THE ROLES OF GIS IN PLANNING:
A CRITICAL APPRAISAL OF THE TECHNOLOGY FOR URBAN AND REGIONAL PLANNING

by

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Abstract

The proliferation of Geographic Information Systems (GISs) in the planning profession has been phenomenal in recent years. However, it is not clear what roles GIS can play in the today's planning context. This thesis sets out to explore this topic through the investigation of the nature of planning, the history of computer application in planning, the GIS technology itself, and half a dozen real-life GIS applications.

On the "demand" side, the literature review shows that today's planning is highly political in nature, with technical concerns having receded to a secondary place of importance. As a result, the use of information in the profession is very much communicative, shifting the emphasis from the analytical use of information to a more presentational use of information.

While on the "supply" side, the study of the technology itself reveals that GIS is a hybrid technology that is the marriage of electronic mapping, database technology, and computer modeling. It has the technological potential to be customized to serve different ends in planning.

There is an apparently good match between planning's use of information and GIS's functionality, suggesting that there is considerable potential in the application of the technology to the profession. Unfortunately, the current theory about GIS application in planning focuses rather narrowly on the technical use of the technology and turns a blind eye on the technology's capability to aid communicative planning.

This thesis points out that the current theory on GIS's application in planning is inadequate for the profession to take full advantage of the technology. It concludes that GIS can serve all three major information processing functions: information presentation, information management, and information analysis, and recommends more presentation-oriented use of the technology in planning.

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If you do not know to which port you are sailing, no wind is favorable.

—Lucius Annaeus Seneca

1 Introduction

This thesis deals with the roles of GIS—a technology that is relatively new but quickly gaining popularity in the planning profession. This first chapter contains four parts. The first part is background information about this piece of research, showing its relevance to the planning profession. The second defines the focus of the research and explains the rationale behind it. The third clarifies the scope and the limitations of the research, and the fourth lays out the structure of the thesis.

1.1 Background and Trends

Why is this piece of research being conducted at this time? It is because of the rapid rise of GIS technology in planning. This is neither an accident nor a passing vogue, as elaborated in the following sections.

1.1.1 The popularity of GIS in planning

Geographic Information System (GIS) has become a very popular topic in urban and regional planning in the last few years. On the research side, there is an explosion of literature, formed by newly published journal articles and books on the application of this technology in planning (Klosterman 1992). For example, in an annotated bibliography compiled in 1990 that contains 1,500 entries about computers in planning, the term GIS occurs 670 times, compared to spreadsheets 6 times, databases 104 times, and models 8 times (Polydorides 1990). On the practice side, many local and regional planning departments have adopted the technology, and even more are looking at it with great interest. A 1989 study reported that more than one-third of the large and medium planning departments in North America (i.e., those having a jurisdiction over 75,000 in population) had acquired a GIS, and two-third of those that had not done so planned to purchase one sometime in the period of 1990 to 1993 (Juhl 1989). Currently, there is no sign that this trend will alter its course in the foreseeable future.

1.1.2 Trends underlying the rapid GIS growth

This rapid proliferation of GIS applications in planning can be attributed to a number of reasons:

- Advancements in the design and production of micro chips have been significantly reducing the cost of computer hardware on the one hand, while drastically improving its performance on the other. Inexpensive memory and fast micro processors have made computer databases and graphical interfaces widely available to the majority of computer users. Even so, the software as a whole seems to have been experiencing a more rigorous growth, utilizing every bit of the newly available computing resources. As a result, computer applications have become more and more powerful, yet less and less intimidating to use. The increasing power/cost ratio and ease-of-use of GIS in particular are opening the door ever wider to the application of the technology in the planning profession.

- Moreover, the widespread financial austerity of government, the growing global competition, the restructuring of the economy, dwindling natural resources, and the deteriorating environment all put pressures on the various levels of governments to make decisions that do more with less and are proactive instead of reactive. Since information is a vitally important element in quality decision-making, governments are in constant search for innovative ways to collect and make the best use of it. GIS, as a type of information technology, has become one of the most prominent tools that promises to bring revolutionary enhancement into information support for decision-making.

- The use of information technology is also a self-propelling process—it consumes as well as generates massive amounts of information that can only be processed by even better information technology. For example, the amount of data that is constantly being sent back to the earth from remote-sensing satellites is so huge that it is unthinkable to merely manage those data, let alone to utilize them, without the help of computers. As an example, more than 95% of the images that have been sent back by the Landsat satellite have never been able to meet the human eye (Gore 1991). As our society moves further into the so-called information age, a new culture is emerging—information is expected to be provided and accepted in digital forms. In recent years, GIS has become the most favored technology to handle spatially-related digital information and thus is in ever greater demand.

The above-mentioned themes that caused GIS to be one of the fastest growing areas in the rapidly growing computer industry are ongoing trends. Therefore, the popularity of

GIS is expected to continue to grow. In the past four years (from 1991 to 1994), world-wide GIS sales grew by more than sixty percent; while in the next 4 years (from 1995 to 1998) it is expected to grow by another sixty percent, reaching 1.2 billion US dollars by 1998 (O'Malley 1994). GIS is becoming a technology within the reach of more and more planners and an important part of their working environment. Under such circumstances, it is of great significance to understand critically the role of the technology in and its increasing impact on planning.

1.2 Research Focus and Its Rationale

In the current surge of GIS application in planning, there are many aspects about it that have not been researched and well-understood. An initial literature review has revealed to the author of this thesis that, despite the versatility of the technology, the use of GIS in planning or the vision about using it for planning is rather confined. This contradiction intrigued the author to embark a further investigation upon GIS's role in planning.

1.2.1 The utility of GIS in planning

GIS is a powerful tool for managing, analyzing and presenting information that is associated with geography. Since most planning information is location specific, GIS can be utilized to process this information. GIS brings efficiency to planners through fast retrieval, easy maintenance, and compact storage of planning information so that they can better carry out their responsibilities. Because of this efficiency, planners can use GIS to pull together diverse information from different sources to explore patterns, relationships and trends, some of which would not be apparent or detectable without this integration of information. The analytical capabilities of GIS, which are based on rigorous quantitative methods, can be used to enhance the quality of planning analyses and in turn help to boost the technical credibility of planners. Once the required information is available in proper digital form, GIS can generate quality maps with great ease and little additional cost. As a result, planners will not have to mete out the use of these maps for analytical and presentational purposes.

1.2.2 The focus of current GIS application in planning

Despite the popularization of GIS in planning in recent years, however, the role of this technology in planning has been implicitly or explicitly confined within the context of the "technocratic planning" tradition, which essentially regards planning as an endeavor of professionals to solve technical problems. In the literature, there is considerable discussion about GIS application in planning from a substantive perspective, i.e., dealing with concrete planning problems such as those in housing, transportation, land use planning, etc. By contrast, there is little concern expressed regarding the actual and potential impact of GIS on planning from a procedural point of view. For example, the discussion has not touched questions such as:

- Who should be the users of GIS in a planning process?
- What diverse roles can planners play with GIS?
- How should GIS output be reconciled with the output from a political process if they conflict with each other?

- Since the data available in a GIS largely determine what planning issues (i.e., planning agendas) the GIS can support, is it not problematic to leave the decisions of including and excluding data items only to technical experts?
- Can GIS also enhance social qualities, such as democracy—people's control of their collective destiny, of the community being planned for?

With the self-imposed confinement of technocratic planning tradition, GIS seems to be perceived simply as a tool useful for technical problem-solving in planning. Consequently, among many of its capabilities, the analytical one has become the focus of research and practice. As manifested by Goodchild (1987):

> . . . the ability to manipulate spatial data into different forms and to extract additional meaning from them is at the root of current interest in GIS technology . . . many definitions of GIS make reference to the four basic functions of input, output, storage and analysis. From the perspective of spatial analysis the first three exist to support the last, which is seen as the real purpose of a system.

In contrast, both the history and the functionality of GIS seem to suggest that the technology is very capable of visualization and information management, which are very useful for problem-solving as well as the arguably most important activity in modern planning—communication. It is also reported by many authors that the current use of the technology is focused upon those so-called low-order planning activities, which chiefly consist of presentation and information management activities (Wiggins and Ferreira 1991; Batty 1991). What then are the reasons that have caused the mismatch of the perception of GIS and the actual use of the technology in planning? Among other plausible reasons, is it possible that the current paradigm that guides GIS application in planning is deficient and the practice actually has its theoretical justification (i.e., the theory lags behind the practice)?

1.2.3 Should GIS's role necessarily be so confined?

In this thesis, it is hypothesized that GIS's role in planning can go beyond technical problem-solving. The purpose of this thesis is to explore what current and potential uses GIS has for planning. In other words, the emphasis is on what this technology may be, and should be applied to, rather than how it should be successfully implemented. Hopefully, this study will help solve the contradictions with regard to using GIS in planning, and make it an even better tool for the profession in the upcoming decades.

If the hypothesis is false, the use of GIS in planning will necessarily be very limited since technical problem-solving comprises only a small part of contemporary planning. More significantly, this false hypothesis implies that, in terms of their roles in planning, GIS is no different from those computerized modeling technologies that were tried in planning in the 60s and early 70s. The lack of success of those large-scale modeling attempts in planning can, at least, be partially attributed to the inability of such technology to be harmoniously integrated into modern planning processes. If GIS planning application follows the direction that those large-scale planning models took, it will be subject to the same pitfalls as the previous attempts were, even with today's more sophisticated and powerful computing hardware and software.

If the hypothesis is true, then the current focus of GIS application in planning sends a wrong message to GIS developers and GIS professionals as to what planning really needs from the technology. For example, when the emphasis is on the analytical capability of GIS, it is unlikely for developers and GIS professionals to give high priorities to improving presentational features. It is even less likely for them to make GIS conducive to tasks such as mediation, negotiation and public participation. The current technocratic focus also alienates the majority of planning practitioners, whose role in planning is more of advocates, advisors, mediators and facilitators rather than solely technical experts, from the technology. They cannot see much relevance of GIS to their jobs, if the essence of applying the technology in the field is only technical problem-solving.

1.3 Scope and Limitations

In order to be feasible, any piece of research has its finite scope and hence limitations. This piece is no exception. It approaches planning and GIS with its particular angle.

1.3.1 Public domain planning

Unlike many other articles on GIS applications in planning that automatically confine themselves to the domain of rational planning, which consists of mainly technical problem-solving activities, this thesis regards rational planning as a subset of a wider planning spectrum. Here, planning refers to making guidance for future actions that will have impact on the public in general and individual citizens in particular. It will be examined in the context of Western democracies, in which the planning process usually involves multiple parties, such as elected officials, bureaucrats, citizens, with different vested interests and levels of political power. The concept embraces a wide range of planning endeavors such as transportation planning, health planning, housing, and land-use planning. It is what John Friedmann (1987) calls "planning in the public domain," or John Forester (1989) calls "planning for public well-being."

This type of planning is characterized by so-called "ill-structured problems," i.e., problems without clear definition but with many interrelated and sometimes conflicting objectives, problems that have to be tackled with incomplete knowledge and information, and problems whose solutions are sensitive to both rationality and politics. For instance, the results of a strategic transportation planning project in a city will have many kinds of impacts on the community and its members: environmental—in terms of air and water pollution, noise, and energy consumption; economic—in terms of jobs, public expenditure, and movement of goods and people; cultural—in terms of the image of the city, street social activities and heritage conservation; political—in terms of benefits and costs to different social groups. It is difficult to make trade-offs between conflicting impacts purely quantitatively because there is no way to find out, for example, the value of cleaner environment versus that of economic well-being without value-laden judgment. With current understanding of the issues involved in transportation planning, many of the impacts cannot be accurately calculated in meaningful quantitative form. Different people have different concerns about the transportation system in their city: local residents are concerned with safety and noise; business people, traffic capacity; commuters, peak-hour congestion; pedestrians and cyclists, street amenity; etc. These concerns become part of the planning agenda through political power playing.

1.3.2 The focus of this thesis

In this thesis, a Geographic Information System (GIS) is defined as a computer system that inputs, stores, retrieves, maintains, analyzes geo-referenced data and displays information cartographically. The term GIS also refers to the technology underpinning the systems that fit the above definition. Any implementation of GIS is necessarily based on other technologies: for example, the display of information by GIS can only be realized with some kind of output devices such as a CRT monitor, a printer or a slide maker. They are all treated as part of GIS in this thesis and hence their functionality as part of GIS's functionality. Therefore, technologies such as networking, virtual reality, artificial intelligence, and so on will all be considered part of GIS in this sense.

This thesis is neither a textbook to introduce GIS technology to novices, nor a comprehensive review about the latest development of the technology. The author has painstakingly avoided plunging into technical details, such as the meaning and the difference between the concepts of raster and tessellation, so that the focus of the thesis is not lost. The few technical concepts that are used in this thesis are explained conceptually to facilitate the discussion.

Moreover, this thesis will not discuss the necessary conditions such as technical expertise, political support, financial resources, computing hardware/software, and implementation tactics for successful GIS application in planning. Rather, it focuses on the potential application of the technology to planning in general. This thesis approaches planning procedurally rather than substantively. Therefore, substantively different planning endeavors, whether they are transportation planning, environmental planning, or health planning, are all treated to be of no fundamental difference in this thesis.

1.4 Methodology and Organization

The information that this thesis is based upon is from three sources: a literature review, an electronic discussion forum, and four interviews of local planners. The thesis starts with the introduction of the research and ends with a conclusion chapter, with the context of the discussion for the research focus, GIS technology, GIS's application in planning, and the analysis of GIS's role in planing in between.

1.4.1 Research information sources

Since the thesis examines the role of GIS in planning on a general level, it is only appropriate to carry out the analysis on a broad literature base. This base includes books and journal articles on planning in general, planning theories, computer applications in planning, GIS technology, and GIS applications in planning. The literature on planning in general helps to define the scope of planning. Planning theory literature exhibits alternative planning paradigms. The literature of computer applications in planning offers past experience of applying computing technology for planning, which may also be applicable to the particular technology under scrutiny. The literature on GIS informs what the technology is and what it is capable of. Further, the literature about GIS planning applications suggests the ways in which and the areas of planning to which GIS has been applied and what may be the theory behind the current use of this technology in planning.

Moreover, the *GIS-L (comp.infosystems.gis),* an electronic discussion forum on the Internet, has been frequented for the last two years to feel the pulse of ongoing GIS research and practice in the field. The forum is also used to develop ideas and to get feedback on those ideas. The composition of the subscribers of the forum is rather diverse: it consists of GIS theorists, GIS developers as well as GIS practitioners in the field. Many of the active participants of the forum are GIS pioneers, computing gurus, and seasoned planning professionals. Consequently, the opinions and advice voiced in the forum are often insightful and occasionally inspirational. On the other hand, like the authors of the literature on GIS and its application, most of the participants of the forum are also enthusiasts and stake-holders of the technology. Therefore, they tend to hold a "GIS-centric" view, often regarding application of the technology as the ultimate goal.

Lastly, four interviews with planners in local municipalities (North Vancouver, North Vancouver District, Richmond and Vancouver in the Greater Vancouver area) have been conducted to investigate the application of GIS in local planning departments. The attitude toward the technology that was reflected in the interviews represents perhaps a more typical one that exists among planning professionals: they generally favor but feel no compelling need for the technology. In contrast with those who work directly with the technology, planning professionals in general seem not to be so prepared to embrace the technology in any major way.

1.4.2 The structure of this thesis

Following the first chapter that provides the background, raison d'être, methodology, organization and limitations of this thesis, chapter two is concerned with the wide and ever-changing domain of planning profession from a theoretical point of view. The chapter is designed to examine the nature of planning: is it a technical problem-solving endeavor, or purely a matter of politics? Only in relation to the nature of planning can GIS applications in planning be meaningfully judged in terms of their usefulness to the profession. For example, if involving the general public is a vital part of planning and GIS sets forth to weaken the effectiveness of public participation in planning because of its inability to adapt to participatory planning processes, then the usefulness of technology to planning is seriously questionable. Since GIS is a type of computing technology, it necessarily shares in its application to planning many of the advantages as well as the pitfalls that are common in the application of other computing technologies to planning. Therefore, a discussion of the history of computer applications in planning is included in chapter two.

Next, the thesis will explore GIS technology in particular, by presenting its origins and evolution, its definition and its common functionality in chapter three. Intellectually, GIS has its roots both in cartography and computer modeling in planning. Technologically, GIS is the product of marrying other existing computing technologies such as those of computer graphics and database management. As a result, GIS has a wide range of features that will in turn determine its application potential in aiding planning. For this reason, chapter three is constructed to define the technical scope and limitations of applying GIS for planning.

Chapter four contains six real-life cases in which GIS has been utilized in various planning practices. These cases are presented to show how and for what purposes GIS has been used in implementation. Care has been taken to ensure that those cases are sufficiently different from each other so that they can reflect a wider range of use of the technology in planning. The six cases are from the United States, Canada, the United Kingdom, Holland, and Australia.

Chapter five starts with a critique on the current technocratic use of GIS in planning. Then, based on the discussions of the nature of planning, the history of computer aided planning, the functionality of GIS, and the cases of GIS application for planning, chapter five analyses the role of GIS through the purposes of using the technology and the use of the technology in different stages of the planning process. Chapter five also contemplates the appropriateness of different hardware-software configurations in the implementation of the technology in planning.

Finally, chapter six summarizes the findings and implications of the previous chapters, suggests future research topics, and speculates on the future of GIS in planning. By this point, the thesis will have concluded whether GIS is a versatile technology that is capable of more than helping planning professionals solve technical problems. The conclusion calls for more research about what kind of impacts GIS has on planning processes and how GIS can be best meshed with participatory planning activities. The future of GIS will certainly lie in the further development of computing technology in terms of processing power, storage capacity, transmission speed, and human-computer interfaces. But the demands from various GIS users, in which planners are only one among many other groups such as scientists, engineers, business people, administrators, will also shape the ultimate form of the technology.

2 *Context of Applying GIS in Planning*

GIS has been widely regarded as a very promising addition to the planner's tool box. There is no doubt that, with its help, today's planners can do many tasks that were impossible to do before due to their excessive technical complexity, time consumption and hence cost. However, does this necessarily mean that GIS has a central role to play in planning, and that it is a valuable tool for planners? As the old wisdom goes: "it does not really matter how good a hammer is when all you need is a screwdriver." The actual and potential usefulness of the technology in planning can only be examined with reference to the overall values and objectives of the profession. The first section of this chapter, therefore, attempts to sketch some historical trends that are pertinent to the focus of planning in different times.

The second section of this chapter deals with the use of information in planning. On the one hand, the focus of this thesis is the use of GIS technology in planning: GIS is essentially a type of information technology—its input, output and what it processes are all information. On the other hand, information has a vital role to play in planning (Scholten and Stillwell 1990). Thus, it is especially instrumental to look at how information has been used in planning before we embark upon the investigation of GIS application in planning.

GIS is the latest surge of computer application in planning. Moreover, it is an integration of many other computing technologies, many of which have been in one form or another applied in planning, and hence has inherited a lot of its traits from those technologies. Therefore, it would not be too far-fetched to assume that GIS shares much potential as well as many limitations with other computing technologies. Section three of this chapter discusses computer use—its history, current state, purposes, and limitations—in planning.

2.1 The Evolution of Planning

In this thesis, planning refers to "community and regional planning" and its variations such as "urban planning", "rural planning", "city planning", "town planning", etc., in a western democracy. There are many different perceptions about the profession, both outside and within planning circles. Perhaps, the most popular one is to perceive the planner as a technical expert, concerned with the efficiency and aesthetics of a geographic area. Other well-known perceptions include the planner as: public servant, facilitator, advocate, mobilizer, and so on (Friedmann 1987). Yet even more perceptions are the combinations of the above-mentioned ones. Although some of these perceptions contradict each other, all of them seem to have their validity in reflecting the diverse nature of the profession. Behind this apparently confusing cognizance of the profession, however, there are some disçernible trends in what planners have been doing and what they have been striving for.

To aid the discussion, the history of planning, which started as planning became a new profession at the end of last century, has been divided into three distinct periods of time:

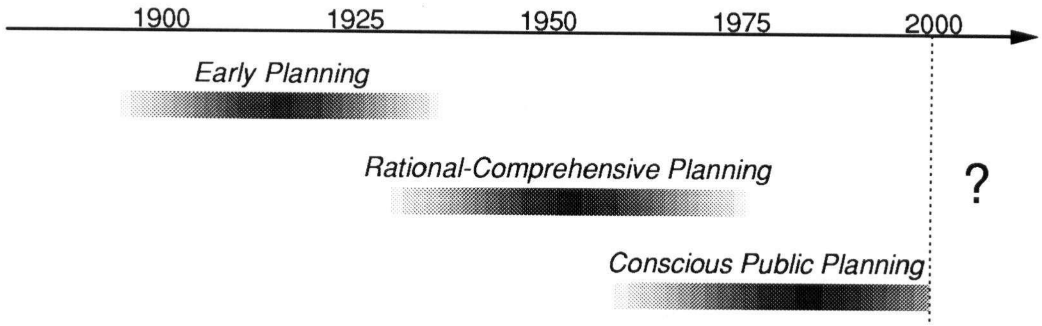


Figure 1: Three Periods of Planning History

2.1.1 The *Early Planning* period

In the early years of planning history, the majority of planners entered the profession with an architectural or engineering background (Alexander 1987). For example, the important pioneer planners that are mentioned in Hodge's book *Planning Canadian Communities* were architects, engineers, landscape architects, and surveyors. First and foremost, they viewed planning as a physical urban designing endeavor, regarding the city as a giant architectural structure or a mechanical system (Hodge 1989). There was a movement called "city beautiful" at the turn of the century, followed by another labeled "city efficient" in 1920-1930 (Burchell and Hughes 1978). In the former, the planning focus was mainly on the aesthetic aspect of the physical urban environment; while in the latter, more emphasis was on the functionality of the city. During those early years, planning was largely limited to the realm of physical planning with tasks such as the separation of uses, the efficient movement of vehicles, the aesthetic layout of parks and boulevards, the creation of civic centers, etc. It was done more with intuitive personal visions about what a city physically ought to be than with formal and conventional knowledge about planning. The approach to planning in this early period tended to be unstructured, unsystematic, and uncomprehensive compared that in the later years of planning history.

2.1.2 The *Rational-Comprehensive Planning* period

As the profession matured, the scope of planning was widened to additional planning elements such as housing, economy and demographics. Theorists and practitioners became increasingly aware of the inter-relatedness of different aspects of the community and the need for comprehesiveness in planning. As John Friedmann pointed out:

> The philosophers of planning—Mannheim, Tugwell, Mumford—all stress the need for comprehensiveness in planning analysis, though they use different words to describe it. Mannheim speaks of interdependent thinking grounded in specific situations, Tugwell uses the metaphor of a collective mind capable of overcoming the partial and fragmented knowledge of disciplinary specializations and Mumford declaims eloquently the need for simultaneous thinking (Friedmann 1987).

In the United States, at the end of 1920s, there appeared plans such as the *Regional Plan of New York and its Environs,* which includes "economic and population problems as well as the more standard physical elements" (Levy 1988). In Canada, "by 1930, planning legislation accorded the general plan for the community" (Hodge 1989). In 1949, the US government created a national housing act calling for the conformity of all federally-aided urban developments to the general plan of their respective recipient community and thus acknowledging the importance of comprehensive planning. Five years later, the US government specified the development of a comprehensive plan as a prerequisite for a community to be eligible to receive federal funding for community development. Furthermore, it devised the *701 Planning Assistance Program* to encourage local communities to make plans that encompassed transportation, housing, economic base studies, community facility assessments, and so on. (Burchell and Hughes 1978)

Theoretically, this comprehensive planning practice was chiefly propelled, on the one hand, by the notion that planning is ultimately a rational activity, i.e., choosing the most desirable option over less desirable ones, because to be rational, the calculation of the desirability of different options needs to be as inclusive as possible within the time and cost constraints. On the other hand, comprehensiveness in planning also calls for a simple, easy to articulate, codifiable, structured methodology, which happened to be the rational approach, so as to manage to organize the many components of comprehensive planning.

After World War II, systems theory, cybernetics, operations research techniques were borrowed from other fields and introduced into rational planning to handle "the complexity of modern society" (Beer 1974), solving multi-variable and multi-objective planning problems. These techniques offered some of the most rigorous and yet executable methods to apply the rational-comprehensive philosophy to planning practice and, as a result, reinforced its dominance in planning.

2.1.3 The *Conscious Public Planning* period

The widespread adoption of rational-comprehensive approach in planning represented a major step forward in planning. It made the profession more distinguishable from other specialized ones such as architecture and engineering, and offered planners some scientific basis to fall back upon. However, despite its comprehensiveness, it did not appear to have stopped ill-natured developments such as urban sprawl, central area decay, street violence, traffic congestion, chronic poverty and environmental degradation. Some well-intended plans met serious resistance when implemented; while others, which were meant to serve the general public, in effect aggravated existing social problems (Rodwin 1981). For example, without the proper treatment of social relationships, an award-winning design for a neighborhood could be turned into a disaster area. The most well-known case is the Pruitt-Igoe development in St. Louis, Missouri, in which three public-housing high-rise buildings had to be physically razed because of the uncontrollable violence and vandalism associated with them (Eckhardt 1972).

These failures disillusioned planners and citizens about the effectiveness of the rational-comprehensive approach to planning. Starting in 1960s, the planning profession began to acknowledge that planning is only partially technical but also social and political. The attainability of the "public interest" in a community in concrete terms was questioned and so was the universality of optimum plans (Howe 1992). What to plan, for whom to plan, how to plan and how to implement plans are all ultimately determined by the politics of the society (Burgess 1993). As a response to the *Rational-Comprehensive Planning* philosophy, the radical planning school, which emphasizes people and the social relationships among them, exerted considerable influence on the profession. In order to make socially responsive and effective plans, planners were encouraged to treat planning as a social endeavor and to participate actively in the reproduction of social relationships in the community. Not only were they asked to work for the people, but also with the people and to let the people plan for themselves (McClendon 1993).

In addition, besides planning for substantive issues, contemporary planners are also increasingly concerned with the planning of the planning process. This activity is sometimes considered to be especially distinctive of professional planners and thus of great importance. As Dyckman (1981) pointed out:

> Substantive rationality or what planning is about takes second place to procedural efficiency in this environment. Any planner preparing environmental impact studies knows that these will be judged more for how they are done than for what they imply.

Today's planners are not only concerned about what is in a plan, but also (perhaps even more) how it is constructed. In many instances, they are required to carry out a participatory planning process, in which they need to work with very diverse people: elected officials, developers, interest groups, and individual citizens.

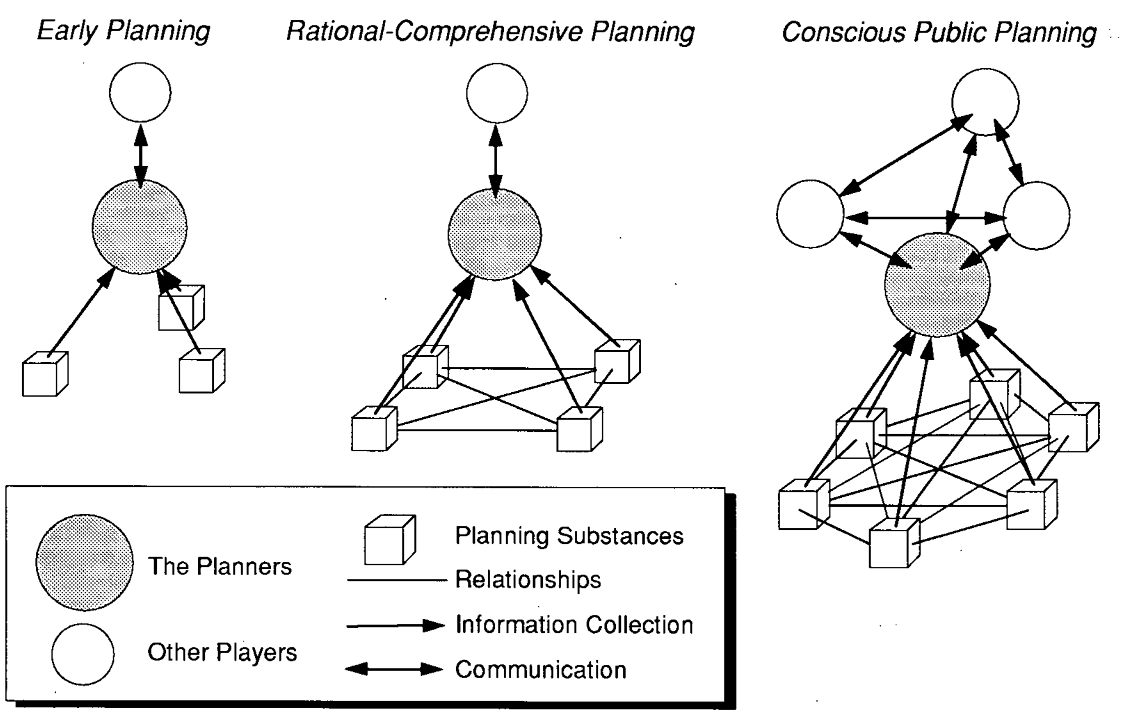


Figure 2: The Expansion of the Planning Universe

The discussion in this section uncovers three clear trends, which are also depicted in Figure 2: 1) planning is incorporating more and more substances into its scope; 2) it is becoming ever more social from its rather technical origin; and 3) it is focusing more on the procedural side of planning than before. Many researchers and practitioners alike now regard technical problem-solving as only a small or comparatively less important part of modern planners' multi-faceted work (Solnit 1988; Forester 1989). Instead, words like advocating, educating, communicating, organizing and mobilizing often better reveal the nature of today's planning activity.

2.2 The Use of Information in Planning

Information has always been important in planning. However, its role is different at different times. This section of the chapter discusses the use of information in each of the three previously defined periods of planning.

2.2.1 Planning information and its flow in the first period

In the *Early Planning*, the use of information was much less intensive than how it is today. The information itself was mostly in the form that is easily perceptible to the human brain. When working as a specialist, the planner consumes information to get to know the reality, so as to make plans that best fit the existing conditions based on his/her professional judgment. For instance, the planner could do a physical plan for an area relying heavily on his/her own first-hand visual observations of the vicinity plus some second-hand technical documents and background materials. The flow of information in planning was also relatively simple in those early years:

- the planner get planning tasks from the client;
- the planner collects information related to the planning tasks;
- the planner presents planning results to the client.

(See the first representation of planning universe in Figure 2)

2.2.2 Information to reduce uncertainty in the second period

When planning entered the *Rational-Comprehensive Planning* period, the use of information was intensified. Not only did the amount of planning information explode because of the expansion of the scope of planning and the institutionalization of the profession, but also because of the need to pull different information together in a synoptic manner. The rational-comprehensive school formally and explicitly established the role of information in planning—reducing uncertainties in technical problem-solving. With rationality, it is believed, the more and better information the planner has, the closer the planner can bring the plan to the absolute ideal solution. This belief is exemplified in quantitative analyses where quality of planning appears directly linked to the quality of data, and the problems with planning are frequently attributed to "not enough data," "garbage in, garbage out," "data incompatibility," etc. In comprehensive planning, a much wider spectrum of information, including socio-economic data, needed to be collected and processed in order to make planning decisions plausible. However, the role of information had not fundamentally changed, i.e., it still functioned mainly as a factual base for technocratic analysis. "The planner uses data on past and present conditions to predict the future trends on which his planning is based; the feedback of information to the planner assists him in evaluating the effectiveness of the planning process" (Stevens and Eyres

1971). The information flow in the rational-comprehensive period was also more complicated, for team work is a necessity to make any plan truly comprehensive. Nevertheless, this increased complexity does not appear to be obvious in Figure 2 because the communication is mainly among supposedly disinterested professionals and hence apolitical.

2.2.3 Information as a political resource in the third period

As shown in Figure 2, the planning universe became much more complex in the *Conscious Public Planning* period than it was in the previous periods. The scope of planning continued to expand into new areas: growth management, environmental planning, community economic development, and procedural planning, to name just a few. More significantly, the planning process has been opened up to the public and planners have been much more exposed to the politics of planning. This means a whole set of new issues have entered the arena of planing: the rights of those impacted by plans, economic disparity, minority rights, gender equality and so on. Being intertwined with the old ones, these new issues further complicated the use of planning information. Although efforts have been made to quantify intangibles and to establish "social indicators," it is now generally agreed that both qualitative and quantitative analytical methods and information are essential to modern planning. For example, the information used for designing planning procedures is mostly qualitative and empirical in nature. The understanding of the political, bureaucratic and social environments in which planning takes place is crucial to "planning for planning." Moreover, because all the affected are encouraged to participate in the planning process, the need of communication becomes of paramount importance in planning. What needs to be stressed here is that the increase of social focuses and planning participants is not only a quantitative change but also a qualitative one. So is the increase of planning information. The role of planning information has gone beyond serving planning merely as an intellectual exercise, but to planning as a social action. In his book *Planning in the Face of Power,* Forester explains how planners use information to prepare the social climate for good planning: they "transmit facts, but they also shape relationships, political ties, and others' attention, thus shaping not only others' thinking but their concerns and participation, too." Therefore, communication in *Conscious Public Planning* is fundamentally different from that among a number of experts aiming to solve technical problems as in *Rational-Comprehensive Planning*.

The evolution of the use of information in planning suggests the following implications:

1) the diversity of planning information: Since modern planning is inherently multi-disciplinary and complex, planners need to work with different types of information about the natural and social environments. In addition, because planners have to work with very diverse people (in terms of their economic, political, cultural, and educational backgrounds), who are therefore interested in different topics and accustomed to different styles of communication, the information that planners deal with is necessarily on various subjects as well as in various forms.

2) the intensification of using information: The substantive comprehensiveness and the procedural complexity of today's planning demand the use of a greater amount of information. On the supply side, the development of information technology has drastically cut down the cost of using information per unit. To cope with this

situation, planners need new labor-saving tools to automate the process of planning information.

3) the growing importance of communication: The sophistication of modern planning and its new planning style have both put communication in a prominent position in the profession. Traditionally, information technology in planning was mainly used for analytical tasks and information management purposes. New ways of utilizing information technology to facilitate the communication of planning information need to be explored to adapt to the shift in information use.

2.3 Computer-aided Planning

There are four segments in this section: 1) the history of computer application in planning; 2) the use of computers in planning today; 3) the structure of computer applications in planning; and 4) a critique of the technocratic use of computers in planning. Segment one provides an overview on the change of computer use in planning over time, while segment two offers a snapshot of today's wide range of computer applications in planning practice. Segment three suggests a framework of analysis that leads to the identification of problems in computer-aided planning in segment 4.

2.3.1 The history of computer application in planning

The use of computer technology in planning can be traced back to the late 1950s (Levy 1988), roughly a decade after its birth. The history can be divided into two eras: The large-scale modeling period and the office automation period. The former is characterized by the development of large-scale analytical models as the way to apply computer technology in planning, while the latter is full of all kinds of computer applications enhancing various day-to-day work in planning. The transition of the two eras coincides with the transition from the *Rational-Comprehensive Planning* period to the *Conscious Public Planning* period, as well as with the emergence of microcomputers in the 1970s. As shown in Figure 3, the triangles that indicate the distribution of the analytical levels for different computer applications in planning are vertically oriented before the collapse of the large-scale modeling effort but horizontally after.

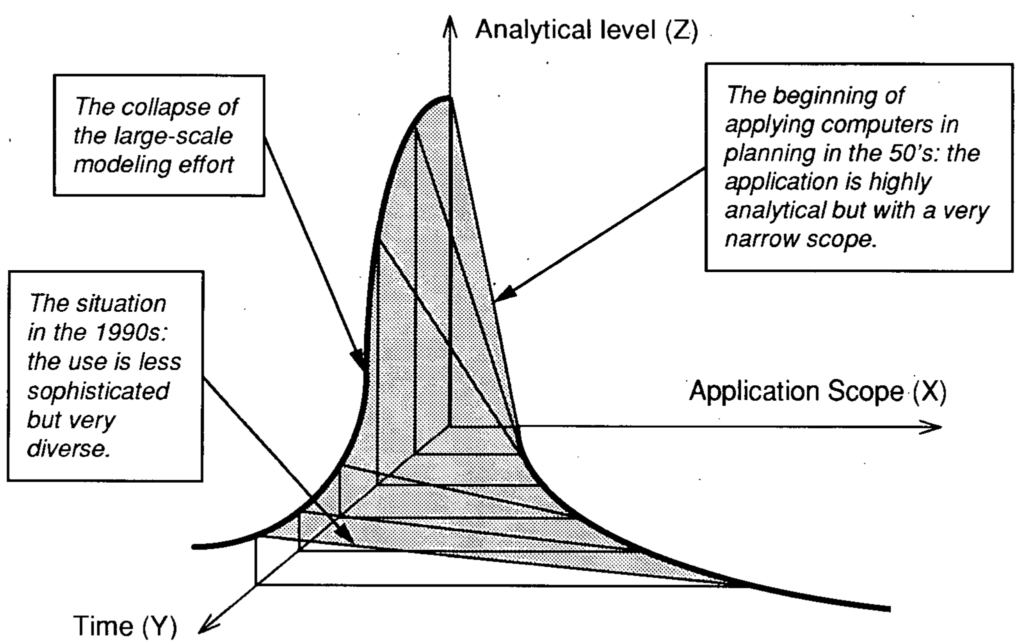


Figure 3: The History of Computer Application in Planning

The large-scale modeling period was marked with the high hope that planning could be made into a science (Klosterman 1992). "The unparalleled accuracy and apparently unlimited computational power of computers seemed to foreshadow the birth of a new urban planning based on the scientific understanding and guidance of the urban development process" (Klosterman 1990). Endorsed by the rational planning philosophy, practitioners and academics alike attempted to reduce planning activities to mathematical problem solving, and used computers in planning mainly as computing machines for finding these mathematical solutions. The attempts manifested themselves in the enthusiasm to develop large-scale models for urban and regional studies. Admittedly, there have been some successes of computerized modeling in sub-fields that are amenable to quantitative analyses (Rycus 1982). For example, computerized analyses have been entrenched in today's transportation planning as an essential component (Klosterman 1992; Brail 1987; Levy 1988). However, large-scale modeling was later criticized as "overly comprehensive and complex, inadequately grounded in theory and data, and poorly adapted to the needs of policy makers." (Klosterman 1990). It is widely acknowledged that Douglas Lee's "Requiem for Large Scale Models" in 1973 signaled the collapse of the dominance of computerized modeling as the focused form of computer application in planning (Klosterman 1990, 1992, 1994). In Figure 3, the curve on the Y-Z plane starting high and then plunging to a rather low level reflects the drastic change of computer use in planning in the 1970s.

It was the emergence of microcomputers in the mid–1970s that revolutionized the computing world. The impressive performance, low-cost and ease-of-use of microcomputers made them attractive and accessible to a large portion of the population (Brail 1987; Norris 1986; Griesemer 1983). Computers were no longer merely regarded as machines used by technical specialists for solving inscrutable mathematical problems or controlling sophisticated military weaponry; rather, they became widely recognized as a very versatile tool capable of processing information in different forms and applicable to virtually any field. Today, computers, especially microcomputers, are widely used for word processing, graphic presentation, project scheduling and information management in planning departments very much like how they are being used in an average office elsewhere. In addition, computers are used for quantitative analyses, such as statistical analyses, forecasting and modeling social and physical systems, to visualize, understand and solve planning problems (Brail 1987). Computers are also increasingly being used as a powerful telecommunication tool for planners to disseminate information and to be in touch with their colleagues, government officials and the general public (Neil, 1992; Rycus 1982). From a historical point of view, one finds the scope of computer use in planning has expanded exponentially, as depicted by the intersecting curved edge on the X-Y plane in Figure 3.

The two periods discussed here represent two very different approaches to applying information technology to planning. The approach in the former period was guided by the then dominant planning paradigm—*Rational-Comprehensive Planning*—that planning was mainly an intellectual endeavor whose quality relied on the available information and the analytical prowess of the professionals. Therefore, the approach was rather explicit, i.e. using computers as a tool to enhance the availability of planning information and to augment planners' analytical capability. By contrast, in the latter period, there does not appear to be a consistent, unified and well-articulated approach about computer application in planning. Various computer applications have sneaked in whenever and wherever the circumstances permitted.

2.3.2 The utilization of computers in planning today

The analytical nature of planning is still widely recognized as an important attribute of the profession. So is the legitimacy of using computers for analytical type of work in planning. In contrast to the practice in the large-scale modeling period, computer planning models, if ever needed to be built, should be small, simple, modular, flexible and easy-to-use (Batty 1991). This is in line with the dominant planning philosophy in the *Conscious Public Planning* period—it is important for non-specialists such as politicians, colleagues and citizens to be able to understand or use the models so that modeling does not function as a barrier to deter their involvement in planning.

Electronic spreadsheets are a good tool to build small, simple, transparent and easy-to-use models. No wonder they were hailed as "God's gift to planners" and became so ubiquitous in planning in the late 1980s and continue to be one of the most favored analytical tools by many planners today (Kenyon 1988; Klosterman 1992, 1993; Brail and Bossard 1993). For problem-solving, one alternative technology to the traditional mathematical models is rule-based expert system, which mimics more closely the inference process of a human expert. Unfortunately, the applicability of the technology in direct planning problem-solving is severely constrained by the technical requirements that are not easily met by the majority of planning problems (Langendorf 1985; Han and Kim 1990).

Today, every planning department has a large amount textual and graphical information to keep for development monitoring, planning decision support and public access. Data Base Management System (DBMS) has been utilized to aid information storage and retrieval in many planning departments, though not as many as one might have expected. The information handled by DBMS was traditionally mainly alpha-numeric but now is expected to go multimedia eventually (Laurini 1989).

Coming from engineering and architecture, Computer Aided Design and Drafting (CADD) found its place in physical planning; and from geography and survey, Computer Aided Mapping (CAM) asserted its role in planning map making. The development and synthesis of these technologies has led to new ones such as Automated Mapping/Facility Management (AM/FM), with which mapping of facilities can be easily done and the status of the mapped facilities can be conveniently queried or updated. Here, CADD and CAM were not just technical drawing tools but evolved into management tools.

It seemed natural and almost unavoidable that DBMS and AM/FM would eventually come together to give birth to this new hybrid technology called GIS. The synergy enhances the attributes that GIS inherited both from DBMS and AM/FM: on the one hand, GIS links all categories of data through their geographic references so that data are more integrated and organized to form a better database, which is capable of doing spatial and aspatial queries for all sorts of data; on the other hand, its powerful data management capabilities makes it a super AM/FM. In addition, a geographic information system often has an analytical module containing a repertoire of data analysis methods, which can be directly applied to the data from the database component of the system.

Last, but certainly not the least, is the large array of "off-the-shelf" applications, such as word processors, presentation packages, desktop publishing systems and so on, which are so commonly used that they warrant no introduction here. Nevertheless, their contribution to planning practice should not be underestimated. They are the staple computer applications that planners use almost everyday, and they produce concrete enhanced planning products (Griesemer 1983).

2.3.3 Three major uses of computers in planning

This segment is an attempt to introduce some structure in the wide range of computer applications in use in planning today. The applications have been ordered according to the analytical levels of the tasks that they typically handle. Please note that many applications' actual level of analytical sophistication is dependent on the implementation in the field. For example, expert systems by themselves are used to aid the user to find technical solutions. When they are built into a database system, however, their function may well be mainly to enhance data management. Another example could be that spreadsheet can be used to conduct complicated quantitative analyses, as well as simple tabulation. Therefore, the ordering of the applications represents a fluid rather than clear-cut static structure.

The order of the applications according to their analytical level seems to correlate very well with their scope of adoption, risk of failure, perceived value, setup cost, and research appeal. As shown in the following table, the applications have been categorized into five groups:

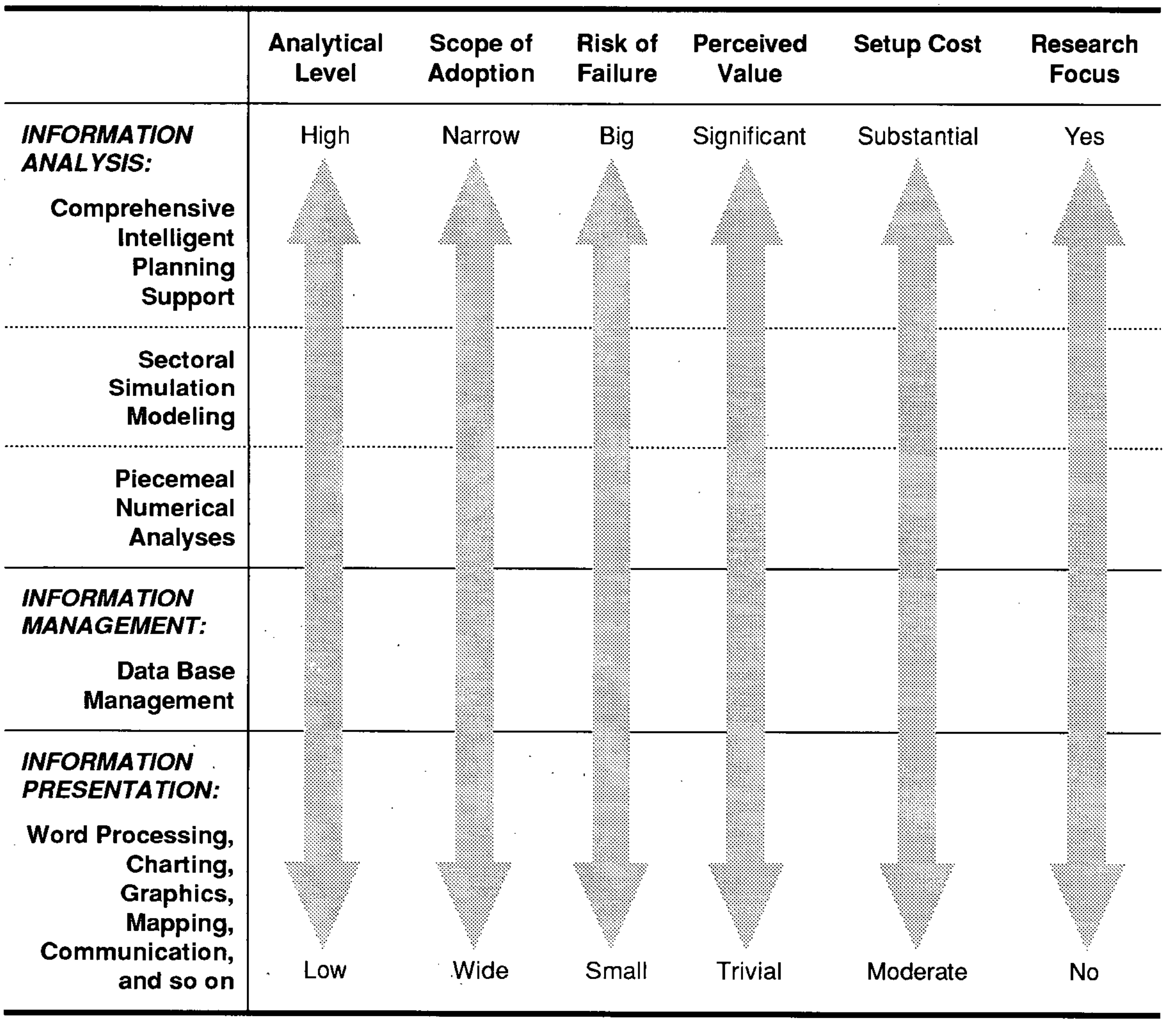


Figure 4: The Hierarchy of Computer Applications in Planning

The category at the very bottom of the table deals with what used to be mainly clerical type of jobs, with little analytical substance. The *Data Base Management* category involves a lots of low analytical "housekeeping chores", as well as some fairly analytically demanding tasks, such as those related to searching for useful data, judging on the usability of a certain chunk of data, and integrating data from different sources. *Piecemeal Numerical Analyses* refer to those ad hoc ones conducted on problems with a few variables. *Sectoral Simulation Modeling* represents the effort to duplicate the behavior of planning sub-systems, such as those of transportation, local economy and urban land use. Finally, the category at the very top includes the ultimate, but hardly ever materialized applications, which are believed to be able to, in response to a particular planning need, automatically turn raw data into sensible information for planners to use. Naturally, the more complicated tasks the category can help with, the more value it will be perceived to have. This is probably an important reason for researchers to concentrate on the upper categories in the table. However, in reality, there are very few computer applications in planning that fall in the upper categories but colossal numbers of activities happening in the bottom categories.

There are two root causes that prohibit a wide adoption of those high-level analytical computer applications:

1) There are not enough good and robust planning-specific applications around. This is because of the inherent difficulty to make computers work with often ill-defined, poorly-structured and hard-to-quantify planning problems. Moreover, this type of application needs to be developed vertically to suit to the idiosyncrasies of both planning substances and planning styles in a given situation. Doing this is always prohibitively expensive to most planning agencies, and consequently, compromises often have to be made to forgo computing efficiency, friendly user-interface, proper documentation and operational reliability.

2) There is incompatibility of this type of computer applications with the new *Conscious Public Planning* paradigm. First, the computer-based rational planning will compete with other more action-oriented planning approaches for the limited

planning resources. Even if planning resources are not an issue, how should the differences brought up by computer-based planning and participatory planning be reconciled? Without a satisfactory answer to this question, there is resistance to a wider adoption of computer analytical applications.

There are also some other impediments, which are considered as spin-off causes, to popularizing the use of analytical applications. The inadequacy of quantitative analytical skills of planners, the reluctance to break old traditions, and the lack of incentive to be innovative are just a few examples of such impediments. All these factors make adopting large-scale computerized planning support systems a very difficult, expensive and risky undertaking. Such effort is usually beyond the affordability of planning agencies and thus only feasible when there are special grants available.

In contrast to those in the upper categories, applications such as word processing, graphics and telecommunication are so generic (i.e. marketable), that they have managed to attract sufficient business interest into their development to emerge as the most polished, well-designed, efficiently implemented applications. Because they help the user on such a low level, e.g., correcting spellings, drawing perfect geometric shapes, making mailing lists, and picking out records that meet certain criteria, they can be smoothly blended into any existing planning process without intrusion and disruption. As a result, most computers in planning agencies work mostly with the applications belonging to the bottom categories in Figure 4. The current use of computers in planning was described by Klosterman in 1992 as "very broad but shallow."

Mitchell Rycus (1982) summarized the use of computers in planning into three general operations: text and graphical presentation, data storage and retrieval, and arithmetic calculations. To accommodate the rapid expansion of computer technologies, the author of this thesis has adapted the concept into a more inclusive scheme of classification: information presentation, information management and information analysis. One will find that each of the three operations will occur to a varying extent in any computer application. For example, word processing applications are mainly used to produce pleasant looking documents, but they also facilitate the creation and editing of the documents, and thus help to improve the quality of the contents. They also can function as a tool to manage textual information through easy storage, updating and retrieval of textual documents. Nonetheless, most computer applications do have or lean towards a chief purpose. An appraisal of the five categories listed in Figure 4 reveals the orderly pattern in terms of applications' main purposes: the top three categories are mainly for planning information analysis; the bottom one for information presentation; and the one in between for information management. These functions themselves also have a hierarchical relationship among them. Information presentation is the most basic function. It is the interface between the computer and its user. All interactive computer applications have to have this function. Information management and information analysis functions also need to work with the information presentation function to be functional, e.g., to display query results and analytical solutions. Similarly, information management is often a built-in component in information analysis because of the need of storing, retrieving, and maintaining the data for information analysis. As a matter of fact, information systems initially "had been simply appendages to models that enabled data to be stored and retrieved efficiently" (Batty 1994).

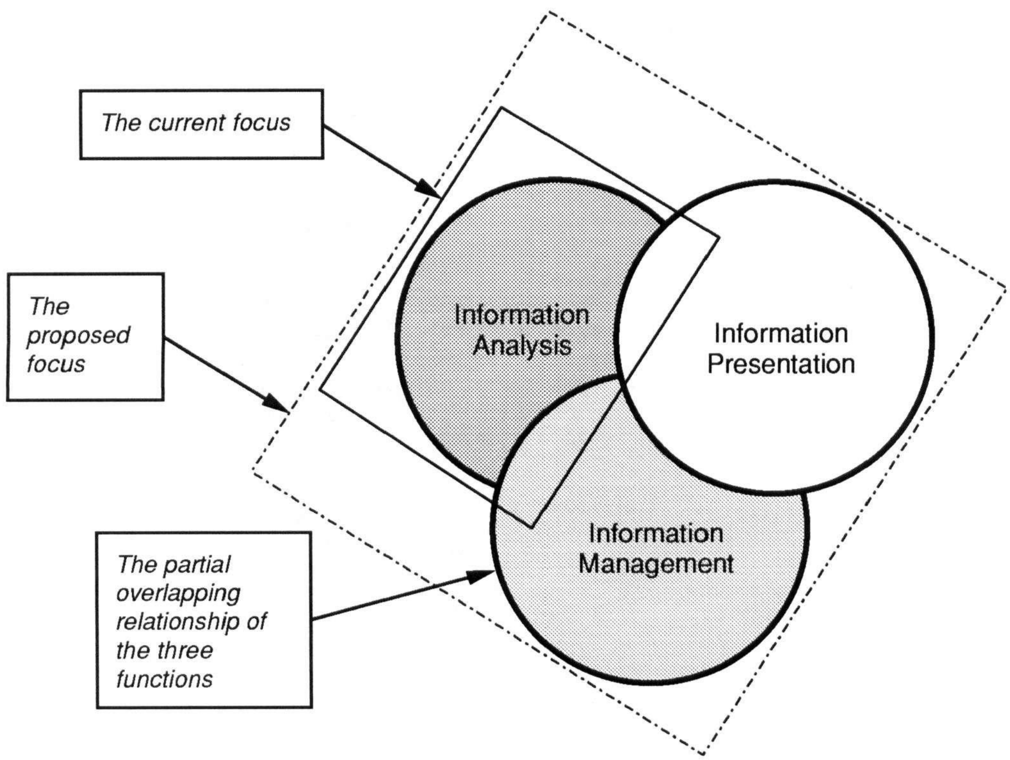


Figure 5: Three Main Functions of Computer Application in Planning

2.3.4 A critique of computers in planning today

As described in the previous section, most attention on computer applications in the published planning literature has been directed towards the upper categories of computer applications in the table. This is reflected in the planning professionals at the forefront of computer applications in planning relentlessly calling for more "high level" computer use in planning, as well as in the apathy of socially-oriented planners about the technology. Typically, computers are still considered as "an indispensable tool to urban planners who deal with various information for their [technical] problem solving tasks." (Han and Kim 1990). The remark shows that the popular mentality about using computers in planning is still focused on information analysis, in spite of the spectacular failures of information-analysis-centered computer applications in the large-scale modeling period, and mushrooming of numerous computer applications for information presentation and information management purposes in recent years (Innes and Simpson 1992; Klosterman 1992). The mismatch is not just between mentality and reality, but also the attitude towards a relatively new planning tool and the overall planning philosophy. It seems that, since the mid–1970s, the center of planning as a whole has shifted from rational analysis to communicative political action, but not the conscious focus of computer application in planning.

The technocratic use of computers in planning has been criticized on the following three grounds:

1) It ignores the impacts of using computers on the style of planning. The technocratic use of computers tends to reinforce the top-down planning approach and discourage public participation (Lee 1994). It directs planners' attention to technical issues at the expense of neglecting the political, organizational and ethical dimensions of planning. Moreover, the inherent limitations of computer-based analysis will skew planning agenda toward issues that are amenable to quantification and structured analysis (Kraemer and King, 1985).

2) It assumes that the use of computer is value-neutral and beneficial to the whole society. Research shows however, the technocratic use of computers is generally conservative in nature—serving the existing power structure, strengthening bureaucratic control and increasing social control over service recipients (Dutton and Kraemer 1985; Kraemer and King 1985).

3) It fails to see role of information in planning beyond technical problem-solving (Gordon and Anderson 1989). Han and Kim (1990) cited two ways of articulating the technocratic view—the purpose of using information in planning is: a) "to understand the environment where the complex planning activities take place," and b) "to reduce the inherent uncertainties in decision making."

A point in question is that whether computer technology itself has any political bias. The answer is no. Computer technology is a tool, just like any other tool, capable of serving different interests and what it serves depends on what and how it is made to serve. Only when the technology is being put in the context of its application, can the involved political implications be meaningfully discussed. Computer technology itself does not have to be generally "conservative" or "technocratic". For example, Colby (1990) discussed the possibility of using expert systems with different planning theories in her thesis. The criticisms mentioned above are on the technocratic use of the technology rather than on the technology itself.

Another myth is that planning is a profession in which it is intrinsically hard to utilize computer technology. This may be or may not be true in comparison with other professions such as business management, law, education and so on. What is erroneous is to confuse the challenge to applying the technology into the profession with the inherent incongruence between the nature of the computer-based analyses and the nature of the profession: one yearns for technicality, objectivity and explicitness; while the other indulges in politics, subjectivity, and implicitness (Dueker 1982).

The review of computer-aided planning reveals that a shift of computer use in planning has occurred along with the shift of the broader planning philosophy. Nevertheless, the shift of computer use seems to be a reluctant one and one without theoretical support. What is the rationale of still being preoccupied with information analysis, which is only one of the three main functions that computers can perform in planning, but blind about the attractiveness of the other two, when planning as a whole has changed from an analysis-oriented activity into an action-oriented one? Is it not the time to give the attention to the other two main functions, especially the information presentation, which has been neglected the most? It is clear that more effort needs to be channeled into making computer applications help planners with their communication tasks to suit the current style of planning. This is also the direction that the advancement of computer technology has been pointing to—"in 1980, the dominant mode of processing was still number-crunching; by 1990 it had become word-processing, and the most likely prediction for 2000 is of picture-processing and visualization" (Batty 1994). The latest development in technologies such as multimedia, networking, groupware, pattern recognition and virtual reality has provided planners myriad of new opportunities to take advantage of computers for better communication.

In the following chapters, we shall see that GIS as a hybrid computing technology can be made to serve all of the three main functions of computer application in planning that have been discussed earlier in this chapter.

3 *GIS Technology*

Chapter two has set the context in which GIS is applied. This chapter is going to discuss the technology—its definition, evolution, functional roots, ways of representing the reality, and common features that are relevant to planning. The purpose of this discussion is to clarify the term GIS used in this thesis, to reveal the nature of GIS technology, and to introduce some of the most prominent features of GIS.

3.1 The Definition and Evolution of GIS

GIS stands for Geographic Information System. The term is believed to have been coined in Canada in the mid-60s (Parker 1993). It is rather precarious when used in different contexts. This part identifies three levels of intension and extension of the term: the theoretical, the academic and the practical. The theoretical (i.e., the most general) definition helps to uncover modern GIS's two functional roots—one being cartography and the other modeling. When discussing GIS's cartographic root, the thesis will explore the advantages of electronic maps compared to their traditional counterparts. When looking at GIS's modeling root, the thesis will discuss the possible recurrence of the pitfalls that were characteristic of the large-scale modeling period.

3.1.1 The varying intension and extension of GIS

In theory, a GIS simply refers to a system of geographic information. It is not necessarily a computerized information system, nor does it necessarily contain a mapping component. However, there seems to be an unspoken consensus about the practical definition of GIS, which is actually very narrowly defined: i.e., a GIS almost invariably refers to a computer information system that comprises a database component and a mapping user-interface. Very often, the database component is expected to be a Relational Data Base Management System (RDBMS), and the mapping user-interface capable of simulating the manual production of new maps through overlaying existing maps. Academics tend to adopt a definition somewhere in between the above-mentioned two extremes: a GIS is a computerized system for collecting, inputting, storing, retrieving and analyzing spatially-referenced data. Moreover, the acronym GIS sometimes does not suggest any specific system, but rather the technology that underlies the applications of geographic information systems, normally in the sense of their practical or academic definitions (Parker 1993).

3.1.2 GIS's cartography and modeling roots

As mentioned in the previous chapter, GIS resulted from the diffusion of other computing technologies such as Computer Graphics, Data Base Management, Automated Mapping and Facility Management. This observation comes from tracing GIS's origins through its underpinning software technologies. Likewise, it is also possible to examine GIS's emergence in relation to the advancement of computer hardware—it was the availability of relatively cheap processing power and memory that opened the door for the development of this graphics-based and data-intensive GIS technology. These two approaches of understanding the development of GIS would perhaps be more meaningful if the focus of this thesis were on the technology itself rather than on its applications in planning. This segment is going to explore GIS's definition and evolution with a third approach, i.e., along its functional roots, so that a better understanding on what the technology is and what ends it might serve can be achieved.

It is instrumental to use the theoretical definition when we look at the cartographic capabilities of GIS. With it, we can trace the root of GIS back to the time when human beings started to use graphics and symbols to represent geographic features and events for communication and recording purposes. It was, however, not until about two centuries ago that modern cartography came into being. The development of modern cartography laid the foundation for the representation of geography in computers (Parent and Church 1987). Even though computers are capable of representing spatial reality with a 3-D model, today's GISs overwhelmingly stick with the metaphor of a 2-D projection of 3-D geographic entities, just like that of the conventional maps that we are so familiar with. In fact, the computer versions of geographic representation are so close to their paper counterparts that they are alternatively called digital, digitized or electronic maps. Despite their similarities to each other, with computers' processing power, the electronic representations do have a number of superior characteristics over those of their paper counterparts:

a) An electronic map can be conveniently viewed at different scales, with different projections;

b) There are virtually no physical limitations to the kind and the volume of the annotation, be it textual, graphical, audio, or even video, to be attached to a mapped feature;

c) It is easier to locate a feature on an electronic map that satisfies one or a set of conditions;

d) Mapped objects in an electronic map can be easily modified and reused for making new maps;

e) Electronic maps are conducive to automated overlay operations;

f) Any number of duplications of an electronic map can be made without any loss of information or increase in "noise" (i.e., unwanted additional information);

g) Within certain practical limits, hard copies of an electronic map can also be made at any scale either completely or partially.

Because of all these advantages, today's map making is already dominantly computer based. The geometrical processing techniques involved in electronic mapping have a lot in common with those that have been developed in Computer Aided Drafting and Design (CADD), and the solution for organizing extensive attribute data for the mapped geographic features is largely from Data Base Management System (DBMS) technology.

Also with the theoretical definition, we can trace GIS's modeling root: all kinds of computer models that deal with geo-referenced data can be considered as GISs. They include land use models, transportation models, hydraulic models, meteorological models, geological models, natural resource models, demographic models and so on. Among them, the earliest application is perhaps the transportation model used in a traffic study for

Detroit Metropolitan Area in 1955. The model represents the traffic in Detroit with the traffic flows through one-quarter square-mile cells, resulted by applying a grid to the metropolitan area. Through statistical analyses, the model can forecast the future traffic volume distribution in the study area by extrapolating the historical data. Because the computer model did offer geo-referenced information for decision-making activities, it can be considered a forerunner of modern GIS (Parent and Church 1987).

3.1.3 The implications of GIS's functional roots

Maps and models have very different ways of representing reality, organizing information and serving their users. Following is a table summarizing three aspects of maps, models and modern GIS systems:

	Cartographic Origin +	Modeling Origin →	Modern GIS
Representation of reality	Mainly Graphical	Mainly Quantitative	Graphical and Quantitative
Information organization	Based on geographic entities	Based on any entities	Based on geographic entities
Major Functions	Information presentation, information management, and information analysis	Information analysis	Information presentation, information management, and information analysis

Figure 6: GIS and Its Roots

Knowing the origins of GIS helps us better understand not only the technology itself but also its possible roles in planning. Its cartographic root should remind us that it has much of the functionality that is shared with conventional maps; while its modeling root should caution us that it is subject to the same limitations that conventional computer models have in planning.

Maps of all kinds have been used as an important medium for presenting, managing and analyzing information by planners since the beginning of the profession. For example, scaled maps have been a very effective medium to show the spatial layout of an area; zoning maps have been used to document and define planned land use; and schematic and thematic maps have been employed to detect spatial patterns, conceptualize problems and construct solutions. Properly implemented, a GIS can help planning on all these fronts just like what paper maps have been doing.

GIS's other root, modeling, is a very useful, and perhaps in some cases the only, means to analyze some planning problems, e.g. those related to transportation, air quality and demographics (Lee 1994). There is no doubt that, with its modeling heritage, which is enhanced through its graphical front-end, GIS can certainly serve as a very powerful analytical tool in planning. Nevertheless, as discussed in the previous chapter, there are many potential pitfalls in applying modeling in planning that can also fail the application of GIS in planning.

3.1.4 The definition adopted in this thesis

Of course, except for the most theoretical kind of discussions, no one will treat a paper map or a traditional computer transportation model as a GIS. Still, the academic likes to use a definition that is specific enough to distinguish GIS from other related technologies such as CADD, conventional urban and regional modeling and DBMS, etc., while at the same time not so exclusive that it will hinder its assimilation of other technologies such as expert system, networking, virtual reality and so on. Following is a more precise but still quite accommodating definition of GIS:

A GIS is an information system that comprises four functional components:

a) A data input sub-system which collects and/or processes spatial data derived from existing maps, remote sensors, etc.
b) A data storage and retrieval sub-system which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections to be made to the spatial database;
c) A data manipulation and analysis sub-system which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constraints for various space-time optimization or simulation models;
d) A data reporting sub-system which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in tabular or map form. The creation of these map displays involves what is called digital or computer cartography. This is an area which represents a considerable conceptual extension of traditional cartographic approaches as well as a substantial change in the tools utilized in creating the cartographic displays.

(Marble 1990)

The earliest geographic information system that fit the above definition is perhaps the Canadian Geographic Information System (CGIS), developed by Roger Tomlinson of the Canada Land Inventory in 1962. This system had the capabilities of storing and retrieving spatial and aspatial information, re-classifying attributes, changing scales, merging and creating new polygons, and creating lists and reports. Today, around the world, there are hundreds of companies that offer commercial computerized systems that are all, to a varying extent, capable of accomplishing the functionality of the four above-mentioned sub-systems. Dependent on its implementation for a specific substantive area, a GIS could also be called Land Information System (LIS), Environmental Information System (EIS), Highway Information System (HIS), Demographic Information System (DIS) or something else (Visvalingam 1991).

In the following discussions in this thesis, the term GIS is coincident to Marble's definition. It covers all kinds of full-fledged commercial and public domain GIS software, including those easy-to-use desktop mapping packages. The focus of discussion will be on the use of the technology for planning decision-making rather than administrative or engineering purposes.

3.2 Real World Representation in GIS

To aid the discussion on GIS common features in the next part of the chapter and GIS's role and limitations in planning in the later part of the thesis, this part introduces the representation of the real world in GIS. There are basically two ways to represent a study area in GIS: one is to abstract all geographic entities in the area, such as rivers, forests, municipalities, communities centers, etc., into one of the three geometric elements—point, line and polygon—and use vectors to construct them in GIS, as shown in Figure 7 part B; the other is to divide the area into small, regular, and usually square, cells and use rasters to represent them in GIS, as shown in Figure 7 part C.

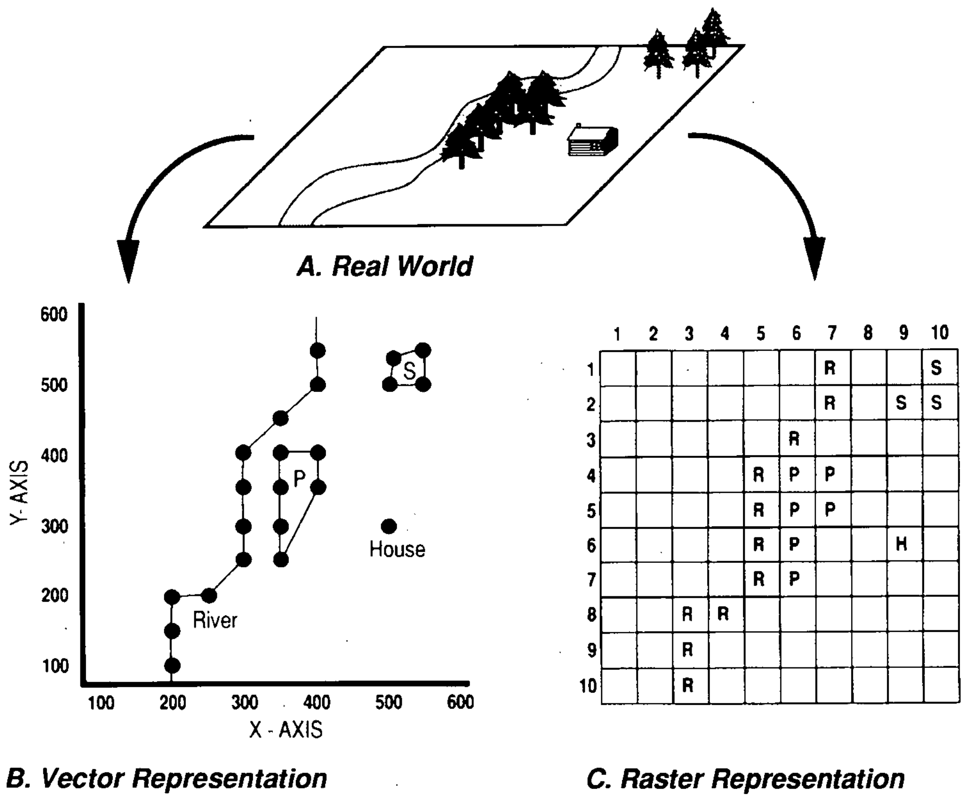


Figure 7: The Vector and Raster Data Models. The landscape in A is shown in a vector representation (B) and in a raster representation (C). The pine forest stand (P) and spruce forest stand (S) are area features. The river (R) is a line feature, and the house (H) is a point feature. (Adapted from Aronoff 1989)

3.2.1 Vector-based GIS

From the geographic reality to its representation in a vector-based GIS, two kinds of abstraction are involved. The first is that all geographic entities in the real world are three dimensional objects, while their abstract representations in GIS are dimension-less points, one-dimension lines, and two-dimension polygons. How these three dimensional objects are abstracted into much simplified geometric forms in a particular GIS is dictated by the intended use of the system. For example, in a vector-based GIS, a municipality may be either abstracted as a point, as in the case of planning on the national level where the physical size of the municipality is not of concern, or a polygon, as in the case of planning on the metropolitan level where the physical size of the municipality is likely to be significant. The second is that complex real world linear and areal features are approximated by line segments with limited joints and polygons with limited vertexes after abstraction. For instance, any coastline is naturally ragged, which has infinite turns and consequently an infinite accumulated length. To represent a coastline with a line segment in a vector-based GIS with reasonable cost and performance, the joints of the line segment are necessarily the representation of some selected locations on the coastline.

All other measures, e.g. population, traffic volume, land use and so on, about the geographic entities are considered attribute data, which are logically linked with the points, lines and polygons that represent the real world entities respectively. This allows attribute data to be accessed and displayed through a cartographic interface. For example, when a point that represents a city is selected in a GIS, the system can retrieve any data that has been linked with this point, and conversely, any piece of data in the system can be identified to be associated with a geographic entity. It is usually assumed that the distribution of any attribute in a given entity where data have been collected is even—the density is the same in an areal entity and the capacity is constant along a linear entity. It is with this assumption that data can be conveniently aggregated and disaggregated with the redefinition of those geometric objects in a GIS, which in turn represent real world entities.

To facilitate flexible and efficient use, the points, lines and polygons in a GIS are often organized into different "layers" according to themes. When needed, those layers can be "overlaid" to produce composite maps. For example, an urban GIS may contain a layer of natural features such as rivers, forests, lakes, etc., a layer of administrative boundaries such as municipal boundaries, a layer of highway network and a layer of land use designation. A demographic study may just need the administrative boundary layer to make the needed maps, while a regional transportation planning project may need to use all the layers to produce a series of composite maps.

3.2.2 Raster-based GIS

The geographic reality in a raster-based GIS is represented by a grid of regular side-by-side cells, which in their simplest form are square in shape and equal in size. Each cell's position, which corresponds to the location of the cell's representation of the reality, is registered with the raster-based data structure. Each cell is associated with one or more values, i.e., attribute data, in somewhat the same way as a point, a line or a polygon is associated with its attribute data in a vector-based GIS. Therefore, in the raster-based GIS the homogeneous basic spatial units are the cells.

Each raster-based map is "a large grid of measurements taken at regularly spaced locations in an area" (Aronoff 1989). It is especially efficient in representing geographic phenomena that have considerable transitional variation in space and those without clear-cut boundaries. Digital maps that are generated by scanners, no matter whether they are installed on airplanes or satellites to scan the earth surface, or in computer labs to scan paper maps or aerial photos, are all raster-based images. They represent a very important data source for GISs. Hence, it is important for GIS to be able to work with raster-based digital maps. Many computer peripherals for graphical output are raster-based too: e.g.

various kinds of monitors and printers. It appears that raster-based spatial manipulation is usually less demanding for computing resources such as memory and processing power.

In contrast, the vector-based representation of geographical reality is entity oriented—all concerned geographical entities are explicitly represented by geometric objects on a one-to-one basis. This results in a more compact data structure, efficient in encoding of topology and therefore conducive to advanced spatial analyses (Aronoff 1989). In addition, vector-based GIS is more in line with cartographic principles and tend to produce maps that are more aesthetically pleasing to the human eye.

Today, many GIS software packages are capable of handling both vector and raster formats. Conversion utilities are available to convert one format to the other. It is also possible to superimpose vector-based maps onto raster-based maps to make composite maps. For example, a vector-based political boundary map can be superimposed onto a satellite image to show the vegetation variations in relation to the political jurisdictions.

3.3 The Common Features of GIS

The eventual features of a particular geographic information system are very much dependent on the implementation of the technology. It can be as crude as a schematic map generator as well as a tool for stunningly realistic visualization; as limited as only being able to work with the data stored in its own proprietary database as well as being so flexible that it can integrate wide range of data from multiple data sources; as simple as merely serving mundane data management purposes as well as conducting sophisticated problem-solving tasks. Here, to aid later discussion on the role of GIS in planning, this segment reviews a number of most common features that are often readily available in popular GIS software packages.

As already made apparent by the previous discussions, GIS should have: strong data management function because of its DBMS solution for its data management, strong map making function because of its cartography origin and its employment of various computer graphics technologies, and strong spatial data manipulation function because of its modeling origin and its representation of the geographical reality. Therefore, the diverse features of GIS are grouped into three categories according to the functions they serve. The categories are presented in the sequence of electronic map making, data management and spatial data manipulation, which is ordered in accordance with their analytical levels.

3.3.1 Electronic map making

GIS software packages often are bundled with digital base maps, i.e., the maps with the most essential geographic and administrative features such as rivers, roads and boundaries. Governments are also an important source to obtain base maps. For example, TIGER files are available for all American cities. Moreover, there are many vendors who are specialized in offering digital base maps (including satellite images) or digital map making services to produce customized digital base maps. Alternatively, the end user can make his/her own base map with a digitizer, a mouse, a scanner, a keyboard or other kinds of input devices (Bracken and Webster 1990). High-end GIS packages usually include a digitizing module to facilitate the digitization process, and/or a remote sensing interface to import satellite images.

Nevertheless, most GIS end users are not directly involved in making base maps. Rather, they are more interested in maps that serve their particular ends. For instance, a planner planning a bicycle path network could manually trace a digitized street base map to draw a planned bicycle path network. In a GIS, natural, human-made and administrative entities are often stored in different files according to themes: for example, the boundaries of neighborhoods in one file, the street network in another. Thus, the planner could load the neighborhood boundary file and the street network file into the computer and display them on two logically separate but perfectly overlaid layers, while working on a bicycle path network on a third blank layer, which can be then saved into a different file. In this way, the planner could draw the planned bicycle path network with reference to the street network and neighborhood boundaries without worrying about altering the original street network map or the neighborhood boundary map.

Anyone who has used a modern word processing software application on a microcomputer will appreciate its obvious advantages over traditional typewriters. Once the text has been typed into the computer, it is a breeze to insert, delete, copy, move, and format any text segment. With computing technology, there is no more need for whiteout ribbons, correction liquid, or erasers, yet the output can be easily impeccable in terms of avoidable typing errors. The flexibility of using different fonts, applying alignments, adding headers and footnotes and combining graphics and text in a modern computer word processor is beyond comparison with what even the most sophisticated typewriter can possibly achieve. Moreover, the digital nature of computer word processing makes those useful utilities such as spelling and grammar checkers possible. Lastly, words stored in the electronic form can be readily merged into other documents seamlessly without the need of retyping them.

Likewise, with a user-friendly GIS, once a map has been input into the system, it is very easy to add, delete, or move the annotations, be they in textual, audio or any other form, and the graphic elements (i.e., dots, lines, and polygons) on the map. Just as easy and flexible as formatting text with a word processor, it is very convenient to apply different fonts to textual annotations, different symbols to dots, different styles to line segments, different patterns to areas, and different colors to all kinds of map elements, to change the look and feel of a digital map. With computer's computational power, changing the scale or projection of a digital map is just a matter of a few mouse clicks or keystrokes. Finally, the maps from a GIS can be readily reused to make other maps, or be incorporated into printed documents, on-line databases, video and multimedia presentations.

With GIS, geographic information can be presented in various cartographic forms—reference maps, choropleth maps, distribution maps, and isarithmic maps. The reference map is the most common type, which shows the boundaries and labels of the geographic entities. The choropleth map is also widely used, which uses different colors and/or patterns to indicate different attribute values of the geographic entities. Distribution maps use points to show how one or more attributes are distributed in space. The familiar pin map is an example of the distribution map. Isarithmic maps are made of lines that indicate equal attribute values, as in a elevation map. (For more detailed discussion on these different types of maps, see Garson and Biggs 1992.)

3.3.2 Database Management

Computer database management systems make it possible to handle large volumes of data that would be too costly, too time-consuming or practically impossible to do using manual methods. A GIS should be capable of doing what a conventional computer database system is capable of, given that they belong to the same stratum of technical sophistication. Like their conventional computer database system counterparts, a GIS can be made to deal with information in all kinds of media: text, sound, still graphics, animation, and even video clips. Nevertheless, up to this date, conventional computer databases are still dominantly text-based and the textual information is mostly organized in form of records, each consisting of same number of the most elementary data units called fields. For example, a database for a transportation study may use traffic zones as basic entities, each of which is described by a record, which in turn contains identification code, population, employment, average income level, number of vehicles and so on as fields. Commonly available database features can be categorized into four groups: database creation and maintenance, database query, database manipulation and database report.

A DBMS normally offers facilities to convert existing data files into database files in the system's native format. Alternatively, the DBMS can create an empty database and then import and extract data from existing data sources to construct its database quickly. The most labor-intensive way to build up a database is through manually editing a database from scratch. The editing features of a DBMS include inserting, deleting and copying records in a database and modifying fields of the records. Once data have been saved into a computerized database, they become easy to store, duplicate, and access.

Sorting is to arrange the records in a database in a specified order. Suppose that we have a computerized database containing records on every individual property in a city, and each record consists of the values of 6 fields: *Identification Number, Owner Last Name, Owner First Name, Type of Use, Built Year, and Property Value*. We can sort the records according to the alpha-numeric value of any one or combination of the fields. For example:

Identification number	*Owner Last Name*	*Owner First Name*	*Type of Use*	*Built Year*	*Property Value*
234522	Green	Grant	Residential	1975	$234,000
245243	Ross	Bob	Commercial	1987	$575,000
245249	Thomas	Kelly	Residential	1956	$223,000
245245	Smith	John	Residential	1978	$563,000

Sorting by the owners' last names

Identification number	*Owner Last Name*	*Owner First Name*	*Type of Use*	*Built Year*	*Property Value*
234522	Green	Grant	Residential	1975	$234,000
245243	Ross	Bob	Commercial	1987	$575,000
245245	Smith	John	Residential	1978	$563,000
245249	Thomas	Kelly	Residential	1956	$223,000

Figure 8: An Example of Sorting Records

Querying is to find records that meet certain user-specified criterion or criteria from the database. Multiple criteria are structured with logical relations such as AND, OR, NOT using a "query language" of some kind, some of which are quite close to the natural language compared with most other high level computer languages. For example, still using the earlier mentioned scenario, we can query about the residential properties whose estimated market value is above $500,000. What the system will do is essentially to extract those records whose *Type of Use* is residential and whose *Property Value* field is larger than $500,000 from the database.

Identification number	*Owner Last Name*	*Owner First Name*	*Type of Use*	*Built Year*	*Property Value*
234522	Green	Grant	Residential	1975	$234,000
245243	Ross	Bob	Commercial	1987	$575,000
245249	Thomas	Kelly	Residential	1956	$223,000
245245	Smith	John	Residential	1978	$563,000

Querying according to *Type of Use* and *Property Value*

Identification number	*Owner Last Name*	*Owner First Name*	*Type of Use*	*Built Year*	*Property Value*
245245	Smith	John	Residential	1978	$563,000

Figure 9: An Example of Querying Records

There is some capacity to do data manipulation in a DBMS. This includes creating new fields whose values are functions of values in existing fields, aggregating existing records to produce totals and subtotals, and producing cross-tabulation tables with existing fields. For example, if the property values stored in the database are in 1986 dollar terms, and they need to be turned into current dollar figures, a new field can then be created by applying a proper financial function to the old field and store the results into the new field; if the range of identification numbers corresponds to neighborhoods, the total property value of a neighborhood can be calculated by summing up the property values in those records that have their identification numbers falling into the range; and lastly, through cross-tabulating *Built Year* and *Type of Use,* it can be revealed that how many of today's existing industrial, commercial and residential properties have been build in each decade in the last fifty years. Also, a DBMS usually has some simple built-in statistical facilities such as sum, mean, and standard deviation, to describe the overall status of a database.

The output of the above-mentioned features can be put into a separate file and presented as forms, lists, tables, and/or graphs. This process can be fully automated through a little or no programming.

A DBMS can also function as an effective interface between data and the end-user as well as other application software by hiding the complexity of the physical and logical form in which the data are stored. The data that make up a database can reside physically in many different locations and logically in various files. In addition, they are often allowed to be viewed and modified by multiple users. Tackling the problems of data redundancy, data inconsistency and redundancy, DBMS presents the collection of data as a seamless and robust database to the outside world (Aronoff 1989). This data integration capability is perhaps especially significant in the planning profession where data are so various and their sources are so diverse.

What GIS has that are beyond these conventional database features are those that work through the mapping interface or require spatial processing facilities in order to be functional. With GIS, one can do "visual searching" to locate information. Though zooming and panning of the mapping front-end, the user can quickly obtain an overview of the database and then focus on interested locations to find out detailed information (Garson and Biggs 1992). Depending on the actual implementation, all GISs are, to a varying extent, topologically "aware." It can track such spatial relations as "nearness," "adjacency," or "inside/outside," of one record relative to another (Garson and Biggs

1992). For example, query can be done spatially in a GIS, i.e., extracting the records that meet one or more spatial conditions. Furthermore, spatial querying can be combined with conventional non-spatial querying. With a GIS, the user can find out, for example, all the commercial properties in one and its adjacent neighborhood. Finally, beside capable of outputting information in the formats of forms, lists, tables and/or graphs as conventional DBMS is, GIS can present information with maps in a variety of styles as discussed in the last segment.

3.3.3 Spatial elements manipulation features

A GIS usually comes with a suite of functions pertaining to spatial information processing, ranging from simple descriptive ones to sophisticated analytical ones. For example, there are GISs that can calculate the area of a given polygon, the length of a chain of line segments, the distance between two points, etc. There are also GISs that can figure out the shortest path(s) connecting any two points on a network, the center defined as the optimal point from which the sum of distance(s) to a given set of points is the smallest, and so on. For detailed discussion on available GIS features, please consult a GIS textbook (e.g., *Introductory Readings in Geographic Information Systems* edited by Peuquet and Marble and published in 1990).

One of the most frequently mentioned GIS features is *overlay analysis*, which refers to the manipulation of spatial elements across multiple layers of maps for one same area. There are many different kinds overlay operations available in GIS. For example, depending on the logic involved, overlaying two different polygons can result in sixteen different operations (Bracken and Webster 1990). Following is a presentation of the two most basic ones of the possible sixteen operations: the union of polygons and the subtraction (exclusion) of polygons.

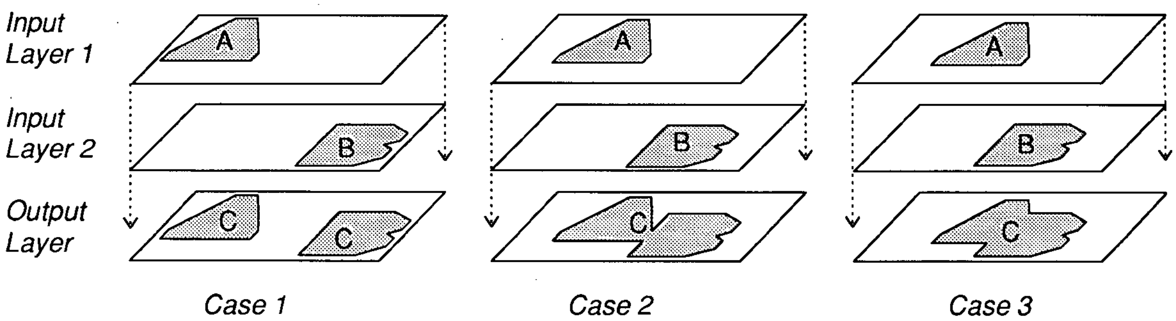


Figure 10: Union Overlay Operation

If we have polygon A and polygon B on two overlaying layers and C is the result of the union of A and B, then:

1) if A and B does not overlap and share a common segment of their boundaries, C is two polygons—polygon A and polygon B (see Case 1 of Figure 10);
2) if A and B share a common portion of their boundaries, C is a polygon formed by polygon A's boundary and polygon B's boundary less the portion of their common boundary (see Case 2 of Figure 10);
3) if A and B does overlap, C is a polygon formed by polygon A's boundary and polygon B's boundary less the portions of boundary that fall within the other polygon (see Case 3 of Figure 10).

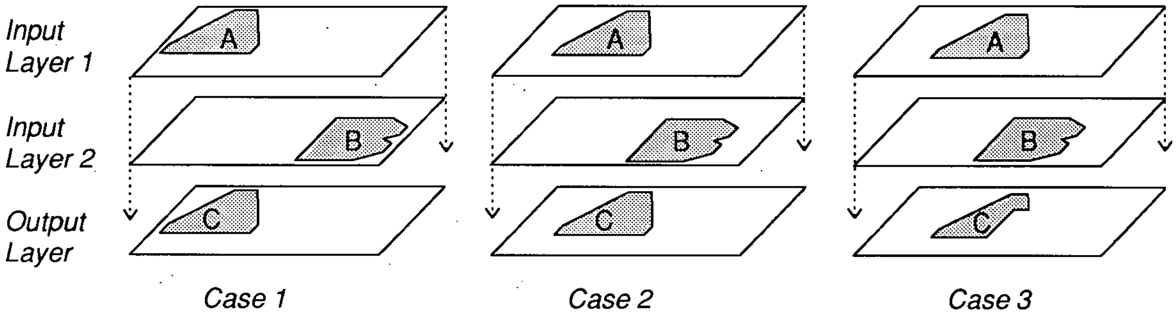


Figure 11: Subtraction Overlay Operation

If, again, we have polygon A and polygon B on two overlaying layers and C is the result of the subtraction of B from A, then:

1) if A and B does not overlap, C is the same as polygon A (see Case 1 and Case 2 of Figure 11);

2) if A and B does overlap, C is a polygon formed by the portion of polygon A's boundary outside polygon B and the portion of polygon B's boundary within polygon A (see Case 3 of Figure 11).

The *Union Overlay Operation* is useful in, for example, identifying the areas that are protected from urban development when maps of designated environmentally-sensitive areas, reserved farmlands, national parks and so on are available separately. An example of *Subtraction Overlay Operation* could be to identify the areas that potentially suitable for new residential development by subtracting the environmentally-hazardous areas from the vacant land areas.

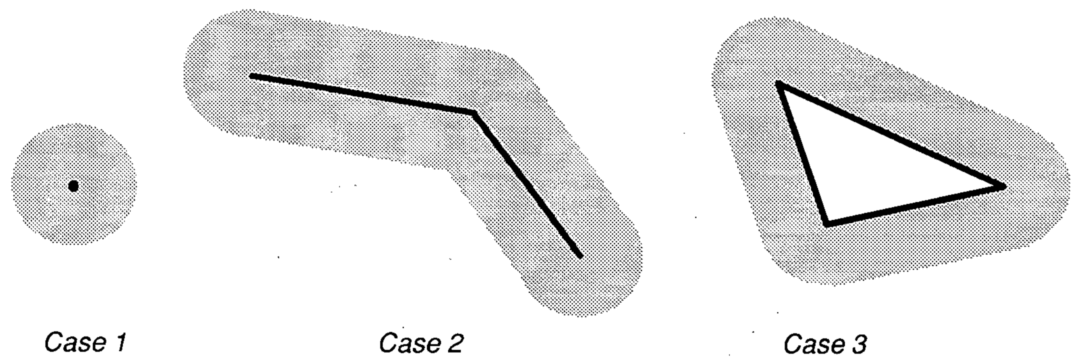


Figure 12: Buffering around Point, Line and Polygon

Another well-known and frequently-used feature is *buffering:* a buffer is an area surrounding one or more selected map elements (e.g., points, lines, or polygons) within which no point is further away from the selected elements than the specified distance. In the case of a point, its buffer is a circular area with the point as its center (see Case 1 of Figure 12); in the case of a line, its buffer is a strip area with rounded ends (see Case 2 of Figure 12); and in the case of a polygon, its buffer is the area that is in between its original boundary and its buffered boundary (see Case 3 of Figure 12). Buffering feature is useful to define a surrounding area of a given geographic entity, and to simulate spatial expansion of certain phenomena such as urban growth, spread of pollution, and so on.

Planning models can be built on top of a GIS so that they can directly utilize the data residing in the database component of the GIS and its built-in spatial functions. This can be achieved through programming with the macro language that is specific to the GIS system in question or with more generic computer languages that can be integrated into the system. For example, using a gravity model, one can estimate the traffic demand between two traffic zones by feeding in the zoning and demographic information stored in the GIS and the distance between the two zones, which can be derived by the spatial analysis component of the system. The potential in modeling with GIS is virtually unlimited and is continuously expanding with the rapid advancements in computing technology. Even though there are very few successful sophisticated, whether GIS-based or not, computer planning models in use, modeling with GIS nevertheless is the hottest research topic about GIS application in planning.

The GIS features presented in this chapter are by no means a comprehensive treatment of the myriad of existing GIS features. (The annual *International GIS Sourcebook* published by GIS World Inc. is a good source to get a good idea about what are the latest GIS features available from the state of the art commercial GIS software packages.) The presentation here is meant to show what kind of functional "building blocks" are typically available for constructing more complicated functions to serve planning ends. The next chapter will present six cases of GIS applications so that we can see how these features can be used to work for planning.

4 *GIS Applications in Planning*

The purpose of this chapter is to use case studies to support the more theoretical discussions in the previous chapters and to demonstrate the wide range of possibilities of implementing the technology for planning. It is argued in theory that today's *Conscious Public Planning* has the need for information presentation, information management and information analysis, and that computer technology as a whole and GIS in particular have the capability to aid these activities. Can we find cases that can substantiate the theoretical arguments? Since there is no shortage of documented GIS applications in planning in the literature, criteria must be developed to select the appropriate cases for use in this chapter:

- the emphasis of the GIS application in each case must lean towards non-routine planning support;
- the cases must have been implemented in planning practice and proven to be successful;
- together, the cases must be able to reflect the diverse roles the technology can play;
- there must be enough information about the cases (and adequate graphical material) to facilitate the illustration of the cases.

Therefore, GIS application cases presented in this chapter did not result from a random selection process. They probably cannot form a good sample of the reported GIS applications in planning that can be regarded as a faithful reflection of how the technology is currently being utilized in planning as a whole.

4.1 Georgia Resource Center's GIS

Georgia Business Location Center (GBLC), later called Georgia Resource Center (GRC), was a business information center set up by the Georgia Power Company (GPC) in 1986 to encourage businesses to locate in the state of Georgia. GPC is an utility company in the state, which serves 75% of the total state population. In the early 1980s, the company saw the connection between Georgia's economic development and its own business, and therefore decided to invest in the economic future of state. GRC's mandate is to provide relevant information to businesses interested in locating in Georgia. It maintains large state wide databases about the majority of the sites, buildings and communities. The information comes in the forms of alpha-numeric data, still images and motion video clips, which are narrated in English, French, German and Japanese. Information of this quantity and variety needs a capable data management system with an effective interface for the user to make best use of it. That is where GIS technology kicks in.

Like using other GISs, the user of GRC's system can heavily rely on its on-screen maps to locate information. The system actually has six display screens to the user: three large-format multimedia screens at the front of the presentation room and three liquid crystal displays (LCDs) embedded in the conference table (see Figure 13). The three liquid screens are used to navigate within the system, while the three large multimedia screens to present retrieved information. A typical session of retrieving information about potential locations suitable for a certain business starts with entering the search criteria. At the center of the conference table, the state display, on which the 159 counties of Georgia are displayed, will highlight those counties that contain sites suitable for the concerned business. Using a pointing device, the user can then select one of the highlighted counties, which will bring up a more detailed map of the county on the LCD screen on the left side of the table. Now, the user can see the icons that indicate the sites that meet the search criteria. Selecting one of the icons will bring up: 1) to the two large multimedia screens on both sides alpha-numeric information about the specific site that the icon represents; 2) to the center multimedia screen pictorial information, which includes still imagery and motion videos; and 3) to the LCD screen on the right side of the conference table the index about any additional information item available about the same site. At this point, the user can choose to: 1) stop; 2) select a new county from the center LCD screen in the table and start a new session; 3) select another potential site from the county display on the left side of table; and 4) select an additional information item from the LCD screen on the right side of the table. As soon as a selection is made, relevant displays will be updated automatically.

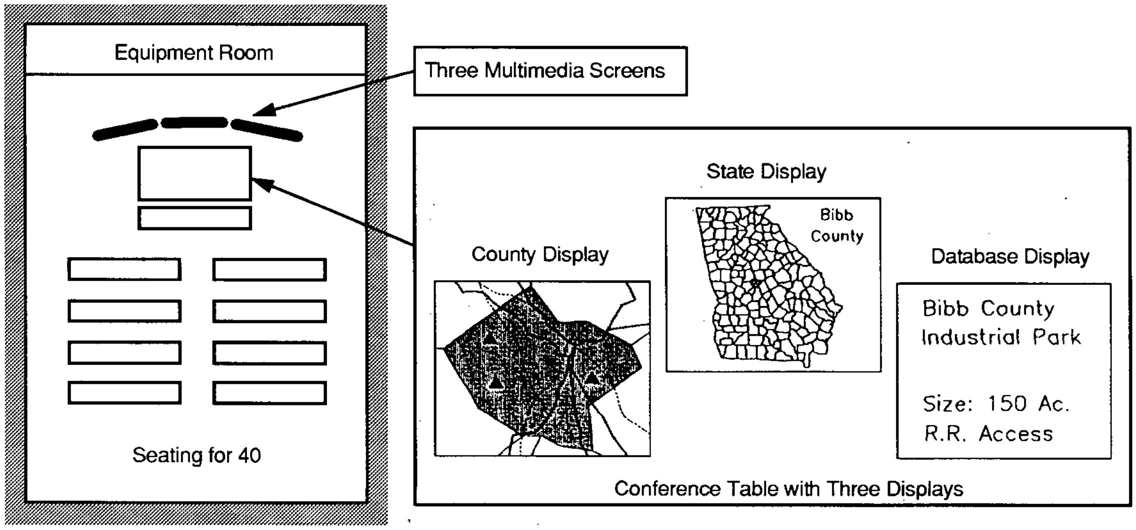


Figure 13: Georgia Resource Center's GIS (Adapted from Drummond 1993)

Compared with the majority of GISs, which are typically designed for single-display implementation, the presentation capability of the system is greatly enhanced by the six simultaneous displays. The user can have alpha-numeric data, pictorial information, and cartographic presentation of the environment at different scales all displayed at the same time. These displays are driven by six networked microcomputers, which are in turn controlled by a seventh computer, to function like a giant display divided into six divisions. In addition, the single cursor of the system can travel from one LCD screen to the next LCD screen seamlessly so that the user can interact with all the objects displayed on the three LCD screens in the conference table. The system also has an eighth and a ninth microcomputers hooked up with the network: one functions as the text-based database server, and the other manages the bank of 20 laser-disc players that supply motion video and still imagery information. Lastly, a tenth microcomputer, also networked with the system, is used as an input system to handle the database search criteria entered by the user.

Drummond reported this GIS based multimedia presentation-oriented system as a success: "The fundamental decision to use a map-based user interface has been confirmed by a reduction in the need for paper maps, and by the increased ease-of-use of the system as a whole. GIS has proven itself as an important visualization tool for economic development (Drummond, 1993)." The use of analytical capabilities of GIS was minimal in the system implementation. In fact, the GIS that was employed is a rather low-end GIS called *Atlas*GIS* from Strategic Mapping Inc. The GIS was not even linked with the system in real-time, because of the unacceptably slow performance of the GIS on the microcomputer platform at that time. Instead, it was used to produce raster-based maps for screen displays so that the system could achieve limited GIS functionality at a speed that is conducive for the audience to enjoy the presentation.

4.2 Waterloo Generic Urban Model

If we could say that most of planning computer applications (i.e. those dealing with routine and low-order planning activities such as mailing-list compilation, permit tracking and site selection) support planning on a micro level, there are a few that are developed aiming at helping planners do strategic planning. The development of Waterloo Generic Urban Model (WATGUM), a model shell developed in the University of Waterloo in the late 80s, is such an attempt.

WATGUM itself is not an application for any specific urban problem. It is a simulation framework for strategic planning. In WATGUM, GIS is only a module of the model and mainly used to produce "professional quality mapped output of simulated futures;" while simulation is done in the modeling system based on its own time-series database outside the GIS module (Newkirk 1991). The model is zone-based and capable of projecting future forecasts for population, households, labor force, economic activity, government activity, physical services, natural resources and so on for individual zones based on user-defined scenarios. With the projected figures for different sectors in place, the model can then detect any demand-supply inconsistency (e.g., unemployment and low-cost housing crisis) that comes into being due to unbalanced development in these sectors. It is reported that the most important difference between WATGUM and those conventional regional models is that WATGUM does not solve detected inconsistencies by default. Instead, it treats these inconsistencies as "tensions" and leaves them to the user to decide whether they are technically and politically acceptable. If any unacceptable tension occurs, the user may choose to modify the initial scenario settings and/or apply remedial policies to ease the tension.

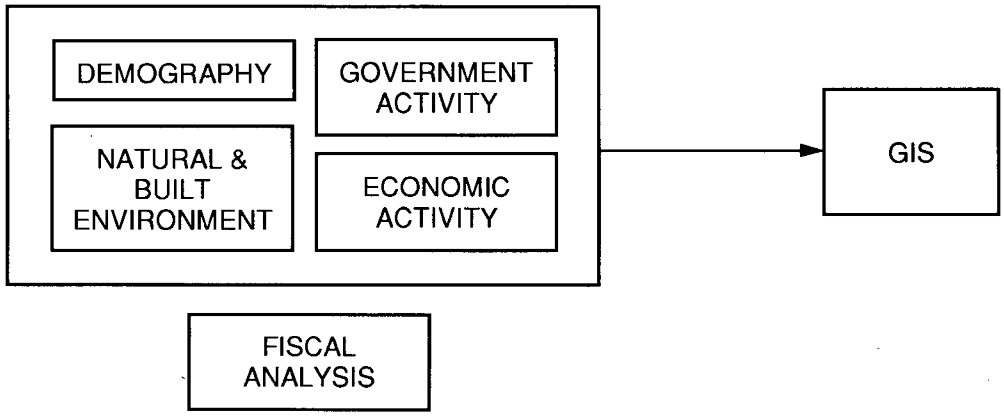


Figure 14: WATGUM—Waterloo Generic Urban Model (Adapted from Newkirk 1991)

Therefore, WATGUM was not designed to function like a magical black box: you feed in initial conditions at one end and get technical solutions to planning problems at the other without any knowledge about the internal mechanism. It was built to simulate the dynamics and the interactions of different components of an urban system. Its thoughtfully-designed interface allows the user to function as a part of the feedback-loop of the model so that the user can intervene to affect its output in the middle of a run. WATGUM allows disequilibrium in its simulation, which is considered a better representation of reality compared with traditional equilibrium simulation. Properly implemented, the model can accept diverse policy options and calculate their consequences accordingly, functioning as an effective communication vehicle to facilitate a participatory planning process.

A prototype implementation of WATGUM, which is called The GTA Prototype system (GTAP), was carried out for the Greater Toronto Area (GTA). The prototype is based on 30 zones that correspond to the 30 municipalities in the study area. In his "Mapping

Metropolitan Area Futures: A Case Study from Toronto," Newkirk (1991) provided examples of output from the prototype, which include population by region, sewage treatment capacity, inter-municipal commuter trips, and built-up area. To demonstrate the use of GIS in the prototype, only one of the examples is shown below.

The prototype is capable of forecasting future population for the study area. With the assumption that the density of residential development will be kept at the current level, the prototype can then calculate the area needed to accommodate the increased future population. Assuming that new development will fairly evenly distributed in the not-yet built-up areas that are adjacent to the built-up ones, one can use GIS's buffering feature (see Chapter 3 for explanation of this feature) to simulate the growth of built-up area along time. Following is an output produced with GTAP's *ARC/INFO* system. For clarity, the base map only shows the boundaries of the five regions—Halton, Peel, York, Durham and Metropolitan Toronto—instead of those of the 30 municipalities.

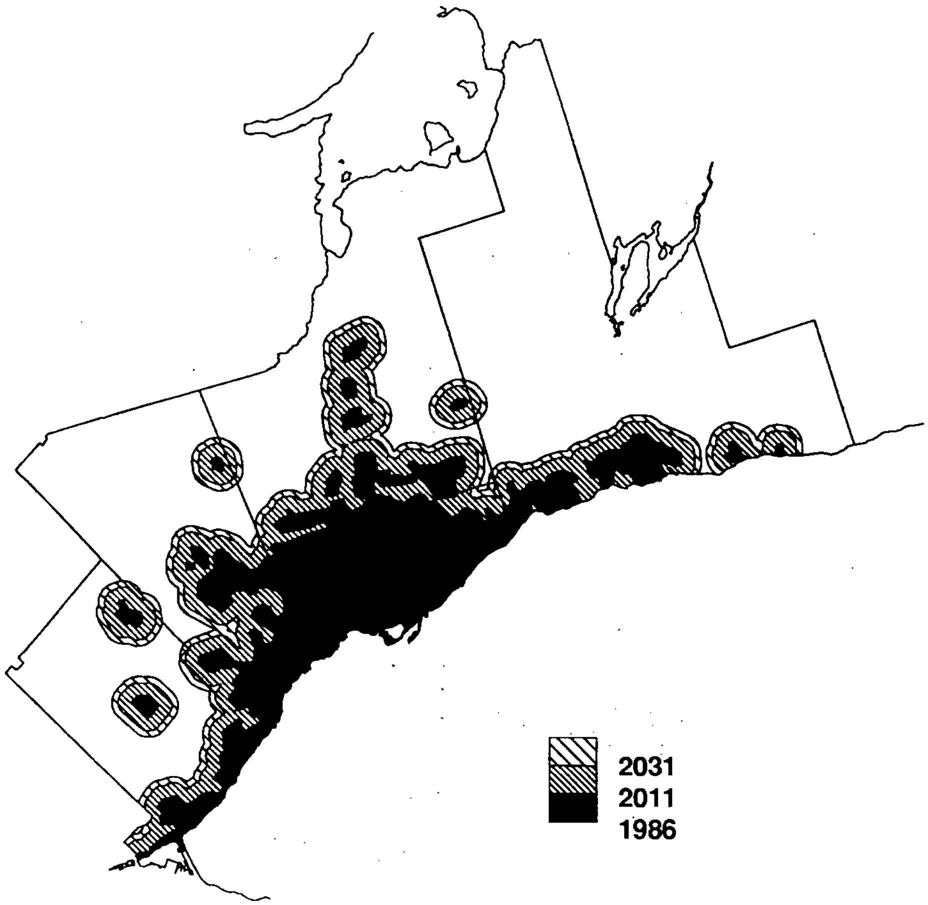


Figure 15: Graphic Display of Built-up Area in GTA (Adapted from Newkirk 1991)

In this exercise, there are a couple of noted omissions: 1) the simulation did not take into account the land required for new economic activity and infrastructure; 2) non-developable land such as environmentally sensitive areas and protected agricultural land was not excluded from the buffered areas. These omissions, plus the assumptions mentioned in the previous paragraph render the output map only "a reasonable graphic impression of increased consumption of land" in GTA into the next century (Newkirk 1991).

Regardless of its simplicity in simulating the reality as reflected in the above example, GTAP has functioned as a thought-provoking stimulus in the discussion about the future urban development in the GTA in the coming 30 to 50 years. Via the GIS module, output from the simulation model was produced in the form of maps and has been extensively used in several regional workshops on effective growth management in the Greater Toronto Area. Newkirk (1991), one of the chief developers of the prototype, described the GIS's role in planning:

> In the Toronto case, the GIS package *ARC/INFO* has provided an effective medium for displaying results. While I have identified some technical problems with the use of *ARC/INFO* in the context, the generation of different maps associated with the differing assumptions . . . provides a very clear visual impressions which non-technical decision-makers can understand and subsequently use.

This case clearly demonstrated the utility of GIS as a presentation tool to facilitate group processes. Because of the assumptions, omissions, and aggregated data used in the prototype, the output from the GIS is obviously anything but a reliable prediction of the future, and will not be too dissimilar to the estimates that are derived through other means. Nevertheless, the GIS output "has proved to be a very useful resource to assist in the process of identifying the outcomes of a range of possible development scenarios for the Greater Toronto Area (Newkirk 1991)." This case highlighted that at strategic level, conceptual communication is more important than technical accuracy. Sophisticated spatial analytical capabilities are not essential in this case, and a GIS system more rudimentary than *ARC/INFO* would have sufficed.

4.3 The St. Helens Urban Program GIS

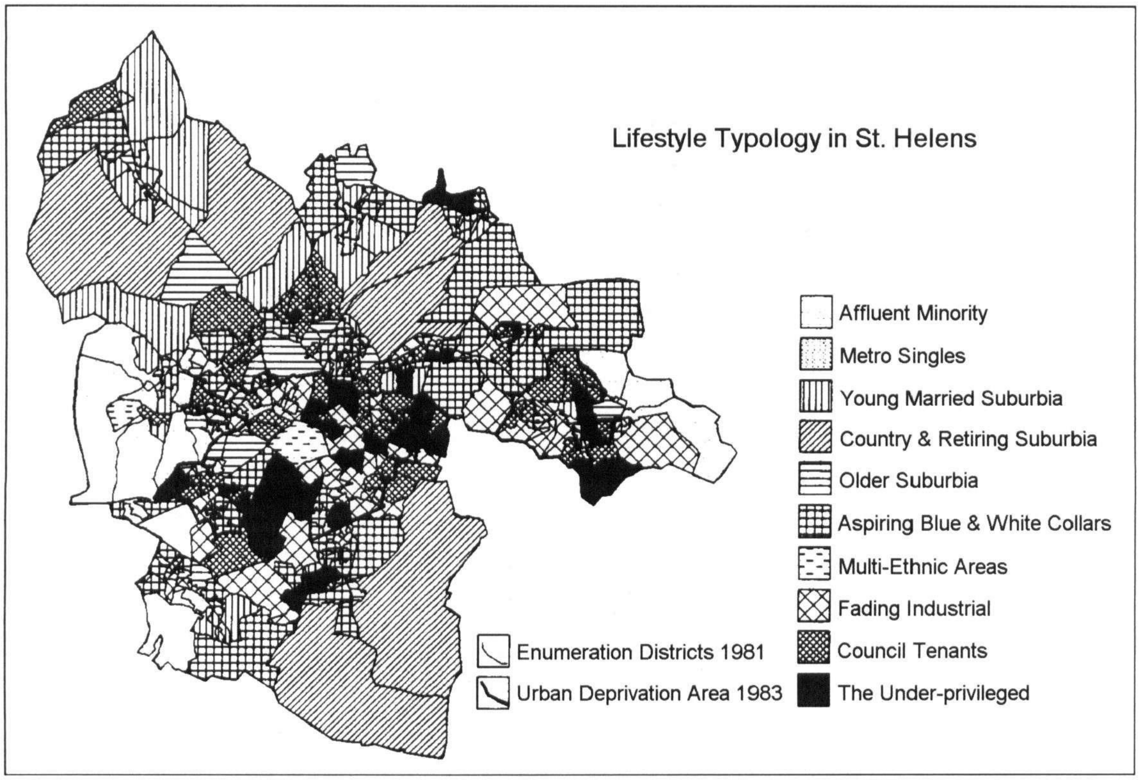
In the late 1980s, St. Helens Metropolitan Area UK was recognized as one of the urban areas facing serious social and economic problems that needed governmental assistance to relieve its deprivation. The Department of the Environment (DoE) ran a program called Urban Program to provide resources from the central government to these deprived areas. Because the extent of deprivation is quite different even within one metropolitan area, it would be more efficient if the additional resources could be directed more precisely to the areas that need the assistance the most. In addition, feed-back information, i.e., information about how situations in the recipient areas improved or continued to deteriorate after a certain period of time, is vitally important to evaluating the effectiveness of the Urban program. To achieve this, the decision maker needs to have access to detailed and relevant information about all the areas to be considered.

In St. Helens, an *ARC/INFO*-based GIS was developed to support the management of its Urban Program. The data contained in the information system can be categorized broadly into two categories: operational and background. Operational data are those directly and specifically related to individual projects. They include allocated and actual expenditures, geographic locations, main objectives, targeted beneficiaries, evaluation measures and sponsoring organizations. Background data are those more general kind of socio-economic data such as population, unemployment, average income and so on.

With the operational and background data readily available, a number of analyses could be carried out for St. Helens:

- Where had been the most socially and economically deprived areas?
- How the expenditures of the Urban Program were distributed?
- Have the socio-economic situations in the recipient areas improved in terms of employment, health and housing conditions after the expenditures?
- Who benefited the most from the Urban Program?
- Has the deprivation shifted or developed spatially over time?
- Have the expenditures followed the movement of the deprivation?
- What are the changes in the Urban Program's objectives in recent years?

For example, comparing the following two choropleth maps (see Figure 15), the researchers concluded that a large proportion of the Urban Program expenditures has been allocated to the "under-privileged" areas (Hirshfield, Brown and Marsden 1991).



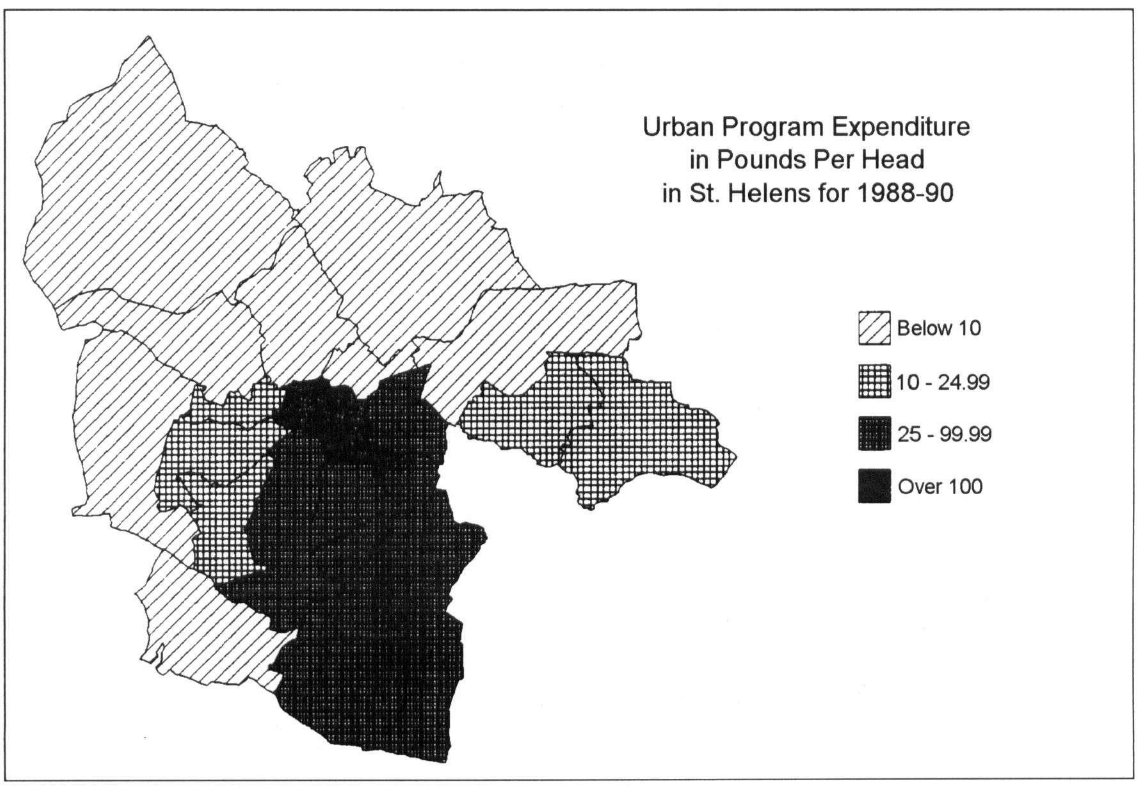


Figure 16: Choropleth Map Outputs from the St. Helens Urban Program GIS (Adapted from Hirschfield, Brown and Marsden 1991)

Compared with the previous two cases, the St. Helens Urban program GIS is a better representation of an average implementation of GIS—one that is centered around a single GIS software package (in this case, i.e., *ARC/INFO*) with its focus on efficient access to information. What GIS offered in this case is enhanced data accessibility, data integration and data presentation. At the time when the system was set up, the majority of the data that were later incorporated into the system already preexisted but scattered in different organizations. The GIS integrated these data and made it practical to cross-reference and display them in the form of thematic maps with great ease.

4.4 Housing in Randstad Holland

Geertman and Toppen (1990) gave a series of typical examples of using GIS's spatial manipulation capabilities in planning. The context of the application is that it is a challenge to find new housing development areas in the already densely populated and ecologically fragile Randstad, Holland and the purpose of the application is to "translate general policy statements into concrete location decisions.

Figure 16 schematically describes how the GIS helped to identify areas that are suitable for housing development. In the figure, the boxes that are enclosed by the box of dashed borders represent the components that make up the GIS implementation. The criteria for evaluating whether an area is suitable for housing development are derived from the *Fourth Memorandum on Physical Planning* and other relevant reports. Published in 1988 by the Dutch government, the *Fourth Memorandum on Physical Planning* is a policy document which "sketches a broad perspective for urban and rural development in the

Netherlands up to the year 2015" (Geertman and Toppen 1990). For example, to meet the general goal of reducing mobility, one of the criteria could be set as "no new building site should be five or more kilometers away form the existing railway stations."

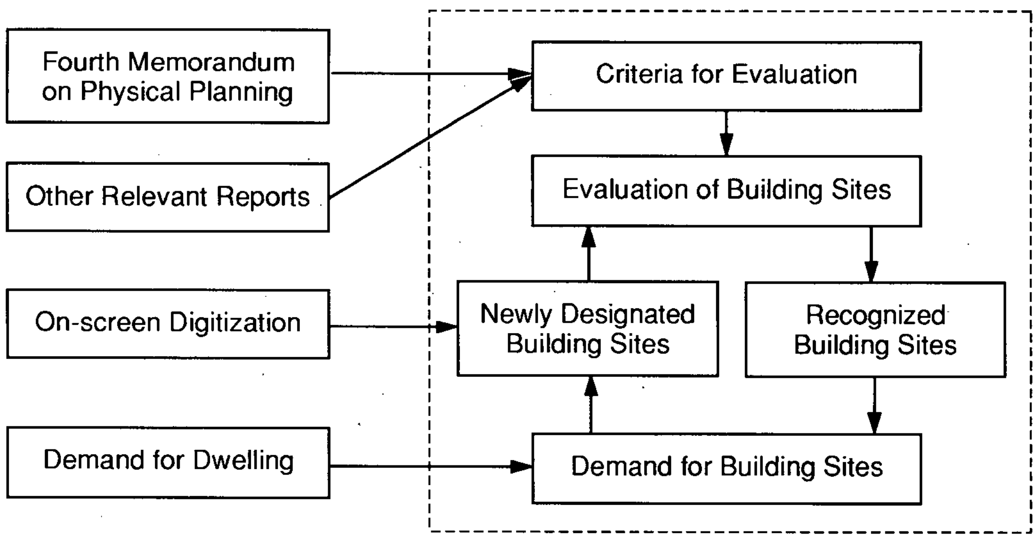


Figure 17: The Implementation of GIS for Housing Planning in Randstad Holland (Adapted from Geertman and Toppen 1990)

With the derived criteria, the system evaluates the suitability of the designated building sites and regard those suitable ones as recognized building sites. Then, demand for building sites, which is derived from demand for dwelling, is compared with the recognized building sites. If the recognized building sites cannot meet the demand for building sites, the user can designate new building sites through "on-screen digitization." Newly designated sites, together with the recognized sites, are then treated as designated building sites and fed into the evaluation module again. Proceeding as such, this process is an iterative one: it keeps repeating itself until the designated building sites meet the demand for building sites.

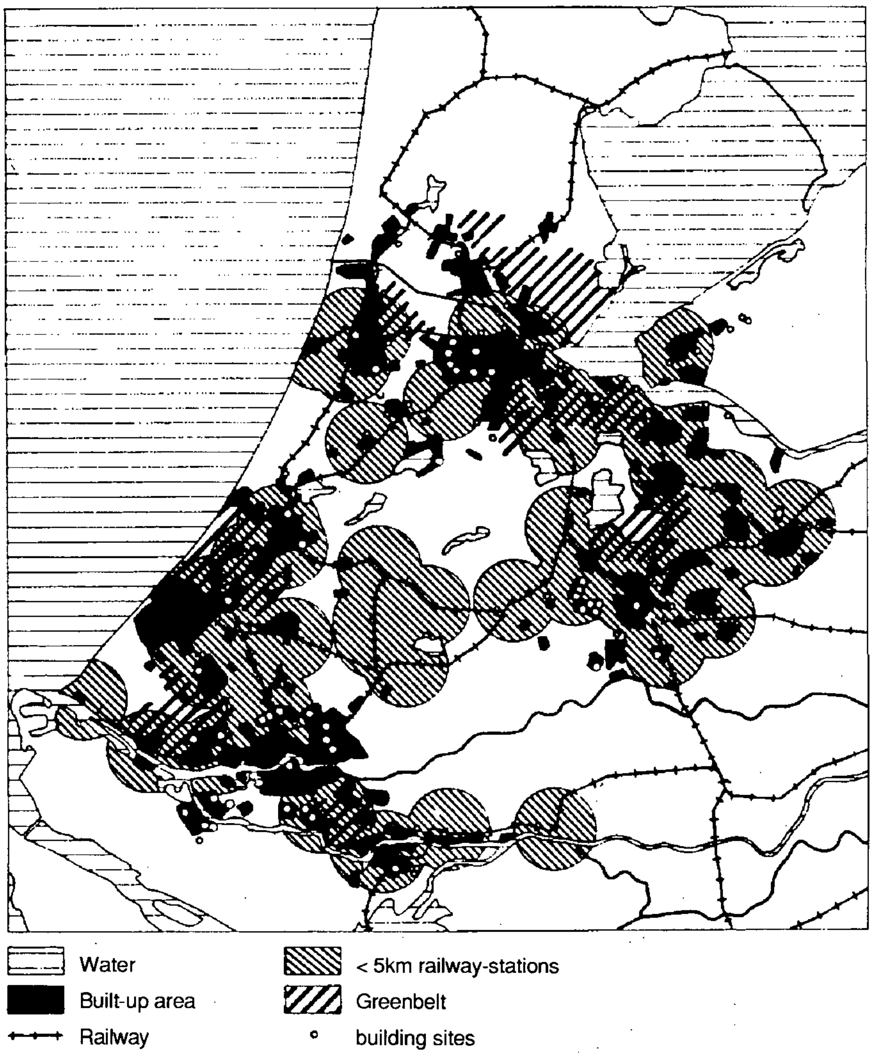


Figure 18: Built-up, Greenbelt and Railway-accessible Areas in Randstad Holland (Geertman and Toppen 1990)

Figure 17 is an example of using the GIS to identify different areas that are pertaining to some of the criteria for new housing development. Obviously, it is not very practical to build houses on water. Water and land are indicated by horizontal line pattern and solid white areas respectively. Built-up areas, which are indicated by solid black area, cannot accommodate additional population and are not considered as suitable for new housing development. The thick line pattern areas are not suitable for housing because they are greenbelt zones, which are protected from further development. The bubble-like zones along the railway network were generated by the GIS's buffering function, which suggest locations served by the existing transportation infrastructure. Through subtraction overlay function, areas that are within five kilometers of railway stations but outside water, greenbelt and built-up areas can be generated. These generated areas were reported to have two uses: 1) to evaluate how many existing designated building sites fall outside these areas; and 2) as a reference (background) for on-screen digitization of alternative building sites. It is interesting to note that more than one-third of the areas designated using more traditional planning methods were found to be outside the areas. This was considered a good example of showing "the superiority of GIS methods over more traditional planning techniques." (Geertman and Toppen, 1990)

This case highlights the use of GIS's spatial manipulation capability. The implemented system is capable of deriving more relevant information from the existing not-so-relevant information. As a result, not only is the accessibility of information enhanced, but also the quality of information. The functions that are involved in the derivations are spatially-oriented and not expected to be found in conventional Data Base Management Systems.

Besides demonstrating GIS being used as an evaluation tool, the case also exemplifies the use of GIS as a design tool through on-screen digitization.

4.5 Territory Assignment in Australia

The spatial data processing capabilities of GIS make it possible to automate some spatial division tasks. In Australia, the Australian Resources Information System (ARIS), a continental scale GIS, was used to delimit the country into seventy-five regions for national economic development monitoring and policy making purposes. The building blocks of these regions were local government areas; and seventy-five towns, cities and metropolitan areas were predetermined as the centers of the regions. Each unselected local government area was then allocated to the closest center and each center with the areas allocated to it formed a region. Following is a map showing the delimited Australia, produced through the above-described process plus some modifications on the boundaries with the consideration of natural geographical features and major communication networks(Garner 1990).

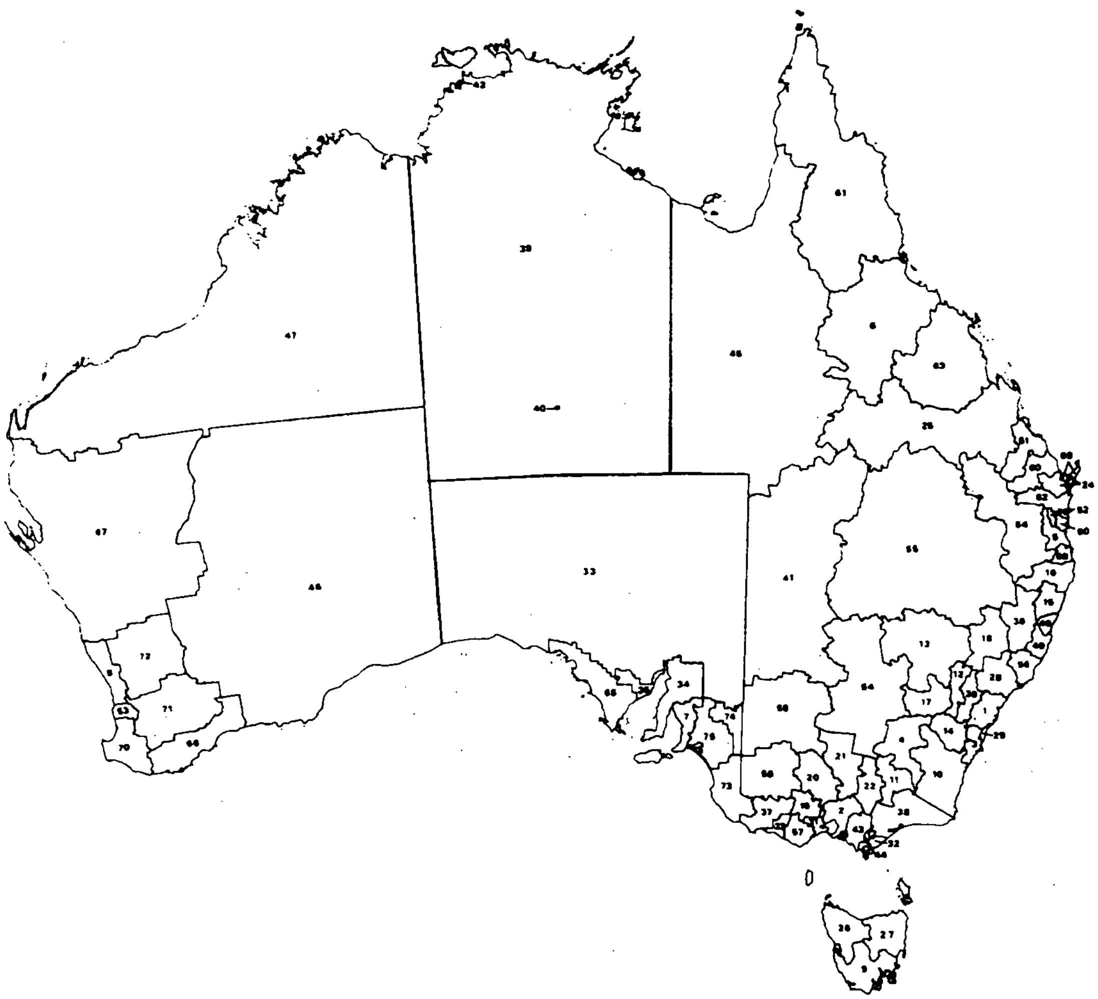


Figure 19: Australian Urban Regions for Economic Development

Garner also gave another example of territory assignment using GIS in a different approach. The task was optimizing the deployment of headquarters needed to administer the provision of fire brigades in New South Wales. The constraints used with the exercise are:

1) the headquarters are all located in major towns;

2) the Superintendent of each headquarters shares a similar amount of workload which is under 42 hours per week;

3) each administrative region is a set of local government areas; and of course,

4) the regions do not overlap but cover the whole New South Wales state.

To solve this problem, the modeling of the workload of a potential region and algorithm for optimization are needed in the employed GIS. For this purpose, the Interactive Territory Assignment (ITA) system, which is a model-oriented GIS designed specifically for solving different kinds of territory assignment problems, was developed. The following figure illustrates the fire services administrative regions in New South Wales before and after the optimization.

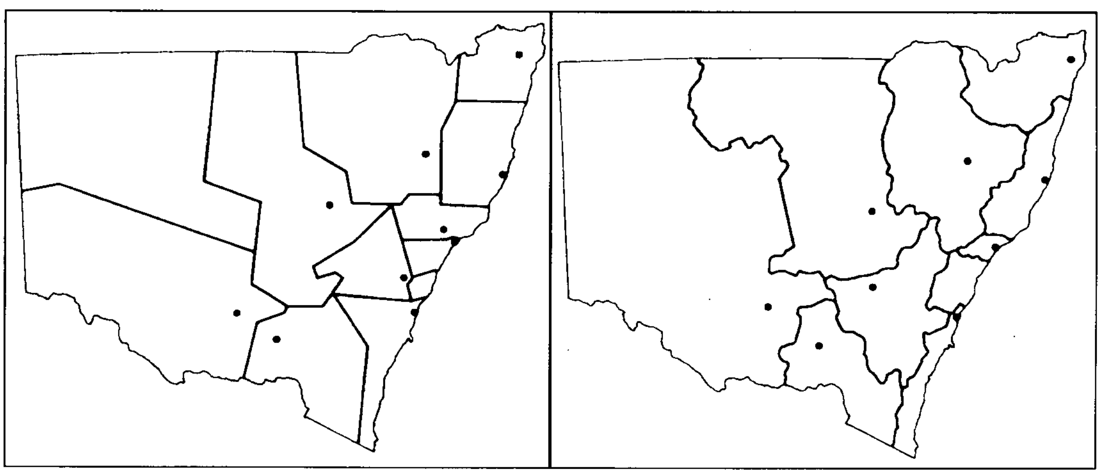


Figure 20: Initial (Left) **and Optimal** (right) **Fire Service Regions in New South Wales** (Garner 1990)

In the above two territory assignment cases, GIS has been used to solve planning problems. This is the level of application that could show the superiority of technically sophisticated GIS and that many GIS specialists are striving to reach. However, the success of this type of applications can only occur when the planning problems to be solved are well-defined and non-controversial.

4.6 Local Labor Catchment Area Analysis in Northern Ireland

Hart, Bond and Devine (1991) documented one of the more sophisticated analytical applications of GIS—deciding the "correct" religious composition of the employees for each firm in Belfast. The theory was that discrimination is considered to have occurred if the religious composition of the employees in a company does not correspond to that of the labor pool in its catchment area. To apply the theory, one has to know the actual labor pool within the catchment area of the company under scrutiny. Thanks to the *1981 Census of Population,* the labor pool, i.e., those who are capable of working for a certain type of job, can be queried for a given catchment area and consequently its religious composition calculated. Now comes the difficult part—how to determine the catchment area for a given workplace. Without GIS's advanced capabilities of spatial analysis, such a problem would be out of the question. A crude approach would be to define the catchment area of a company as a circle surrounding it with a certain radius (in a GIS, this can be achieved simply by using the buffering feature). This approach assumes the accessibility to a workplace is merely a function of distance, which, apparently, is a far cry from the reality. The fact is that the surrounding topography and transportation facilities will have a very significant influence on the accessibility to a workplace. Therefore, a better approach would be to use a GIS to model the accessibility to a given workplace taking into account the topographical impedances and the traffic facilities in the surrounding area. In Belfast, this approach has been implemented with *ARC/INFO*, as described by Hart, Bond and Devine (1990):

> The modeling of the underlying catchment area for a workplace using *ARC/INFO* consists of using the data derived from the census on the travel characteristics of different skill groups to find out from where that group would travel to the workplace. Using the impedances built into the topographic data *ARC/INFO* will work backwards from the workplace to find out the limits of travel. For example, if messengers on average travel on foot to work with an average journey time of ten minutes then *ARC/INFO* will work outward from the workplace and select all parts of the transport network which are within ten minutes journey (walking) time.

The problem-solving process, as presented above, is quite sophisticated technically. Yet, it omitted many factors that may significantly affect the final results. For example, are the spatial units used for the census appropriate for the accessibility analysis? Are the impacts of neighboring competing workplaces really negligible for calculating the labor force pool for a given workplace? "What figures should be used to derive the average journey time and travel made of the various skill groups" (Hart, Bond and Devine 1990)? Are the one-decade-old data still suitable for this kind of analysis on such a micro level? What level of random fluctuation is allowed for the judgment of whether discrimination has occurred? Knowing that these questions do not have clear, well-founded answers, one may wonder what validity a derived "correct" religious composition has for a given workplace.

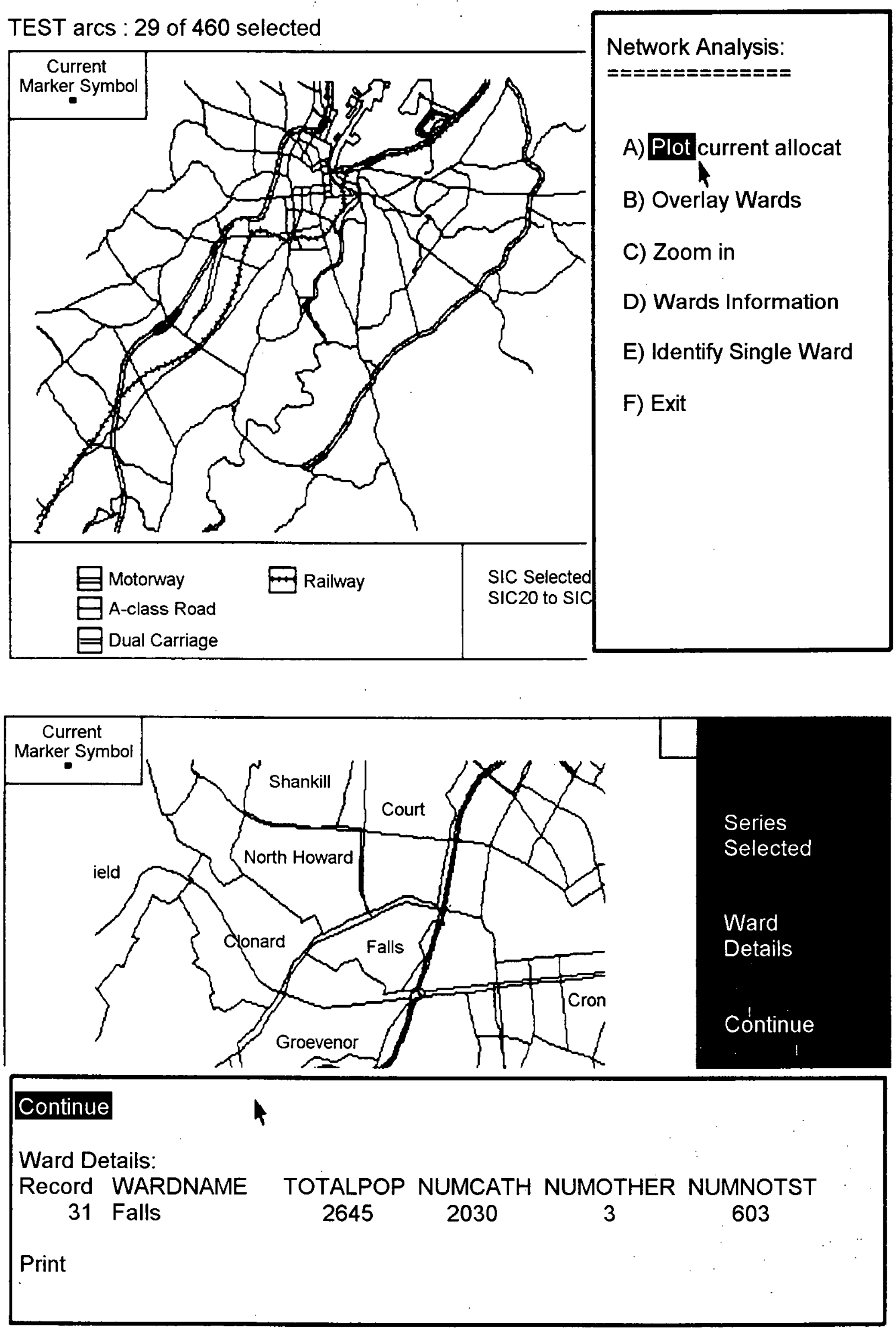


Figure 21: Allocating Travel-to-Work Patterns in Belfast (Hart, Bond and Devine 1990)

Nevertheless, it is beside the point to criticize the application based on its technical deficiency. Even if there were an ideal GIS that had a well-calibrated model running with perfectly accurate and up-to-date data, the "correctness" of a religious composition for a workplace derived from such a GIS would still be challenged by different groups with different definitions for "correct" religious compositions. What is lacking in this case is the social progress that might have been brought about with the involvement of the public in a participatory social planning process. It is possible that the calculation of "correct" religious composition figures will also trigger a public debate about the discrimination in the locale, however, the focus would likely be misleading. The real problem does not lie so much on the lack of technical tools to determine the right catchment area for a given workplace per se, but on the lack of understanding and tolerance among people. Compared with a public participatory planning process in which problems are identified, options generated, consequences of the options evaluated and decisions reached all in a collective manner, a solution to a social discrimination based on the "correct" numbers derived by some experts working with a geographic information system behind a closed door looks very pale in overall effect. Most importantly, what the technical fixes such as the one in this case lack is that a public participatory planning process invites people to think and understand planning problems, and transforms people in the process of solving planning problems.

4.7 Findings from the Case Studies

The case studies in this chapter have illustrated the versatility and customizability of GIS, and diverse roles the technology can play in planning. Chapter 2 explained what planning needs from computing technology. In Chapter 3, we saw from a technological point of view the potential of GIS to be used for information presentation, information management and information analysis. This chapter has provided concrete examples of what types of planning tasks have used GIS and how the potential of the technology was realized in some planning situations.

Although this chapter has shown six very dissimilar cases, the functions that GIS served in each case can still be covered by the three main functions of computer technology in planning that were developed in Chapter 2. What makes GIS different from other computing technologies in the context of planning is that GIS can be equally suitable to serve any of the three functions.

In the GRC case, the GIS was almost solely used for presentational purposes. In fact, the GIS functioned as an interface for easy navigation in a presentation system. With the limitation of the available GIS technology, the non-alphanumeric forms of the data in the system were not suitable for extensive and efficient information management or analysis. Furthermore, the time requirement that the system had in order to keep the presentation flow did not allow complicated data processing on the fly. From the end-user's point of view, what is needed from such a presentation system is credible, informative and impressionistic information rather than in-depth explanatory insights or ready-to-use optimized solutions.

In the WATGUM case, GIS functioned mainly as a visualization tool, generating visual aids and helping convey planning ideas to non-technical people. In contrast to the first case, the application context of the WATGUM case did not require real-time use of the system. Instead, the output of the model had been distributed in the form of maps and tables, which made it possible for the GIS to carry out more elaborate cartographic data processing on the fly when producing mapping output.

Different from the first two cases, which are examples of using GIS for information presentation, the St. Helens Urban Program GIS took on the task of information management. Operational and background data that were relevant to the program had been stored in the GIS for efficient information retrieval. In this case once again, cartographic display of interested data is obviously an important feature of the GIS, but its main utility was based on its capability of pulling out specified data and integrating them in some meaningful fashion to answer specific planning questions. This GIS functioned more like a workbench for policy analysts to test out their hypotheses and identify hidden patterns.

The last three cases all focused on using GIS's analytical capability to solve problems technically. In the Randstad case, GIS was able to identify the areas that are most suitable for new housing developments when criteria and constraints were input into the system. The Australian case demonstrated GIS's power in offering optimized solutions to territory assignment tasks. In the Northern Ireland case, GIS was employed to define catchment areas of workplaces and then to derive population compositions of those areas.

The cases presented in the chapter have demonstrated GIS's versatility in serving different purposes. Indeed, coupled with other technologies, GIS's possibilities of planning applications in information presentation, information management and/or information analysis seem countless. Still, as present in all case studies in this chapter, information presentation is the most basic function that all GISs have, whether or not they are intended to be used as presentation systems.

Now with Chapter 2, Chapter 3 and the support of the six case studies, we have completed the discussion of what planning seems to need from information technologies and what the GIS can offer to the profession. It is time to move on to the analysis of what is lacking with the current GIS application in planning and how to take the full advantage of the technology to make it work for planning. And this will be the task of the next chapter.

5 Roles of GIS in Planning

This chapter contains three parts: the first is a critique of the prevailing view of GIS application in planning, the second an analysis of GIS's roles in planning, and the third an evaluation of the suitability of different GISs to planning.

Looking into the literature on GIS application in planning, one finds that the underlying theory of utilizing the technology is of no fundamental difference from the technocratic one that was underlying the application of computers in the large-scale modeling period. This seriously hinders taking the full advantage of the available technology and subjects many planning GIS applications to the same pitfalls that led to the collapse of the large-scale modeling effort in the early 70s.

The discussions in the previous chapters should make it clear by now that GIS is a hybrid technology. It can serve planning in all the areas that computers have been aiding the profession: information presentation, information management and information analysis (Scholten and Stillwell 1990). After exploring GIS's role as the three tools in planning, this chapter moves on to discuss the use of GIS at different stages of the planning process.

Because the diversity of GIS features, different emphases on certain features during the development of GIS software by different developers have created a wide range of GIS products. Are they all equally effective for planning purposes? The analysis in the third part of this chapter will explore whether the principle that "small is beautiful" applies when it comes to choosing a GIS software package for planning applications.

5.1 Technocratic Use of GIS in Planning

The literature shows that the application of GIS in planning is guided by the rational planning theory. Most of the articles do not even mention that there exist different styles of planning. They basically fall into the following two categories: 1) methodological discussions on how GIS can better help planning; and 2) reports on specific GIS planning applications. The focus of the first category is mainly on augmenting GIS modeling and analytical power (e.g., Batty 1991a), while the second category is a collection of examples of GIS-based technical problem-solving cases (e.g., Worrall and Rao 1991). Invariably, the authors pay very little attention to the pluralistic actors in the realm of public planning and the production and reproduction of social relationships in the affected community. Lurking within those relevant Internet discussion lists and news groups, or talking with the GIS people in the Greater Vancouver Area, one finds that the proper use of the technology in the modern planning context is seldom an issue, and the preoccupation is with various "nuts and bolts" problems about the technology. There is no evidence that the current use of GIS in planning is in any way informed by social theories. In fact, "[a]t present, the GIS practitioners and the social theory discoursers are far apart, with minimal mutual communication" (Wheeler 1994).

To most GIS practitioners, planning is essentially a technical endeavor and the core of the activity is Aristotelian reasoning. It makes no difference who actually does the planning (their top choices are probably professional planners or computers), as long as the rationality of the reasoning involved is rigorously upheld, the outcome should be equally effective. They favor quantitative methods over qualitative ones, and generally regard the involvement of politicians and the public as a nuisance to rationality in the planning process. Therefore, they make no effort to have their problem-solving methods receptive to extensive planning participation. In their version of planning, social action has no significance. Occasionally, some of them do talk about organizational and political factors, but only treating them as necessary external conditions for the successful execution of technical problem-solving procedures, not as a integral part of planning problem-solving processes.

With this technocratic view, GIS people see spatial analysis and modeling as the essence of GIS application in planning. As observed by Peuquet, "the most widely accepted assumption is that the analytical aspect [of GIS] is both the essential aspect and distinguishing characteristic of GIS" (Peuquet 1991). As a result, they find GIS is both powerful and problematic in planning because of the same reason—its analytical capability. They believe that computerized planning models are the interface to link GIS with planning processes and regard the current use of GIS focusing on mapping and database management as a less desirable, if not unfortunate, situation (Batty 1991). Ironically, these two aspects are exactly the major distinguishing factors that set GIS apart from traditional large-scale models. They are the reasons why this technology has gained some good reputation in the field and has intrigued the planning community once again as a useful computer-based tool for planning. Nevertheless, there appears to be an active effort to revitalize the quantitative methods developed in the large-scale modeling period and implement them in today's GIS (Batty 1994; Wegener 1994; Harris 1994; Fisher and Nijkamp 1993).

These professionals working with GIS regard data as only technical resources and the content of data as objective description of the reality. Consequently, an advantage of adopting GIS that is often cited in the literature is that it minimizes data redundancy—with a centralized data base, all the users will draw data from the same database so that replicated data storage and data inconsistencies are avoided (Aronoff 1989). However, it is commonly accepted in planning that data are also political resources: their availability, format, content, assumptions and collection method are all controllable factors to influence the focus and even the result of the analysis (Wachs 1988). Therefore, the above-mentioned advantage of minimizing data redundancy might also be seen as a disadvantage in a different light:

- the enforcement of a single data set may function to strengthen bureaucratic control of data;
- from a systems point of view, a system without some redundancy is not a robust system;
- a single version of data is not reflective of today's pluralistic society; and
- a system without data redundancy puts pressure on telecommunication (i.e., fewer users have to rely on networking if they have data self-sufficiency with their local computers).

In summary, the technocratic use of GIS appeals to planning that is physically rather than socially, politically and culturally centered; knowledge- rather than action-oriented; quantitatively rather than qualitatively based; technical rather than normative in nature. This is in serious contradiction with today's *Conscious Public Planning* philosophy.

5.2 GIS Used as Tools for Planning Information

Planning in the 90s is communicative in nature. Planning solutions that are optimal in the technical realm are not good enough. They must be responsive to the people on whose life they have impacts. The use of information in planning has never been so intensive and complicated as it is today, and therefore calls for help from new information technologies such as GIS. Of course, GIS cannot plan by itself and replace human planning participants. Working on GIS itself is not planning. GIS is just a tool, which, if properly used, can help the user to improve the efficiency and/or the quality of planning.

5.2.1 GIS as an information presentation tool

As we can see through the discussions on the origins, the features and the application cases of GIS in the previous chapters, the most basic and, perhaps, the most useful role of GIS in planning is presenting information in graphic forms—mostly maps.

> Graphics feeds information straight into an observer's mind; information can be presented attractively, and be literally eye-catching; data can be presented not only quickly, but selectively, drawing attention to what is important; trends in data are often readily discernible via graphics presentation, so too, are anomalies (Bracken and Webster 1990).

The maps of GIS are on the electronic medium, which has many advantages over traditional paper medium. Thanks to the development in computing technology, the maps generated by GIS can be output to a variety of media: paper, overheads, slides, videos, and fabrics, not to mention the emerging new medium—computer-based multi-media. Planning participants can employ GIS's mapping capability to visualize, communicate and interact with planning information.

Many planning issues such as those of site selection, land use, and transportation are intrinsically spatial; while others such as environmental impact analyses, housing issues, and economic development also have strong spatial implications. Maps have been an important visualization tool for planners. Likewise, a GIS can also function as a visualization tool to aid recognizing, formulating, understanding, and analyzing planning issues. This visualization function of GIS is especially instrumental in dealing with the substance of planning issues and is useful in all stages of a planning process.

In using the GIS as a visualization tool, the information flows are mainly between the individual user and the system; when the system serves as a medium carrying information to and from different individuals, GIS functions as a communication tool. The efficiency gained in mapping automation with GIS makes possible the widespread use of customized maps tailored to specific issues, which enhances the effectiveness of visualization and communication. The interactiveness of the electronic medium offers an unique opportunity to construct presentations in a way that the audience can have more control over selecting and ordering the information of interest. The simulation potential of the medium makes it ideal to convey complex issues (Godschalk and McMahon 1993). The electronic maps produced by GIS are also in the most appropriate formats to take advantage of the emerging computer-centered telecommunication infrastructure for fast, flexible and cost-effective information dissemination. As it becomes increasingly clear that the computer is the medium of the future, GIS will be a good form of the new medium to carry geographic information. Research has been under way to build remote access capabilities into GIS so that it can be used anywhere in the world through the global computer networks.

As a presentation tool, GIS can be seamlessly blended into planning processes of all styles. What the technology can contribute here are efficiency and effectiveness in the planning participants' understanding of substantive planning issues and interpersonal communication, which is the central activity of contemporary planning. This use of GIS does not have to be seen as an obstacle to involving people into planning but a tool to facilitate planning participation.

Besides functioning as an aid for enhancing the user's appreciation of planning issues, the electronic maps of GIS can also function as a graphical interface to the information stored in or generated by the system. The Georgia Resource Center case presented in the previous chapter illustrated how GIS could be used as an effective interface to access to vast volumes of information; while the Randstad housing case gave an example of employing intuitive on-screen digitization to alter the content of the information system.

Good presentation capabilities and effective human-computer interfaces can also facilitate the accomplishment of information management and information analysis tasks. Therefore, GIS's presentational and interfacing functionalities also serve as an important component of the system as an information management tool and as an information analysis tool.

5.2.2 GIS as an information management tool

As discussed in the earlier chapters, GIS is a technology built on the top of conventional Data Base Management System (DBMS). It inherits all the information management functionality of the DBMS. As a computerized information system, GIS offers a means of automated data collection, compact data storage, fast and flexible data retrieval, and cost-effective data maintenance. Compared with conventional DBMS, GIS has two marked advantages: 1) it has a mapping front-end for the effective and intuitive input and output of information; and 2) because most information in a GIS is geo-referenced, it is possible for the GIS to make multiple databases with various contents appear transparent to the user. As a result, the user will feel like using one integrated information system containing very diverse information. This integration of data brings "added-value" to the existing data (Stillwell and Scholten 1990; Simkowitz 1993).

Database management is one of the earliest computer applications in planning. This is no surprise because planning is inherently an information-rich endeavor and computers are very good at handling information on a routine and perhaps tedious level. Like conventional DBMS, GIS can enhance planning professionals' efficiency in accessing available planning-related information, to conduct analyses, write reports and inform clients. In the *Conscious Public Planning* era, providing planning information to the public has become an important responsibility of professional planners, because in addition to being technical experts, they also play the roles of political brokers, group-process facilitators, special-interest advocates and/or social activists (Howe 1992). Therefore, the role of GIS in information management should go beyond enhancing the efficiency of the use of information within the planning institution.

A GIS can be set up for public access (Marble 1991). As early as in 1986, the Shiga Prefecture Government of Japan published the Shiga Prefecture Regional Environmental Atlas, containing thirty-five data categories on natural and socioeconomic conditions of the prefecture. The publication aimed at educating the general population about the environmental issues, enhancing communications among various social groups and encouraging widespread public participation. In 1988, the data were expanded into forty categories and distributed in the form of GIS planes on floppy disks (Nakayama 1991).

With today's computing technology, GIS specialists have a vast array of tools to implement their systems in a way that people with little specialized training are able to use. Hierarchical menus, graphical icons, windows, hypermedia, context-sensitive help systems are a few widely-adapted but effective ways to provide the end-user with easy access to specific information. Furthermore, new developments in storage technology such as CD-ROM provide cost-effective ways to distribute massive volumes of information. Telephone lines can also be utilized to provide direct access to information residing in a GIS. The emerging high-speed computer network will diminish the significance of the user's physical location. For example, Mike Flaxman (flaxman@aaa.uoregon.edu), a graduate teaching fellow in the department of Planning Public Policy & Management at University of Oregon mentioned in the *comp.infosystems.gis* Internet newsgroup several current efforts of linking GIS and the *World Wide Web* (WWW) interface so that the GISs can be accessed by Internet users all around the globe.

5.2.3 GIS used as an information analysis tool

In essence, the implementation of GIS itself is a form of the simulation of the spatial relationships that exist in reality. Unlike most other relationships, such as those economic, social and political ones in planning, these spatial relationships can be neatly described by mathematical algorithms. Therefore, a computer system can be programmed to model real spatial relationships rather faithfully. This partially explains why GIS has been such a successful phenomenon. With a good representation of spatial reality in place, a GIS can deduce spatial relationships that may not be immediately apparent or intuitive to the user. This is the foundation of any GIS analysis: for example, the buffer function, which is a spatial manipulation, can be used to identify the affected property along an elevated rail transit route, which in turn has complicated and significant economic, social and political implications. Furthermore, non-spatial relationships can be modeled as attempted in the more traditional modeling effort for planning and then combined with the spatial model to perform more sophisticated analyses.

As an analytical tool, GIS can be used to find answers for technical questions. Because of its geographic nature, it is especially suitable to answer "where is" questions. These questions can be of fact-identification type such as where the low-income single-parent families are concentrated, and their answers from GIS can serve as a factual basis for planning discussions. These questions can also be of problem-solution type such as where the subsidized daycare center should be located, given a set of pre-determined criteria, and their answers from GIS can be used as stimuli for active planning participation.

Therefore, GIS is a sophisticated analytical tool to enhance planning practice. It is especially useful when it is applied to those planning tasks that are spatially-oriented. However, GIS is not a panacea for all kinds of planning problems. In the last two decades, planning is ever more economically-, socially- and politically-oriented. Analytically, GIS is not yet capable of handling most of the economic, social and political factors that are so central to modern planning. It is a challenge for GIS and planning professionals to make the analytical component of the technology better suit today's planning style.

5.3 GIS and the Planning Process

A basic planning process can be theorized to have the following stages: the formation of the planning task, the generation of possible solutions, the evaluation of the solutions and planning decision making. In practice, one planning project may involve many recursions of this basic planning process. One finds that as an information presentation tool and as an information management tool, GIS can be useful in virtually all stages because each deals with information, and hence the communication and organization of the information. A genuinely participatory planning process should involve the public in all stages.

In the planning task formation stage, the involved participants need general information about their community that they are planing for and specific information about the substantive issues at hand. This information could come through many channels—first hand personal experience, informal social interactions, media, libraries, governments and so on. GIS could function as one channel to provide some of the needed information such as demographic statistics for defining planning tasks. The technology also can be utilized to document and organize public input at this stage.

During the solution generation stage, a GIS can be used to produce customized scenarios as a basis for planning participants with different views and interests to construct their own solutions to the planning task. It can also be employed as an effective communication tool to exchange planning ideas and stimulate the participants.

The evaluation of different solution options is the most technical component in planning and thus has traditionally been the hottest area in computer application in planning. Admittedly, computer-based evaluation methods have some unique advantages over other evaluation methods: it is a very powerful tool for calculation, extrapolation and complicated but structured reasoning. Therefore, computers can automate many chores that used to be labor-intensive analytical activities in the evaluation process. Moreover, they can conduct virtual experiments that have no physical consequences, which is especially useful in planning since many plans, once implemented, may have irreversible effects. What we should be cautious about is to conduct GIS simulation in isolation of the important planning actors—the public, forsaking the opportunity to evolve the social consciousness dialectically.

Planning decision making is inherently political. As an information presentation tool and an information management tool, GIS technology can be used to enhance the effectiveness of informing and educating interested parties about available planning options and their implications, to mobilize political forces, and shape public opinions (Godschalk and McMahon 1993).

5.4 The Limitation of Current GIS

As we can see in previous chapters, GIS has very specific ways of representing the reality and handling its attribute data. The geography is either represented by abstracting geographic entities into basic cartographic elements—points, lines, and polygons, or by dividing an area into small cells; while the data management component of GIS is based on conventional Data Base Management System (DBMS). These particular technical approaches, like any other ones, have their particular limitations in their application in planning:

1) The technology deals with absolute and concrete space. "Urban planning, however, operates at the intersection of social space and physical space. In social space, abstract, subjective and relative notions of space are of vital importance, but they are difficult to deal with in a GIS. Furthermore, information on individual spatial behavior, a major theme in planning research, cannot easily be stored, managed and analyzed with a GIS" (Ottens 1990).

2) There is not yet a good solution for representing time in GIS. The technology "needs to be developed so that time analysis can be conducted in a more direct and consistent manner" (Durfee, Mccord and Thomas 1993). Generally, planning is about making decisions for the future of the community that has a history. Therefore, the temporal dimension of reality has special importance in planning.

3) Information processed in GIS is still heavily numerically-based. In planning, information is received, processed and presented in different forms, of which textual and graphical forms are especially important. The current implementation of GIS still lacks of multimedia capability of handling information in diverse forms.

4) The technology is data hungry. "Not only does GIS use huge amounts of information, it also creates it" (Parker 1993). Despite rapid developments in computer hardware, computing resources always seem somehow to be inadequate for using GIS interactively. In planning, this inadequacy is likely to discourage the use of GIS for extensive "what if" studies; especially so, if the user is of a non-technical type.

5) GIS's capability of intelligently displaying information at different detailed levels remains problematic (Ottens 1990). For example, a GIS designed for large-scale mapping applications will be very sluggish and inaccurate when used for wide-scope but small-scale applications. This limitation of current GIS technology makes it impractical to implement a single GIS system to satisfy multiple users with different requirements about the scale of the mapping output from the system. One often reported problem with using GIS in planning is that the involved system, originally set up for administrative purposes, is cumbersome at extracting useful information from the stored disaggregate data for planning purposes.

5.5 Appropriate GIS for Planning

GISs used to be run mainly on workstations, minicomputers and mainframes due to their graphical nature and often large data sets (O'Malley 1994). However, with the rapid increase of processing power of microcomputers and the popularization of GIS technology, GIS has been moving towards desktop platforms, i.e., microcomputers (Scholten and Stillwell 1990). Desktop GISs are gaining an ever larger share in the GIS market. Desktop GIS packages such as MapInfo's *MapInfo* and Strategic Mapping's *Atlas*GIS* are now available for under $1,000 US (1995), compared with full-fledged GISs such as *ARC/INFO* starting at $5,000 US (1995). The introduction of low-end desktop GISs by industrial leaders such as Environmental Systems Research Institute signified the structural change in GIS industry.

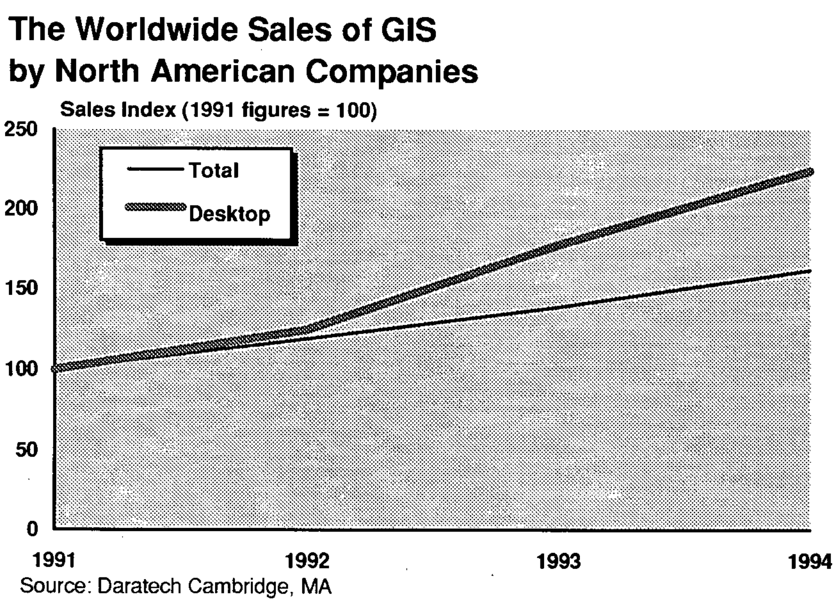


Figure 22: The Rapid Growth of Desktop GIS Sales (Adapted from O'Malley 1994)

From a technological point of view, the more complicated a GIS is, the more advanced it usually is. However, a more sophisticated GIS is not necessarily a better tool for planning. The variety of analytical tools available in a high-end GIS may sound overwhelming to a GIS novice, yet it is too often that one finds that none of these tools is practically applicable to the planning task at hand. A "benign" problem such as finding the best location for a service center strictly from an economic perspective cannot be solved without elaborate modeling. The "real world" planning issues, which are mostly "ill-structured" in nature, render the available machine-based analytical techniques virtually impotent in finding the solutions. Furthermore, the algorithms involved can be so complicated that they actually prohibit the understanding and thus the trust of decision-makers.

On the other hand, in spite of its lower analytical power, low-end GISs all possess basic storage and retrieval capabilities for geo-referenced information, which have proven to be the most useful features that GIS can offer to planning. In fact, as the following discussion argues, adopting low-end GIS in planning can be advantageous over using high-end products. For instance, Thom, a GIS expert working with high level macro planners in Jakarta in 1993, chose to use *Atlas*GIS*, which is a low-end, low-cost, microcomputer-based GIS. He gave his reasons for the choice in the *GIS-L@uvmn.edu*, an electronic discussion forum on GIS on the Internet as follows:

1) Insufficient funding for a high-end GIS such as *ARC/INFO*;

2) There was not much digitized data available other than those generated by word-processors and spreadsheets, and the Macintosh-based version of *Atlas*GIS* can

work seamlessly with word-processing and spreadsheet packages within a Macintosh system;

3) The package could be customized to use the local language—Bhasa Indonesian.

In today's *Conscious Public Planning*, the importance of technical analysis has become secondary; planners are facilitators, mobilizers, educators, and communicators; the general public are entitled to participation in planning their community. What the majority of the planning actors need in this day and age are information rather than raw data, information accessibility rather than analytical flexibility, and user-friendliness rather than programmability. Scholten and Stillwell (1990) have laid out the relationship between different types of GIS and their user groups. Apparently, satisfying the users that fall into the categories in the lower part of the table has great significance in planning. Therefore, planning needs more "small and beautiful" type of GISs.

	Information Demand	**User Demand**	**Type of GIS**	**Development**
Infospecialist	raw data	analysis/ flexibility	large "open"	links to other packages
Researcher	raw data/ pre-treated data	analysis accessibility	compact manageable	macro languages interfaces to other packages
Management/ Decisionmaker	(strategic) information	accessibility weighing/ optimalisation	small and beautiful	user friendly interfaces
Target Group/ Others	information	accessibility	small and beautiful	user friendly interfaces

Table 1: User Groups and Types of GIS (Scholten and Stillwell 1990)

5.5.1 The complexities of different GISs

The rich collection of features that high-end GIS offers adds flexibility and versatility in applying the technology. However, the additional flexibility and versatility also come with increased complexity. A high-end GIS can accommodate data from different sources in a variety of formats, and this creates the problem of data compatibility. A high-end GIS can handle sophisticated modeling, and this brings in assumptions, which are sometimes not so easy to identify and thus, to be aware of. A high-end GIS is capable of working with an array of input-output peripherals, and this is bound to generate a good number of technical problems to be tackled. More significantly, high-end GIS is destined to be implemented to serve multiple users, and this implies a very different kind of complexity that single-user low-end GIS is not associated with, as we shall see more clearly in the following discussion.

High-end GIS is expected to be of high performance, but this is not always apparent to the end-users. To justify the use of the expensive hardware that high-end GIS requires, the users often have to share their computing resources with others. For example, "In the Randstad, Holland, the National Physical Planning Agency ran *ARC/INFO* on a mainframe, which was . . . unacceptably slow when planners wished to use the GIS application interactively: this would be a major constraint in a practical planning environment" (Geertman and Toppen 1990). In the District of North Vancouver in British Columbia, the local government runs an *ARC/INFO* system on a UNIX server, which is accessed by the end-users with their PC-based workstations through their local area network. The result is rather sluggish performance on the end-user side, which discourages interactive use of the system.

A GIS that is under the personal control of the user can be set up for very specific purposes, compared with large "do-everything-for-everyone" systems. There is potentially a danger in believing that, since a powerful GIS can have rapid access to so much information in all kinds of combination, everybody should find it useful and no focuses are needed in designing the system for targeted end-users. For example, the Land Use and Natural Resource (LUNR) inventory system was developed in the state of New York on the notion that a comprehensive inventory information system would be important and valuable. "LUNR, produced by researchers at Cornell University, was based on a cell size of 1 square kilometer and covered the entire state. Begun in 1967 and completed in 1970, the data base contained information on 130 categories of land use. The system was capable of producing inventory maps and overlays. . . . The uses and users were not well identified and as such the system did not satisfy any specific need. . . . If the development of system is not based on a realistic plan with realistic goals, then there is a good chance of failure" (Parent and Church 1987).

5.5.2 The costs of different GISs

Sophisticated GISs are naturally expensive. They demand more resources to be developed, marketed, set up, maintained, and used. The involved hardware has to be of high-performance, i.e., fast processing speed, large amount of memory, generous disk space, high resolution input-output equipment and so on. Dedicated GIS experts, who are often better paid than planners, are needed to attend to these complicated systems and the end-users need extensive training to be competent in using them effectively.

In contrast, low-end GISs cost significantly less than their high-end counterparts in virtually every respect. In addition, because those low-end GISs are often based on microcomputers, they can take advantage of the existing hardware facilities and the growing microcomputer literacy. Kim (1990) commented that "planners generally confine themselves to a personal computer (PC) environment . . . " This may be a minus to using mainframe or workstation based high-end GISs; but it is definitely a plus for adopting the low-end of the technology.

5.5.3 The organizational impacts of different GISs

Because a high-end GIS is expensive, it is often shared by many users in one or more departments within a sizable organization and is mostly run by a centralized Management Information System (MIS) or Computer Information System (CIS) department. Such a system is bound to impose an organizational structure on the institution where the system is running (Drinan, 1992). This adds another dimension to the complexity of applying the technology (Batty 1991). The past experience shows that the compatibility between the GIS system and the organizational structure of the institution is crucial to the success of using the technology (O'Brien 1990).

The introduction of a low-end GIS has a direct impact only on the work procedure of the individual user. It does not require organization-wide adjustments in order to be effective. The changes will be brought along first at the individual level as individual workers see fit. Should low-end GISs lead to any structural change to an organization, the driving force would probably from the bottom rather than the top.

5.5.4 The user-control of different GISs

If a GIS is shared by multiple departments in a local government, as a high-end GIS probably would be, all these departments will compete for the design, implementation and use of the system. Planning department, public works department, engineering department and natural resources department all have different needs for a GIS: they need different categories of data in different formats, different level of aggregation of data, and different kinds of presentational and analytical functionality. For example, the engineering department needs to organize detailed technical data on a project basis, while planning department is interested in integrating more strategic data from diverse sources; natural resources department is more readily to utilize remote-sensing data, depicting natural phenomena, while planning department has to reply heavily on administrative boundaries. Compromises have to be made to accommodate these conflicts.

Because a typical planning department is normally not a powerful department in a local government, a planning orientation of the GIS is often forsaken to satisfy the needs of other departments (Innes and Simpson 1992). In addition, as argued earlier in this thesis, planning is a field that is intrinsically difficult to apply computing technology to; therefore, the priority of applying GIS in a local government often goes to other departments first. Moreover, the majority of planning directors and their staff do not have the technical background that today's GIS still unfortunately requires; as a result they tend either to be unenthusiastic about the technology, or to be impotent in making it work for planning.

5.5.5 The capabilities of different GISs

The prowess of a high-end GIS lies in its ability to analyze well-defined and quantifiable problems, which do not comprise the majority of planning tasks. To make better use of a high-end system, planning tasks that are more conducive to quantification are more likely to be fed into the system and hence, explicitly or implicitly, the rational planning tradition is encouraged. Moreover, because of the high cost of a complex GIS, there would be greater pressure for measurable benefits, which will further discourage the inclusion intangible factors into planning. By contrast, low-end GISs are more presentation-oriented and better communication tools for information dissemination. Since they are mostly microcomputer-based, their output can be readily integrated into a great variety of microcomputer applications such as word processors, desktop publishing packages, spreadsheets, illustrators, multimedia authoring systems, etc. to produce reports, handouts, slides, overheads, templates, electronic publications and so on. Therefore, low-end GISs have greater potential in aiding generic planning tasks.

Although there are exceptions, high-end GIS usually represent a centralized approach while low-end GIS a decentralized approach in a multi-user environment. In setting up a centralized computer system, it has become a standard procedure that the system analysts go to the end-users to assess their computing needs. However, the idea of this kind of need assessment is sometimes elusive because the end-users, albeit knowing their disciplines the best, would not understand the potential of their centralized computer system and thus cannot make very sensible suggestions until they get to know their system well. No matter how accommodating one makes a centralized system to be, the control of such a system by its end-users is no match with the control of their personal computers. The use of a high-end GIS that is treated as a organization-wide resource is likely to be subject to bureaucratic control. As a result, individuals' free, creative and exploratory use of the technology is deterred by the management measures such as committee approvals, limited access to the system, and inter-departmental politics. This is especially a serious drawback since planning tasks are mostly non-routine in nature, which calls for flexibility and creativity in using a GIS.

In addition, high-end GISs are prone to technocratic myth making. Because they must be handled by technical specialists, the data and analytical results may seem to be more valid and value-neutral. And it may also seem to be out of a layman's reach to question and take the limitations of GIS use into account. By contrast, low-end GISs, because they mostly run on micro-computers and employ straight-forward analytical techniques, are less intimidating and therefore encourage both the producers and consumers of the output to understand the scope, assumptions and limitations of the applications.

Low-end GISs take less storage space and demand only moderate computing power; therefore, they can run on portable computers and be taken into the field. As an example, Thom reported in the *GIS-L@uvmn.edu* on the Internet that he used a laptop loaded with a low-end GIS to do presentations in public meetings.

Even where high-end GIS is needed, low-end GIS still has its role to play. Supplementary to a high-end GIS, a low-end one can function as: 1) a training system, familiarizing the user with GIS technology; 2) a prototyping system, testing application ideas; and 3) a presentation system, demonstrating and producing presentational materials for high-end GIS outputs (Newton 1991).

6 *Conclusion*

This chapter consists of three parts: the first is a summary of the previous chapters, highlighting the key observations, arguments, conclusions and implications; the second is a set of recommendations that are intended to provide some directions to planning professionals who are using or considering using GIS for planning as well as GIS developers who are targeting planning as a part of their potential markets; the third is some future research topics suggested as continuations of this research and conjectures about the future of GIS in planning.

6.1 The Findings from the Previous Chapters

In this section, the findings from the previous chapters are presented in eight segments. They are organized on a chapter and section basis: the findings from chapter five, three and four are put into segment 6.1.1, 6.1.2 and 6.1.3 respectively; while the findings from chapter five warrant five segments—one for each of the five sections in the analysis chapter.

6.1.1 The importance of technical analysis secondary in planning

Chapter two started with a discussion of planning from a historical perspective. The segment identified three apparent trends: 1) the profession keeps expanding its scope of practice, incorporating more and more substances into its field; 2) social issues are increasingly the central concerns of the profession; and 3) procedural planning has become an important aspect of planning as a whole. The first trend is one of the reasons why today's planning is such a wide field and planning information is of so many varieties. This creates the need for planning professionals to interact with an ever greater number and variety of people for technical and political reasons. The second trend calls for the opening of the planning process. The third trend brings the focus of planning further away from substantive technicalities. To put these trends in McClendon's (1993) words, the emphasis of planning has moved from "physical determinism (i.e., the City Beautiful movement), to planning for people (social reform), to planning with people (advocacy planning), and now to people planning for themselves (empowerment and self-help)." The three trends together have created the heightened need for communication in today's planning practice. Therefore, information management and communication are of vital importance to planning in the 90s and beyond. By contrast, the importance of technical analysis in planning has gradually become secondary, together with diminishing of the dominance of the rational planning philosophy.

Chapter two then embarked on a discussion of the history of computer application in planning in general and the current state of computer utilization in the profession. It showed that the attempt to automate analytical tasks in planning in the 60s and early 70s was a failure; but that microcomputers found their way into the profession by tackling these so-called low-order chores of the professional planners and flourished despite the wide-spread loss of faith in large-scale computer applications within the planning community. The appraisal of the current computer applications in planning revealed the bulk of them fall into the categories that function as information presentation and information management tools. This pattern on the one hand coincides with the growing need for communication and information management in today's planning world; and on the other, it demonstrates computers' capability to cater to this need.

Despite this shift, the dominant theory about using computers in planning (i.e., computers are useful mainly as analytical tools) has not changed much since they first entered the field and thus has lagged behind their utilization in practice. Moreover, the theory about using computers is also at odds with mainstream planning theories in general. These two inconsistencies were addressed in the last part of chapter two. As a result, it is proposed that, in theory, computers should be used for presenting and managing planning information as well as analyzing planning information. This new theory is a better reflection of today's practice and in harmony with the current styles of planning.

6.1.2 GIS an advanced technology for handling spatial information

Chapter three dealt with GIS as a technology. It identified two intellectual origins of the technology: cartography and computer modeling. This helps us to understand the inherent traits of the technology: it can serve as electronic maps and computer models. From a technological point of view, GIS is the product of merging two technologies—Computer Aided Mapping (CAM) and Data Base Management System (DBMS). This suggests that DBMS functions also be a part of GIS functionality. In the latter part of chapter three, there are detailed descriptions of GIS's map making, data management, and spatial analysis features.

Also presented in chapter three was the way reality is represented in GIS. In GIS, the reality is made of basic spatial units (BSUs), which can be points, lines and polygons in the case of the vector-based approach, or cells in the case of the raster-based approach. All data, except those defining the spatial characteristics of BSUs, are treated as attribute data associated with the BSUs. This knowledge is not only useful for the better understanding of GIS functionality but also for the later discussion on GIS's limitations in planning.

6.1.3 Various GIS uses in planning practice

Chapter four is a collection of six cases of planning GIS applications. They reflect the wide spectrum of roles that the technology can play in planning. The first three cases in the chapter may be considered as examples of the use of GIS for information presentation and information management purposes, while the remaining cases are illustrations of using the technology for technical problem-solving.

In the first case, GIS is used as a very effective front-end through which the user can make powerful presentations to attract potential investment. The second case, the Waterloo Generic Urban Model (WATGUM), focuses on the use of GIS as a presentation module for an urban simulation model. It is evident in this case that GIS can function as a tool to facilitate the communication of concepts and to stimulate discussion. The third case is the use of GIS mainly as an information management tool. The benefits brought by the system are enhancement in data integration, accessibility and applicability of existing information, availability of detailed data, easy maintenance of the information system, and visualization of data.

The last four cases are samples of analytical GIS applications in planning. In the housing case in Randstad Holland, GIS was used to identify the areas suitable for housing development. It is a typical case of using the buffering and overlay functions of GIS to generate new geographical entities. Incidentally, this case illustrated another way in which GIS can provide an intuitive graphical interface for interacting with a database—this time through on-screen digitization. The territory assignment case in Australia demonstrated GIS's power in solving well-defined spatial problems. This type of use of technology brings about the benefits of faster analyses and better results. The final case is an analysis on the local labor catchment area in Northern Ireland. The example given in this case is a typical technical fix to a social problem. GIS was used to calculate "correct" religious compositions for individual workplaces in the hope of easing the problem of discrimination. What GIS can do here at its best is to relieve the symptom of discrimination, while leaving the root of the problem untreated. At its worst, this use of GIS may create an illusion that the social problem is really a technical problem, attributing it to not enough computer power, lack of good algorithms, inadequate data, and so on.

6.1.4 Technocratic use of GIS problematic in planning

Chapter five started with an analysis of the currently prevalent technocratic view of GIS application in planning. This view is a natural extension of the technocratic view of computer application in planning in general. This technocratic view led to many failures of large-scale modeling in the 60s and early 70s, and it is incompatible with the current participatory planning style. The technocratic use of GIS in planning has been criticized in the following respects: 1) it assumes that planning is a technical endeavor in essence and rationality is the center of gravity of the profession; 2) it emphasizes the importance of the analytical capability of GIS, while ignoring or underestimating the utility of the technology when used for information presentation and information management purposes; 3) it regards data as only technical resources and fails to understand that they only reflect reality in particular ways. As a result, the technocratic use of GIS favors scientific analysis over political action, rigorous rationality over dialectical epistemology, and utility over ethics.

6.1.5 GIS as tools in planning

In contrast to the technocratic use of GIS, which emphasizes unduly the analytical aspect of the technology, Chapter five instead proposes the holistic use of the technology in terms of the following three tools :

- *an information presentation tool.* On the demand side, presentation and communication are very important in any planning endeavor today. On the supply side, GIS offers the right forms (graphic, cartographic, tabular, and numeric), and a powerful medium (easy conversion between different forms, capability of simulation, and efficient dissemination) for information presentation and communication. In addition, GIS has proven to be useful as an information presentation tool, as demonstrated in the case studies.
- *an information management tool.* Planning information is increasingly of greater volume and variety. Consequently, there is a growing need for information management. Because it is built upon DBMS technology, GIS has inherited all the

functionality of DBMS and is especially good at handling spatial data and relationships. In most cases, GIS is first and foremost an information system for efficient information storage, retrieval and maintenance.

- *an information analysis tool.* A GIS is expected to be able to perform various kinds of quantitative, especially spatially-related, analyses to help the user to solve technical problems. It has its root in computer modeling and thus can be made to incorporate all the useful traditional computer-based planning models. In fact, this is an active research area and is viewed by many prominent researchers in the field as the direction for GIS application for planning to take.

6.1.6 GIS in the planning process

It is a great help to planning if planning information can be made available in a presentable form at request in planning task formulation, option generation, option evaluation, and decision-making activities. Therefore, as an information presentation tool and an information management tool, GIS is useful at all stages of the planning process, especially so if the process is a genuinely participatory one. Undeniably, planning involves considerable technical analyses, which form an essential component in any planning process. GIS excels as a analytical tool in doing various spatial analyses, which are particularly useful in the evaluation stage of the planning process.

6.1.7 Limitations of GIS regarding planning

If properly implemented, GIS is perhaps the most useful computer tool for planning by far. However, it still has certain inherent limitation no matter how it is being applied:

1) The technology is impotent in dealing with abstract, subjective and relative notions of space as well as individual spatial behavior;
2) It is difficult to put a temporal dimension into GIS;
3) Current GIS still lacks the capability of handling information in forms other than alpha-numeric data;
4) In order to be really useful, it has to consume and produce huge amounts of information; and
5) The capability of extracting information from the database at different detail levels for different purposes is inadequate for large-scale GISs.

6.1.8 Small is beautiful

GIS is a very complicated yet very customizable technology. There can be substantial variations in its implementation and thus a wide spectrum of options available from which to choose. While acknowledging the relative merits of high-end GIS, this thesis advocates the use of desktop GIS because it is:

1) adequate for most use for planning purposes;
2) simple and thus easy to use and understand;
3) relatively inexpensive in terms of hardware-software acquisition, setup cost, training and maintenance;
4) less intrusive to the organizational structure;
5) more likely to be dedicated to planning use only.

6.2 Recommendations for Using GIS in planning

It is clear now that GIS is a very sophisticated tool that can help planning in many ways. The great potential of the technology breeds pitfalls, however, as well as opportunities. Based on the research and analysis in previous chapters, the thesis recommends:

1) *Make it small.* Both the higher-end and lower-end GIS systems have their merits and drawbacks. If we recognize that planning is much more than just technical problem-solving and GIS has an important role to play in advocacy, facilitation, mediation and communication in general, it appears that, on the whole, lower-end GIS is a more appropriate technology for planning. There are available excellent low-end GIS packages, such as *MapInfo*, *Atlas*GIS*, and *Tactician*, that are based on microcomputer platforms. As the performance of microcomputers approaches former mini-computers, workstations, and mainframes, these microcomputer-based GIS will become more and more powerful, but retain their particular advantages.

2) *Make it simple.* The underlying logic of GIS operations should be made as conceptually simple as possible, so that this technology will not suffer from the same fallacies associated with the failed large-scale modeling attempts in planning of the 60s and early 70s. GIS has to be made understandable in order to be communicable among a wide range of planning participants—elected officials, professional planners, developers, interest groups and individual citizens. For example, if a GIS is used to derive transportation demand in a given area, the user must be able to

explain the application clearly to anyone interested in the assumptions and limitations of the model.

3) *Make it user-friendly*. While the "development of more user-friendly software is a trend that is occurring in the private sector as well as the public sector" (Stillwell and Scholten 1990), it is especially important to make GIS user-friendly in planning. This is not only a question of productivity, i.e., a few trained professionals becoming more productive with an easy-to-use system, but also that of appropriateness—the technology used in planning should not be so inaccessible to such a wide range of the population as to become a negative factor in realizing wide-spread planning participation.

4) *Make it versatile*. As we have seen that GIS can help planners on many fronts, there is no need to limit the use of the technology to technical problem-solving. Planning information management and presentation are all important roles that GIS can play in addition to its analytical role. Graphical representation, interactiveness and multi-media potential make the technology a powerful tool for communication. GIS can not only contribute to the quality of plans as end-products but also to planning processes, which potentially lead to better plans and improved social relations within the community.

5) *Make it flexible*. GIS should be flexible enough to be harmoniously integrated into planning. There is a need for the end-user to have personal control over the content of data, the choice of processing methods, and the form of presentation. The planner

should try to understand the information needs of different planning participants and be able to adjust the geographic information system accordingly.

6) *Make it Open*. In planning, a GIS should be set up in a fashion that is conducive to accept input from different sources while being able to produce output in different formats. This allows GIS to function seamlessly with other technologies and thus to be more efficient (i.e., gaining extra-efficiency through synergy), flexible (i.e., adaptable to particular situations) and versatile (i.e., capable of functioning as different tools). Because planning has to work with all kinds of organizations both in the public and private sectors, all kinds of individuals, and all kinds of information, the openness of a GIS is especially significant in planning.

6.3 Future Research on Using GIS in Planning

Applying GIS in planning is a relatively new endeavor. The planning related GIS research is currently still focusing on finding applications for the technology rather than on studying its impact on the quality of planning. As the use of GIS in planning spreads, it is imperative to know what changes it brings to planning, in terms not only of efficiency but also style, philosophy and content of planning.

How does GIS impact upon planning decision-making? How does GIS alter the power distribution among different social and interest groups in a planning process? How does GIS affect the relationships between planners and the general public? How does GIS help to build a sustainable society, by proving the unsustainability of the current mode of development, by improving society's efficiency in terms of turning out more consumer products with less consumption of natural resources, and/or by mobilizing populace to transform the structure of our society?

6.4 Future of GIS Use in Planning

There is no doubt that we will utilize more and more GIS technology in planning as the trend of the ever increasing ratio of computing-power/cost continues. The development of other computing fronts such as Voice Recognition, Computer Vision and Machine Translation shows the great technical potential of bringing computing power to the general public. The Government of the United States has endorsed the idea of building a nationwide information super highway system and is pressuring the world community to do the same. Canada has followed the lead. Other developed countries, as well as developing countries such as India and China, are also building their versions of "information highway" network. These events harbinger that all aspects of our life will get even further intertwined with information technology.

Within such a rapidly evolving environment, GIS researchers all around the world are seeking new ways to improve the representation of reality in GIS by employing object oriented approaches (Ottens 1990); to augment GIS's analytical power by inventing new quantitative analysis methods and applying artificial intelligence techniques; and to improve the communication between GIS and the user by adapting new interfaces with multimedia, 3-D mapping and even virtual reality technologies.

It is rather difficult to foresee what GIS will look like and what roles it will play in planning even in ten years. Because the technology is still feeling its way into urban and regional planning and is one of the most versatile and customizable tools that we have ever had, it will evolve, to a large extent, into whatever users want it to be. Planning professionals should actively involve themselves into knowing and using the technology, and apply their influence to its evolution (Ottens 1990).

In general, however, it is safe to foretell that GIS will become ever more powerful and easier to use. Some experts in the industry foresee the technology becoming so ubiquitous that it will become similar to today's word processors, or even functioning as a standard utility, like today's spelling or grammar checker, in a word processor. When that happens, GIS will be used as a common medium to analyze and communicate spatially oriented issues.

Another promising computing technology, Computer Supported Cooperating Workgroup (CSCW), should also have a great impact on GIS in planning and planning in general. The technology facilitates interactions between individuals as if they are in a group, even though they may be physically scattered in space and time. Major software developers such as Microsoft Borland, Lotus, etc. have all embarked to develop systems and applications for group use. Industrial analysts predict that all software will eventually become so-called groupware—software for group use. With networking and groupware, the users can work simultaneously on a same chunk of data, be the data in a text document, a graphic file, a database or anything else, on their network. What the computer can do in this area is essentially automating the chores such as organizing, recording, communicating information from multiple sources, as well as providing a structure for productive interaction in a group process. This looks promising in reducing the administrative cost and in enhancing the efficiency of planning participation. GIS, combined with groupware technology, may one day finally offer a technology to accommodate social interactions, which are so important to modern urban and regional planning, but nevertheless have so often been excluded from planning computer application.

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