographic concepts can result in the unintentional misuse of the technology and its products. Unintentional misuse is often committed by those unaware of geographic fallacies and concepts. Overt misuse, committed by individuals highly skilled in geographic analysis may use GIS to persuade, and potentially mislead, the unaware or the unsuspecting.
  They may also use their skills to work against adversaries in the political process.

This leads us to the importance of political factors in GIS implementation.

**Political**

- GIS can be construed as a subversive technology because it has the potential to empower those outside the conventional decision-making process.
- GIS is paradoxical because it often involves the centralised control of shared databases for the decentralised needs of planning.
- Diverse agendas operating amongst the cast of characters of any organisation turns GIS into a competitive tool of power. Those who have access to information and know how to use it, may do so to their advantage.

The planning field has much to benefit from the introduction of GIS. This thesis has outlined the many application areas where GIS can be of help in streamlining the business of municipal government. Still, GIS only forms a part of the set of tools that may be involved in the decision making process for planning. Many challenges still exist. The design of systems that are more responsive to the often subjective and abstract nature of the planning process must be further pursued.

Once the decision to adopt GIS technology has been made, municipalities must realise that the implementation process does not stop at simply acquiring hardware and software. It is a long term undertaking that often begins many years before acquisition and must continue to be re-evaluated as the organisation changes and continues to evolve.

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