THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS FOR MUNICIPAL PLANNING: POSSIBILITIES, PROBLEMS AND PERSPECTIVES

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INTRODUCTION

In this paper we will examine the application of geographical information systems (GIS) in the planning practice of local government organizations. Presently, GI-systems are common, well-used tools in many scientific research institutions. The applications, such as automated mapping and land and facility management are installed and operational in an impressive number of systems. There are, however, very few GI-systems that are well integrated with the daily activities of planning departments.

Geographical Information Systems are characterized by the spatial intelligence that is incorporated into the geometrical database (the topology) and the spatial operators of the processing module. With the arrival of object-oriented GIS environments, the amount of intelligence in the databases can be further enhanced (Dangermond 1989). This intelligence allows for complex data processing as well as efficient and effective production of results in the form of maps. Utilized for simple operations only, the Geographical Information Systems merely function as locational query systems, but when the advanced data processing techniques are fully exploited, a generation of "new" information becomes possible. These properties of geo-information processing have lead to a proliferation of application fields. Hanigan (1990) counted twenty one distinct areas of GIS use; from oil exploration to the analysis of crime risks.

Planning is an activity that can benefit from complex geo-information processing, although in practice it appears to be very difficult to employ operational systems for that type of application. A system with complex data structures and data operators requires careful, costly development, as well as close management of databases. Both of these requirements mandate extensive knowledge, experienced users, and are highly time consuming. Moreover, it is very difficult to integrate or link such a complex system with other information systems. Many analytical GI-systems are, therefore, under-utilized and are consequently used solely for database query and automated mapping.

We will examine the following:

- some of the major obstacles in the use of GIS for practical planning purposes;
- two alternative approaches for the introduction of GIS in planning departments; and,
- the outline and results of a pilot-project carried out at the University of Utrecht which addresses the problems previously mentioned.

As the Palma meeting is a gathering of geographers, we prefer to start with remarks on the importance of GIS for our discipline and the role geographers can and should play in the development and application of this technology.

GEOGRAPHY AND GIS

For the past five or six years a distinguished group of Dutch geographers have been working intensively in the field of GIS. They are not, however, the first scientists to initiate research in this area. Technical professionals such as surveyors, photogrammetrists and landscape architects were the first to adopt the new technology. However, the Dutch geographers gained rapidly with the state-of-the-art in GIS, both with respect to research and education. The establishment of the National GIS Centre of Expertise, located within a geography department of a local university, confirmed the role of geography as one of the leading disciplines in geo-informatics. Geographers in the United States and the United Kingdom also have a firm grip on national and regional GIS centres. In The Netherlands many geography graduates have been employed by private and public organizations to work on GIS development and application.

If one examines the nature of research and development work with respect to geo-informatics and the role of geography and geographers, a number of interesting points can be observed:

1. GIS is very much at the heart of the geography discipline. The discussions about data models and data structures to be employed in GI-systems resemble the well-established theoretical debate in geography regarding the nature of space and the conceptualization of spatial structures, processes and systems. Spatial operators employed in GI-systems are to a large extent based in techniques developed in the spatial analysis tradition of geography. Geographers, as well as university researchers, should therefore engage actively in the development of GIS concepts, GIS

operationalizations and new GIS processing techniques.

2. GIS is the most powerful and promising technology that has ever been developed by the spatial sciences. Never before has a theoretical construct or technique attracted so much outside attention. The commercial sector eagerly wants to exploit the resulting scientific work, to such an extent that private businesses have taken over most development, consultancy and training work in this field. Consequently, there are ample opportunities for geographers to promote their discipline through GIS and adequately educated geography graduates can be given entrance into new and promising professions.

3. GIS has reunited spatial scientists that had grown apart over the last decade. Not only do human and physical geographers often work together in GIS projects, but quite frequently multidisciplinary teams are formed which include surveyors, cartographers and architects. As integrated approaches are common place in geography, geographers should feel comfortable and be able to contribute significantly in these types of working environments.

4. It has now become clear that the vast majority of practical GIS applications will be in the field of management and not in research, analysis, or planning. Geography curricula should reflect this fact. With respect to GIS-based urban, rural, natural resource and environmental management, adequate education and training should be provided in order to enable students to compete for the type of jobs that will become available. Sufficient attention should also be given to the often overlooked organizational and financial aspects of the introduction and use of GI-systems.

GIS IN LOCAL GOVERNMENT

Within local government organizations, at least three clusters of activities can be distinguished in which locationally referenced information plays an important role (Figure 1). In a number of technical and administrative departments, geographical information is predominantly used for executive tasks, while in planning departments this information is processed in order to support decision making. In each of these three "realms" one finds different professional backgrounds and working cultures and information processing has specific characteristics.

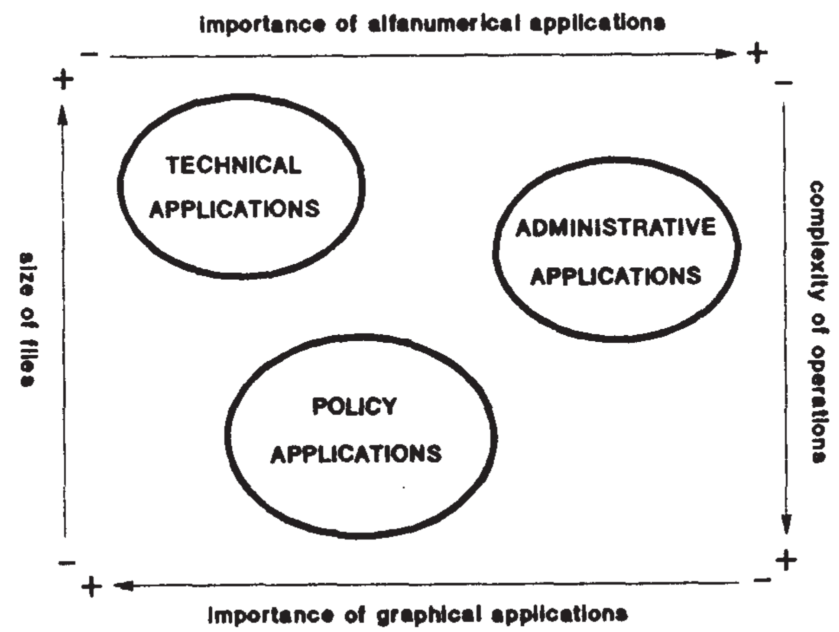

Fig. 1 Working Environments in Local Government

The technical departments deal with the physical aspects of the built environment. They fulfill design, building and installation tasks and are also responsible for control and maintenance. In this type of environment, geographical information systems have to be able to produce detailed and high precision technical maps. Moreover, the systems have to support the daily operations of the department; for example through the production of maintenance schemes and work orders. A central role is played by the large scale base maps (often at a scale of 1:500), including base topography and objects such as buildings, roads and distribution networks. In general, relatively few attributes are linked with these objects.

Administrative departments manage large databases that are necessary for the legal and fiscal management tasks of a municipality, county or province. These type of base systems typically deal with the registration of population, land ownership, real estate, businesses and public institutions. Primarily, the systems are applications of regular relational database management packages and for the most part are routinely utilized. It is often useful to link this information to locations. The scales of the maps that are produced range from 1:1000 to 1:2000 and often have an important topographical component. In The Netherlands, the Union of Municipalities has developed standardized functional specifications for a number of these base information systems.

The policy departments within local government organizations are dealing with the preparatory activities for strategic decision making. Tangible products of these departments are: zoning plans, master plans, urban renewal plans, housing plans, traffic plans and environmental protection plans. Policy activities require information at a higher level of generalization and aggregation than management activities. In order to produce this type of information, many large municipalities have separate statistical or policy/management information departments. Information processing often has a non-standard and ad hoc character and abstract information plays an important role. This information has to be derived from research-based complex data analysis. One can think of the calculation of object attributes like accessibility, location potentials and vulnerability for environmental deterioration. The information processing and the presentation of results requires thematic maps with scales that range from 1:10.000 to 1:25.000.

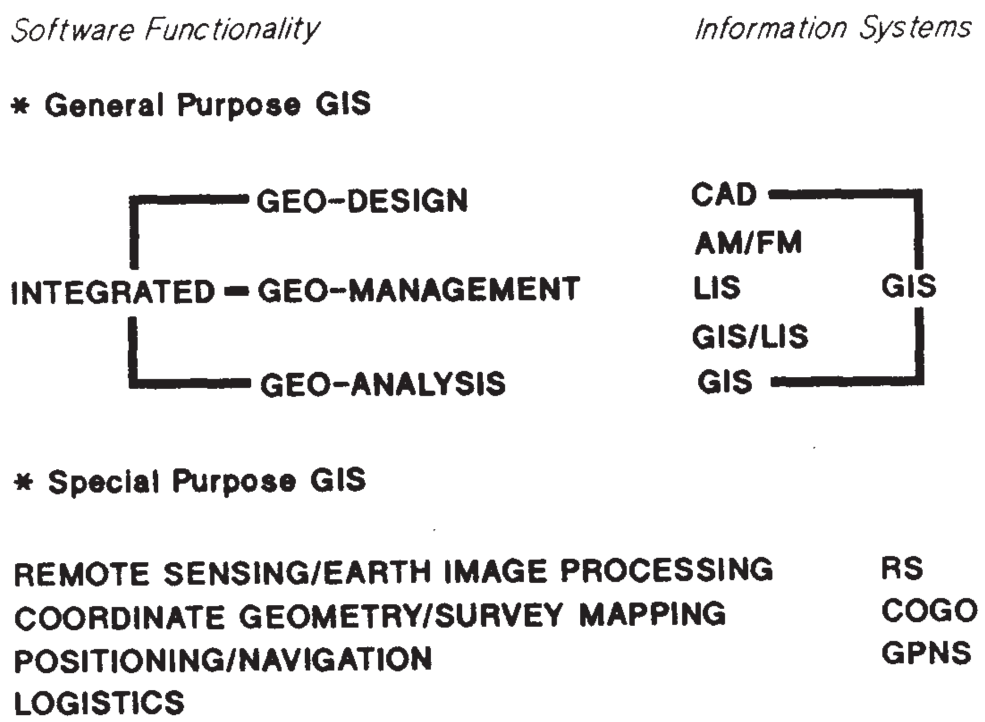

Fig. 2 GIS Functionality and Systems

With respect to the automation of tasks specified above, various information systems will be chosen (Figure 2). Technical departments usually opt for design systems (CAD: computer aided design); administrative departments select systems for alphanumeric data management (DBMS: data base management systems); and, planning departments prefer analytical geographical information systems (GIS, in the narrow meaning of the term).

Where the introduction of information systems begins is partly due to coincidence (Somers 1990). Individuals can play an important role in this respect. In some instances, small scale dedicated solutions on personal computers are the first step. However, the automation of large administrations and registrations leads to direct and easily demonstratable savings. For this reason, computers have often been installed in these departments first. The automated production of technical maps is highly cost-effective which explains the widespread installation of CAD systems. These systems are often combined with database packages to form fully operational automated mapping/facility management systems (AM/FM).

The acquisition and implementation of analytical GI-systems is much more problematic. Cost-benefit calculations with respect to the use of GI-systems for production purposes are difficult to compile, although recently a number of feasibility studies with positive outcomes have been completed (Buxton 1989). The introduction of GIS has to be justified with a demonstratable qualitative improvement of decision making, which is a complicated task. Moreover, individuals working in planning departments are usually more reluctant and skeptical than in other parts of the local government organization, causing delay in the startup of computer support for planning activities.

the system. The joining of the two databases can be done either before or after the generalization and aggregation procedures. When all data manipulation procedures have been successfully completed, advanced information processing and mapping becomes feasible. Nevertheless, there remains a need for small, PC-based dedicated systems. For example, population forecasting

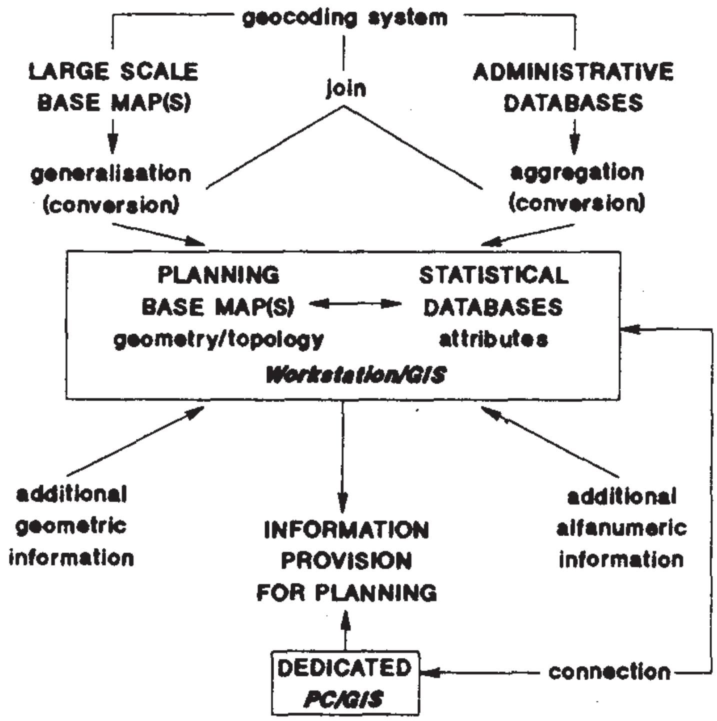

Fig. 3 A Top-Down Approach for a Planning GIS

and traffic modeling is possible on personal computers due to their continuous increase in processing and storage capacity. The PC's can easily be integrated into the data communication network and can load data down from the central databases.

The second approach is initiated within the planning department itself. Based on a small PC/GIS, existing paper maps will be digitized and available statistical databases will be connected to these map files. The map files will most likely be a combination of point, line segment and boundary files. Because of limitations of the PC based systems, separate databases have to be compiled for each district. This approach will result in a planning information system that is useful for many queries and thematic mapping applications. It can be expected, however, that after some time a need for a larger scale system and advanced applications will arise. The possibilities for advanced GIS applications on PC's will grow considerably in the next five years, although a decision to migrate to a GIS based system on a workstation may be unavoidable. In order to preserve the information in existing databases, data conversion will be necessary. The number of graphical and alphanumerical exchange standards, conversion programmes and data restructuring tools have increased considerably, so the fear of complete loss of data is no longer justified. Nevertheless, these migration procedures remain cumbersome and time consuming.

In both cases, a GIS will be constructed consisting of one or more digital planning base maps and statistical data as attributes of the map objects. This database has to be supplemented with data from other information sources. Of course maps of existing plans should be transformed to digital format and added to the system. Additional information of interest may include health, traffic intensity, traffic accident and crime data. Ideally, information in policy documents should be stored in the planning information system as well. In recent years, document processing systems and modules have become available that can be considered for the storage and processing of textual information. Often additional software modules (e.g. modeling software) will have to be added to the GIS packages in order to be able to perform all necessary tasks.

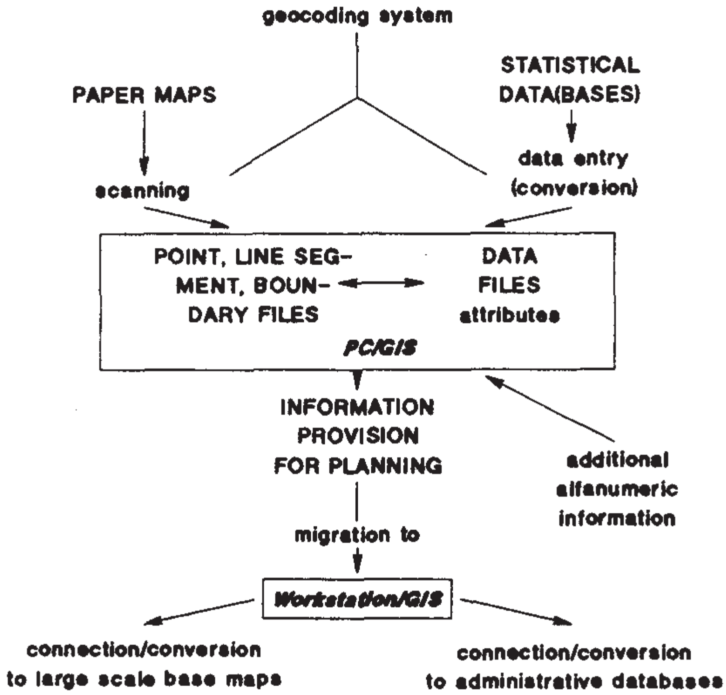

Fig. 4 A Bottom-Up Approach for a Planning GIS

A GIS-based Planning Information System has to be employed for the support of the main activities of a planning department. Four types of applications seem particularly well suited for computer support:

1. Area Monitoring: an analysis of major spatial developments in a region by means of indicators and

geo-statistical methods;

2. Planning Analysis: projections and simulations of alternative future development lines, often supported by spatial modeling;

3. Decision Making: evaluation of alternatives and impact analyses;

4. Plan Implementation and Monitoring: the production of plan maps, the provision of information about plans, the issuing of development and building permits and a regular comparison of planned and real developments.

Given the scope of this paper, elaborating on these activities any further is inconceivable.

The Utrecht Pilot Study

One of the primary goals of GIS research at the Faculty of Geographical Sciences is to explore the application possibilities of GIS on different regional levels. The local level is very important because in municipalities numerous managerial, research and planning tasks, containing spatial dimensions, can be supported by GIS.

The predominantly larger municipalities have been initiated into automation similar to GIS. However, restrictions with particular tasks, such as land and facility management and map making continue. The automation is often more an application of CAD than of GIS.

This is also the case in the municipality of Utrecht (230.000 inhabitants). Ten years ago the surveying and mapping department started with a project to digitize the map of the city on a scale of 1:500 with a CAD system; completing the project in 1989. Other departments of the municipality were aware of the possibilities of GIS to a certain extent: urban development and traffic (physical planning), the economic section (management of business and office districts) and the bureau of statistics. The questions posed were: is it possible to tie the information of the operational administrative databases to the map, and what options will result from this to support management, research and planning tasks?

In the Utrecht pilot study, which began early 1990 in cooperation with the university, the municipality, and additional support from a local computer firm, the first question was: is it technically possible to tie the existing map (a CAD product) to existing non-graphical databases in a GIS environment?

The study was restricted to one district and two databases:

- Buildings (with many characteristics of every building, and used as the basis for municipal taxation on buildings and for statistical purposes);

- Businesses (with characteristics as type of activity, number of employees, etcetera of each commercial and non-commercial organization, used as management information and for statistical purposes).

Both databases contain street names and numbers which offers a potential key to attach the databases to each other and to the map. Although there is an official spelling of street names within the municipal organization, it appeared that there was a lot of mismatch between the two databases. The main problems are non-standardized abbreviations and numbers such as A and 21 bis. Although it was not a problem to restore these mistakes in the pilot, it would have been for the whole city. The data base table of buildings was divided; one table with only dwellings and one table with only business complexes. The latter table was combined with the table of the business database.

The 1:500 CAD map did not have the topological structure required for GIS. The map contains non-closed polygons, crossing and interrupted lines, under- and overshoots, etcetera, complicating the transformation to a topological map.

Two ways can be considered to tie the database to the map are:

- Add street segments with address domains to the map. In this way the original map functions as a background drawing;

- Attach the database to certain graphic elements of the existing map with as little conversions as possible. In this way a part of the map functions as a topological GIS map and the other map information is again a background drawing.

The first solution is an interesting possibility, but could not be completed because of shortage of time. Therefore we can only report the results of the second option.

One of the layers in the original map contains street names and numbers, as well as numbers of the housing blocks. These were used to create a link. Point locations were created at the location of the street number and of the building block number. Each point location received an individual link number. In a newly created table, this link number was added to the street address or the building block number. Two tables were created: one street address table and one building block table. These tables are the bridges between the database tables and the map.

The creation of the tables and link numbers was done by a specially developed software program. By drawing boxes around the street names and numbers on the screen, unique link numbers were created and the tables were automatically filled.

The building block must be closed polygons in order to make it possible to hatch the building blocks. The conversion from the CAD map containing border lines of the building blocks into building block polygons was done by the Microstation GIS software package of Intergraph. Minor adjustments were completed manually.

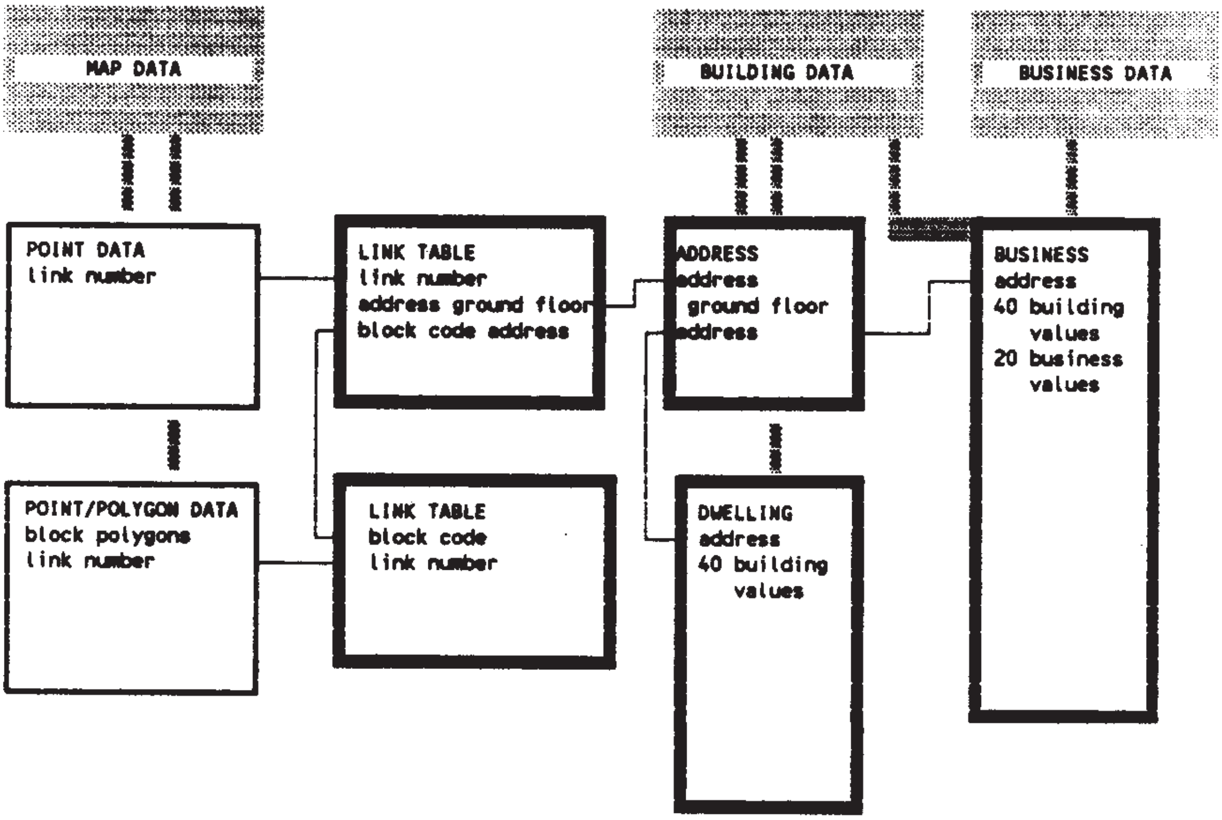

Fig. 5 Data Structure of Utrecht Pilot Study

Upon completion of the operation, we succeeded in creating a whole set of tables, including two tables which formed the link to the map (figure 5). These tables can be managed by a relational database, in this case Informix. The results of manipulations in the database (selections, combinations, etcetera) can be presented in the map which can serve as an entrance to the information of the database.

Following the technical solution of the connection between the database and the map, we began with the question whether this can be useful to the municipal departments involved. We requested a list of ten problems which could be solved by the system. It appeared that priority lies in rather simple questions: queries of the database, selection of certain combinations and mapping of the results. To date, there have been enthusiastic reactions on the results, but skepticism regarding the cost-benefit ratio and the efforts to acquire the knowledge to handle the new system remains. In the next phase of the project, beginning Autumn of 1990, we will explore in detail the possibilities involved in making an analysis of each department's regular production activities. We question whether the departments primarily want a database with a map interface, or an analytic toolbox attached to it, which GIS could potentially be.

CONCLUSIONS AND DISCUSSION

The two models of the introduction of GIS in planning outlined above should be considered as theoretical extremes. Generally, there are circumstances that will lead to an intermediate path. The organizational structure of the municipal organization, the state-of-the-art computerization and databases, and the interest, knowledge and experience of the individuals concerned are all important factors to be considered before decisions about the route to follow should be made. The Utrecht pilot study has made this clear. Additionally, the future of computer hardware and software is always uncertain. Developments are continuously occurring and are difficult to predict. This would suggest a careful, gradual and flexible approach. On the other hand, a stable environment is necessary for production purposes, which means that hard- and software changes should not take place at short intervals.

The implementation of large and complex information systems has proven to be a difficult and risky enterprise. In cases where a planning department cannot build on suitable existing databases, or easily join a successful organization-wide computerization programme, a PC-based GIS application should be considered. This will allow for a gradual introduction of computer-aided planning and for a gradual acquisition of knowledge and experience. Dedicated digital base maps and attribute tables for planning can be built relatively easy. The way the computer is used does not differ fundamentally from the application of word processors, spreadsheets, statistical analysis packages and business graphics software.

Even when a planning department is part of a network environment and works with a large GIS system, the construction of separate planning base maps should be considered. Sole dependance on generalized large scale base maps does not seem to be a feasible option. With the improvement of earth observation and scanning techniques, new data sources for planning will become available, providing the necessary input for planning base maps.

Geographers should try be become involved with the introduction of GIS in local government organizations. This will result in a broadening in the scope of the discipline. Geography can make contributions to forms of computerization which are important for society and for the environment and which will give geographers new professional opportunities.

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