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Urban planning and GIS

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Urban planning is one of the main applications of GIS. Urban planners use GIS both as a spatial database and as an analysis and modelling tool. The applications of GIS vary according to the different stages, levels, sectors, and functions of urban planning. With the increase in user-friendliness and functions of GIS software and the marked decrease in the prices of GIS hardware, GIS is an operational and affordable information system for planning. It is increasingly becoming an important component of planning support systems. Recent advances in the integration of GIS with planning models, visualisation, and the Internet will make GIS more useful to urban planning. The main constraints in the use of GIS in urban planning today are not technical issues, but the availability of data, organisational change, and staffing.

1 THE USE OF GIS IN URBAN PLANNING

GIS were developed in the late 1960s, yet in the early days very few planning departments installed them because of the prohibitive cost of hardware and the limited capabilities of the software. Most of the early software systems focused on computer mapping with few analytical functions. The most powerful software at that time was grid based (e.g. IMGRID: Sinton 1977). The subsequent fall in the prices of hardware, computer storage, and peripherals, accompanying improvement in the performance of hardware and software (particularly the speed of computer processors), and advances in the data structures and related algorithms of vector-based GIS (see Worboys, Chapter 26), has made GIS more affordable, less time consuming and more workable. Since the early 1980s, there has been a marked increase in the installation of GIS in different levels and departments of urban and regional governments in the developed countries, notably of Europe (Bardon et al 1984; Campbell 1994) and North America (French and Wiggins 1990): see Campbell, Chapter 44. With the further decrease in the price of computer hardware and software, the use of GIS has emerged in urban planning in the developing countries in the 1990s (Yeh 1991). GIS is increasingly accessible to planners and is now an important tool for urban planning in developed and developing countries alike.

GIS is just one of the formalised computer-based information systems capable of integrating data from various sources to provide the information necessary for effective decision-making in urban planning (Han and Kim 1989). Other information systems for urban planning include database management systems (DBMS), decision support systems (DSS), and expert systems. GIS serves both as a database and as a toolbox for urban planning (Figure 1). In a database-oriented GIS, spatial and textual data can be stored and linked using the geo-relational model. Current GIS support efficient data retrieval, query, and mapping. Planners can also extract data from their databases and input them to other modelling and spatial analysis programs. When combined with data from other tabular databases or specially conducted surveys, geographical information can be used to make effective planning decisions. As a toolbox, GIS allows planners to perform spatial analysis using geoprocessing functions such as map overlay, connectivity measurement, and buffering (Berry 1987; Tomlin 1990). Of all the geoprocessing functions, map overlay is probably the most useful tool. This is because planners have a long tradition of using map overlay in

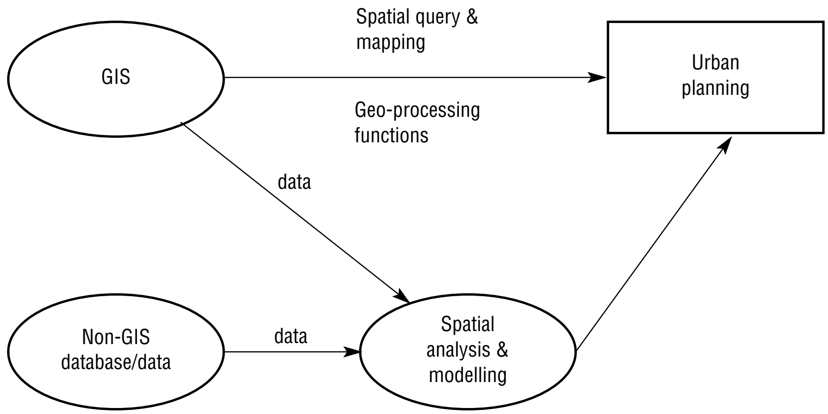


Fig 1. GIS and urban planning.

land suitability analysis which is itself an important component in urban planning (Hopkins 1977; McHarg 1969; Steinitz et al 1976).

Database management, visualisation, spatial analysis, and spatial modelling are the main uses of GIS in urban planning (Levine and Landis 1989; Marble and Amundson 1988; Webster 1993, 1994). GIS is used for the storage of land use maps and plans, socioeconomic data, environmental data, and planning applications. Planners can extract useful information from the database through spatial query. Mapping provides the most powerful visualisation tools in GIS. It can be used to explore the distribution of socioeconomic and environmental data, and display the results of spatial analysis and modelling exercises. Spatial analysis and modelling are used for spatial statistical analysis, site selection, identification of planning action areas, land suitability analysis, land use transport modelling, and impact assessment. Interpolation, map overlay, buffering, and connectivity measurement are the most frequently used GIS functions in spatial analysis and modelling. The use of the above functions varies according to different tasks and stages of urban planning.

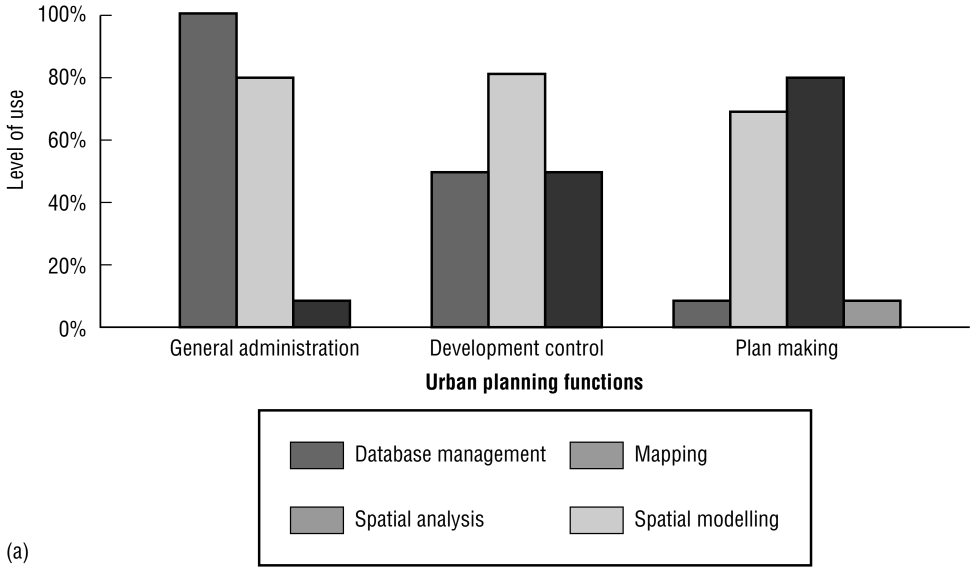
The many benefits in using GIS in urban planning include (Royal Town Planning Institute 1992):

- improved mapping – better access to maps, improved map currency, more effective thematic mapping, and reduced storage cost;
- greater efficiency in retrieval of information;
- faster and more extensive access to the types of geographical information important to planning and the ability to explore a wider range of 'what if' scenarios;
- improved analysis;
- better communication to the public and staff;
- improved quality of services, for example speedier access to information for planning application processing.

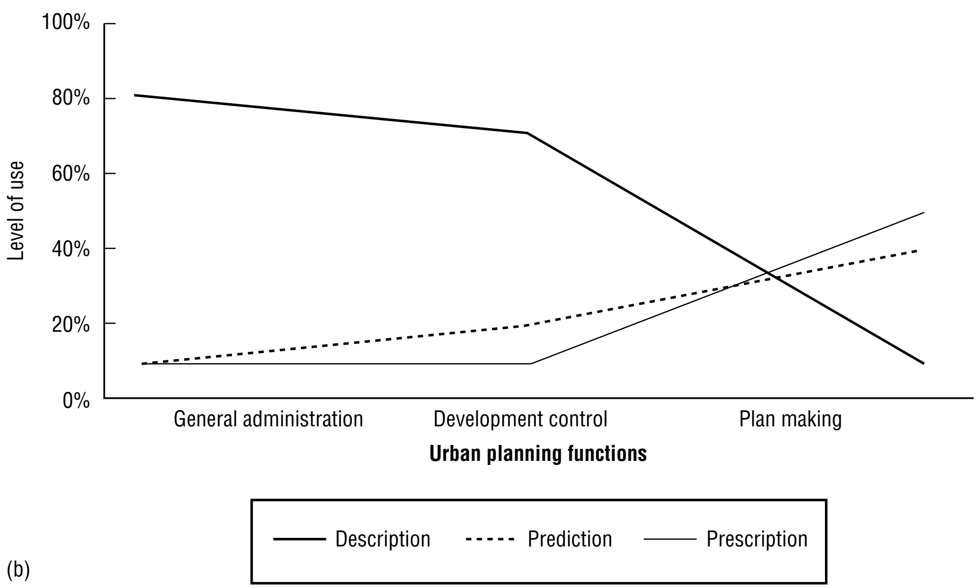
2 THE USE OF GIS IN DIFFERENT FUNCTIONS AND STAGES IN URBAN PLANNING

Urban planning involves many functions, scales, sectors, and stages. In general, the functions of urban planning can be classified into general administration, development control, plan making, and strategic planning. General administration and development control are relatively routine planning activities, whereas plan making and non-routine strategic planning are undertaken much less frequently. The scale of the planning area covered can range from a whole city, to a sub-region of a city, a district, or a street block. The most frequently involved sectors of urban planning are land use, transport, housing, land development, and environment. At each scale of planning there are different stages: the determination of planning objectives; the analysis of existing situations modelling and projection; development of planning options; selection of planning options; plan implementation; and plan evaluation, monitoring, and feedback. Different functions, scales, sectors, and stages of urban planning make different uses of GIS.

The use of the data management, visualisation, spatial analysis, and modelling components of GIS varies according to different functions of urban planning (Figure 2(a)). Data management, visualisation, and spatial analysis are used more in



(a)



(b)

Fig 2. (a) Use of GIS functions in urban planning; and (b) their importance for description, prediction, and prescription functions in three types of urban planning activity.

the routine work of urban planning. Spatial modelling is used more in strategic planning. General administration employs mainly data management and visualisation. Finally, development control uses the visualisation and spatial analysis functions of GIS most. The more routine general administration and development control work of urban planning includes (Newton and Taylor 1986; Newton et al 1988):

- management of land use records;
- thematic mapping;
- planning application processing;
- building control application processing;
- land use management;
- land availability and development monitoring;
- industrial, commercial, and retail floor space recording;

- recreational and countryside facility planning;
- environmental impact assessment;
- contaminated and derelict land registers;
- land use/transport strategic planning;
- public facilities and shops catchment area and accessibility analysis;
- social area and deprivation analysis.

Visualisation, spatial analysis, and spatial modelling are the most frequently used GIS functions in plan making. Webster (1993, 1994) discusses the advantages of using the data management, visualisation, and spatial analysis and modelling functions of GIS as scientific inputs to urban planning. Webster shows that there are significant differences in the degree of GIS use in the description, prediction, and prescription planning process (Figure 2(b)). Description is used more often in general administration, whereas prediction and prescription are used more often in plan making.

Different scales of planning require different data and techniques. Raster data are more useful for city-wide strategic planning, because large areas are involved and high resolution is not required. The processing of raster data is much faster than that of vector data, especially in map overlay and buffer analysis. On the other hand, vector data are generally used for district and local action area planning because of the need for very high resolution analysis.

There are many applications of GIS in the land use, transport, housing, land development, and environmental sectors. Key examples include site selection and land suitability analysis. In contrast, network analysis and route selection are most frequently used in transport planning, and environmental planning and management use buffer and overlay processing. There is an increasing trend toward the integration of modelling in different sectors of urban planning (Goodchild et al 1993).

The role of GIS also varies in different stages of the urban planning process. For example, GIS is more useful in modelling and development of planning options than in the determination of planning objectives. The different stages in the urban planning process can be generalised as the determination of objectives, resource inventory, analysis of existing situations, modelling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring, and feedback (Figure 3). GIS can only provide some of the data and techniques that are needed in different stages of the urban planning process. Any GIS also has to work with other databases, techniques, and models at different stages of the planning process.

2.1 Resource inventory

Geographical information, when integrated with remote sensing, can save time in collecting land use and environmental information. Remote sensing images are becoming an important source of spatial information for urban areas (Barnsley, Chapter 32; Paulsson 1992). They can help to detect land use and land use changes for whole urban areas (Barnsley et al 1993). In particular, stereoscopic pairs of digital aerial photographs can be used to derive 3-dimensional CAD models of buildings for dynamic visualisation of a city, or for direct import into a GIS database (Dowman, Chapter 31).

2.2 Analysis of existing situations

GIS can help to store, manipulate, and analyse physical, social, and economic data of a city. Planners can then use the spatial query and mapping functions of GIS to analyse the existing situation in the city. Through map overlay analysis, GIS can help to identify areas of conflict of land development with the environment by overlaying existing land development on land suitability maps. Areas of environmental sensitivity can be identified using remote sensing and other environmental information (Yeh and Li 1996).

2.3 Modelling and projection

A key function of planning is the projection of future population and economic growth. GIS can be used for prediction and projection (Longley et al 1994). Spatial modelling of spatial distributions makes it possible to estimate the widest range of impacts of existing trends of population, and of economic and environmental change. For example, a range of environmental scenarios can be investigated through the projection of future demand for land resources from population and economic activities, modelling of the spatial distribution of such demand, and then using GIS map overlay analysis to identify areas of conflict. Using socioeconomic and environmental data stored in GIS, environmental planning models have been developed to identify areas of environmental concern and development conflict (Schüller 1992). GIS can also

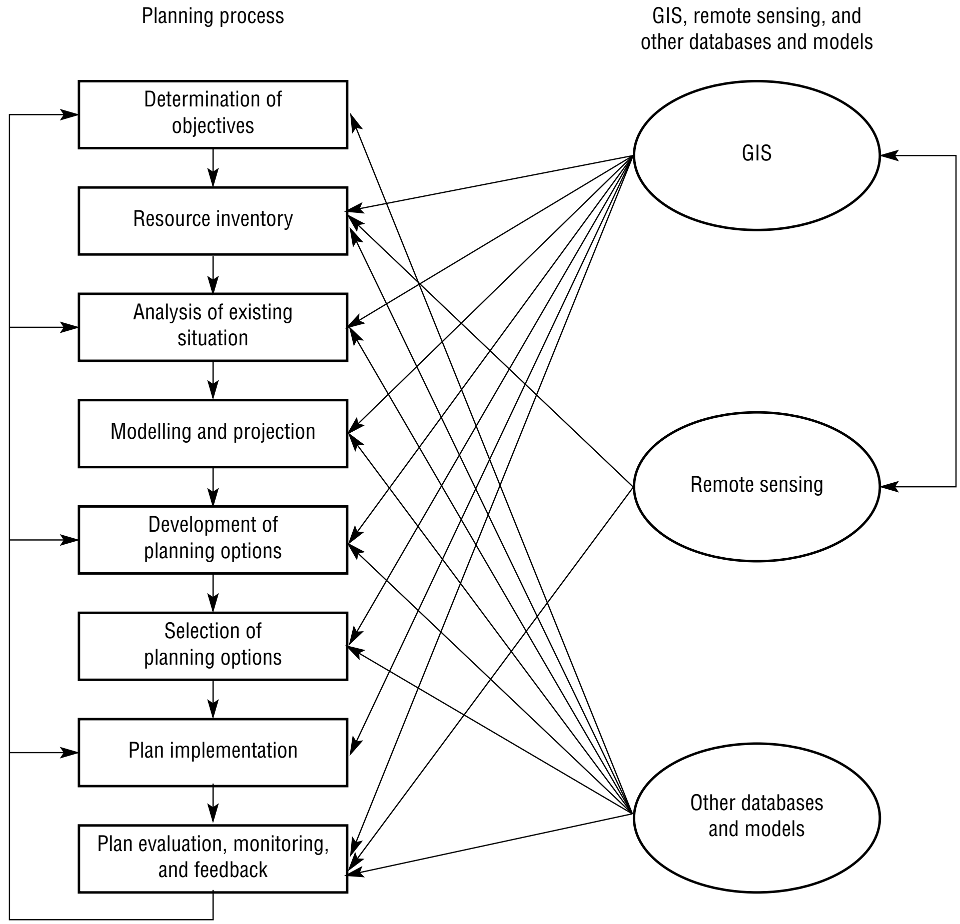


Fig 3. Integration of GIS, remote sensing, and other databases and models in the planning process.

be used to model different development scenarios. It can show the modelling results in graphic form, making them easy to communicate with the decision-makers (Shiffer, Chapter 52; Armstrong et al 1992). Planners can use such information to formulate different planning options and help guide future development so that they avoid such conflicts.

2.4 Development of planning options

Land suitability maps are very useful in the development of planning options. They can be used to identify the solution space for future development (Yeh and Chow 1996). The association of spatial optimisation models with GIS can help to formulate and develop planning options which try to maximise or minimise some objective functions (Chuvieco 1993). The simulation of different scenarios of development with GIS can help in developing planning options (Landis 1995).

2.5 Selection of planning options

The final selection of a planning option is increasingly a political process, but planners can provide technical inputs to this process in order to help the community in making their collective choices. The integration of spatial and non-spatial models within GIS can help to evaluate different planning scenarios (Despotakis et al 1993). The use of GIS with multi-criteria decision analysis can provide the technical inputs in the selection of planning options (Eastman, Chapter 35; Carver 1991; Eastman et al 1993).

2.6 Plan implementation

GIS can be used in the implementation of urban plans by carrying out environmental impact assessment of proposed projects to evaluate and minimise the impact of development on the environment (Schüller 1992). Following such work, remedial measures can be recommended to alleviate the impacts.

2.7 Plan evaluation, monitoring, and feedback

When used together with remote sensing, GIS can help to monitor the environment. It can, for example, be used to monitor land use changes (Yeh and Li 1996). It can also examine whether land development is following the land use plan of the region, by overlaying a land development map produced from the analysis of remote sensing images on the land use plan. In addition, GIS can be used to evaluate the impact of development on the environment to see whether adjustments of the plan are needed. GIS can also be used in the monitoring and programming of land development (Yeh 1990).

3 GIS, SPATIAL DECISION SUPPORT SYSTEMS (SDSS), AND PLANNING SUPPORT SYSTEMS (PSS) IN URBAN PLANNING

Decision support systems were developed as a response to the shortcomings of the management information systems (MIS) of the late 1960s and early 1970s. At this time MIS did not adequately support analytical modelling capabilities or facilitate the decision-maker's interaction with the solution process. DSS provide a framework for integrating database management systems, analytical models, and graphics, in order to improve decision-making processes. They are designed to deal with ill- or semi-structured problems which are poorly defined and partially qualitative in nature. The decision support system concept was extended to the spatial context in the development of SDSS (Armstrong and Densham 1990; Armstrong et al 1986; Densham 1991; Densham and Rushton 1988). The architecture of a SDSS is shown in Figure 4. SDSS help decision makers to make decisions on different locational alternatives (for example, optimal location of service centres). Because of the lack of analysis functions in

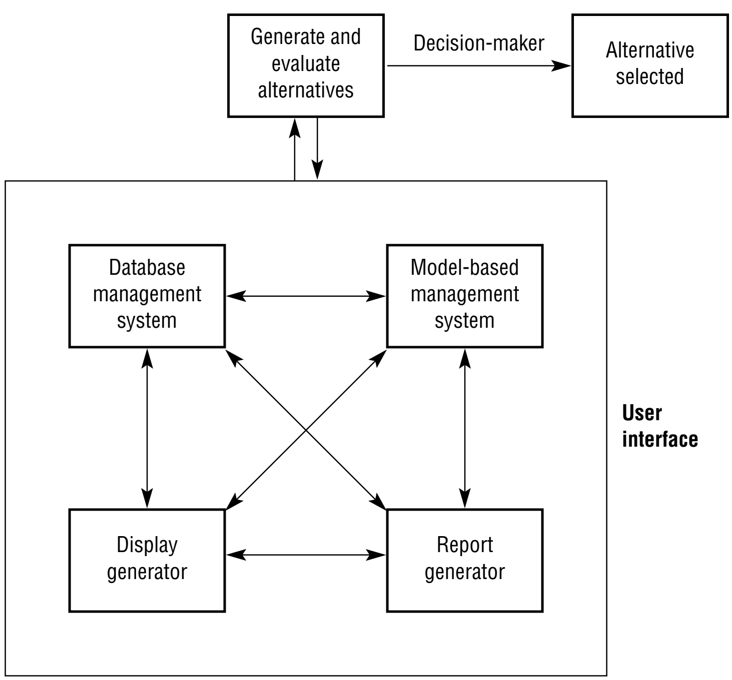


Fig 4. Architecture of a spatial decision support system (SDSS).
Source: Armstrong et al 1986

the past, GIS have not been considered as part of SDSS. Instead GIS have been used to generate and store spatial data which were then used as inputs for the analytical models. Results of the analytical models were then displayed by GIS. Much research has been done on the use of GIS in the visualisation of the results of the analytical models. More recently, advances have been made in incorporating analytical models into GIS. For example, location–allocation and spatial interaction models have been incorporated as a standard function in ARC/INFO. It is to be expected that in the future the distinction between a GIS and spatial decision support system will become increasingly blurred.

A parallel development in the planning field is the concept of a planning support system (PPS). A PSS, as first advocated by Harris (1989), is a combination of computer-based methods and models that support planning functions. PSS not only serve as a decision support system to decision-makers, but also provide the tools, models, and information used for planning (that is, the information technologies that planners use to carry out their unique professional responsibilities: Harris and Batty 1993). PSS comprise a whole suite of related information technologies (e.g. GIS, spreadsheets, models, and databases) that have different applications in different stages of planning (Batty 1995; Klosterman 1995). The ways in which the planning process may be supported by PSS are shown in Figure 5. GIS are becoming important components of PSS by virtue of the geoprocessing, graphic display, database and modelling capabilities they possess. However, a PSS cannot consist of a GIS alone. It must also include the full range of the

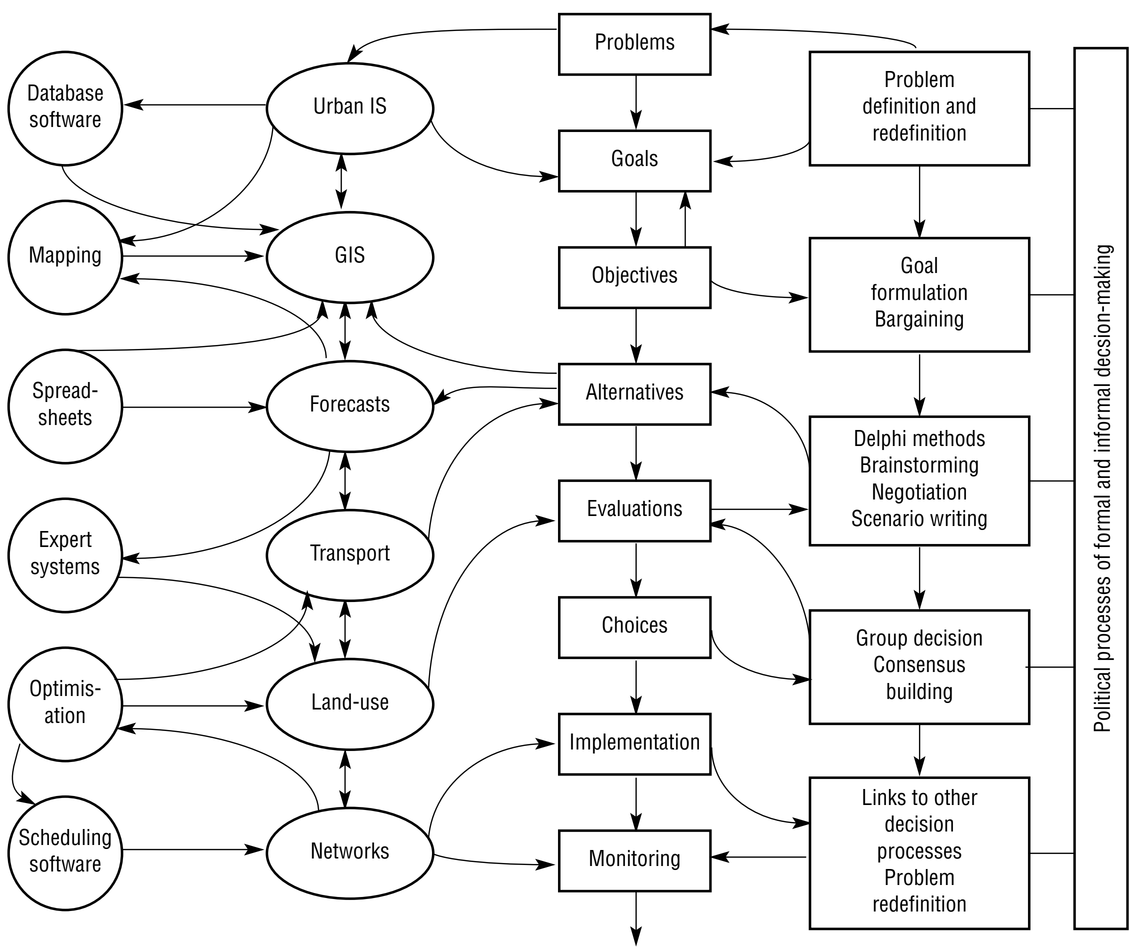


Fig 5. The planning process supported by a formal computation desktop PSS.
Source: Batty 1995

planner's traditional tools for economic and demographic analysis, forecasting, environmental modelling, transportation planning, and land-use modelling. It should also include other technologies such as expert systems, decision support aids (e.g. multi-criteria decision analysis), hypermedia systems, and group decision support systems.

4 TRENDS AND FACTORS INFLUENCING THE USE OF GIS IN URBAN PLANNING

4.1 Trends in the use of GIS in urban planning

The database management, mapping, and spatial analysis functions of GIS have been very useful in many areas of urban planning (French and Wiggins 1990; Levine and Landis 1989; Worrall 1990). The main weakness of GIS in urban planning is their linkage with urban planning models (Douven et al 1993). There are different strategies for linking planning models with GIS. They range from loosely-coupled, to tightly-coupled and fully-integrated architectures.

Integration based on the loosely-coupled architecture involves importing and exporting data between GIS and planning models (Figure 6(a)). Data are exported from a GIS and transferred to an external program for execution. The modelling results may be sent back to GIS for display and further analysis. Tightly-coupled architecture integration involves writing programs within the GIS environment, avoiding explicit data transfer between software packages (Figure 6(b)). Today the loosely-coupled architecture is the most commonly used in the integration of planning models and GIS. The California Urban Futures Model (Landis 1995) uses the loosely-coupled approach in the integration of GIS with models. It makes use of GIS extensively for data manipulation and displaying the results of external modelling packages. Such an approach is also used in multiple criteria decision-making planning methods (Jankowski 1995). The tightly-coupled approach has been used for residential location modelling in the Buffalo, USA region (Batty and Xie 1994a, 1994b). Currently, there is an increasing trend toward the development of fully integrated planning models in GIS. For example, location–allocation and spatial interaction models are now in ARC/INFO. This saves the users from programming the models themselves. However, until most of the commonly used planning models are fully integrated in GIS, there is still a need for loosely-coupled and tightly-coupled architectures. The issue of software coupling is discussed in a business and service planning context by Birkin et al (Chapter 51) and in relation to the development of desktop GIS by Elshaw Thrall and Thrall (Chapter 23).

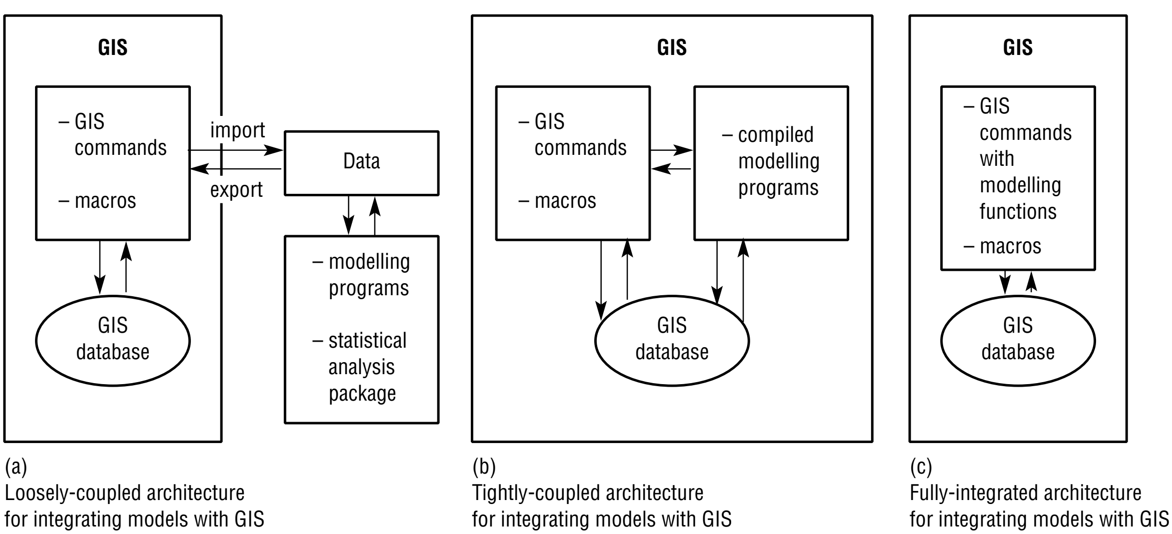


Fig 6. Integration of models with GIS: (a) loosely-coupled; (b) tightly-coupled; and (c) fully-integrated architecture.

Data visualisation is very useful to planning. It can help planners to explore data, and calibrate and visualise the results of planning models (Batty 1992, 1994). It is useful for displaying the results of complicated location–allocation models (Armstrong et al 1986). It can also enhance human–computer interaction in the decision-making process (Densham 1994). Thus data visualisation is a very valuable GIS function in a planning decision support system and the development of user-friendly data visualisation functions has made GIS more useful to planning.

The integration of multimedia data types and the use of GIS in the Internet/Intranet environment (especially the World Wide Web, WWW) are some of the recent GIS developments that have had great impacts on urban planning. The incorporation of images, videos, aerial photographs, and sound within GIS can increase the planners' comprehension of the planning problem that they are analysing (Fonseca et al 1995). The integration of GIS with virtual reality can enable planners to examine the space that they are planning more realistically (Faust 1995). The Internet and intranets are useful for communicating design ideas (Coyne et al 1996). The use of GIS in the Internet and WWW environment can also facilitate the dissemination of planning information and enhance citizen participation in the planning process (see Coleman, Chapter 22; Shiffer, Chapter 52). Unlike the past in which citizens had to go physically to the town hall to examine plans, they can now see them in their offices and homes via the Internet at any time. The WWW can help in the development of a multimedia-based collaborative planning systems (Shiffer 1995).

4.2 Factors influencing the use of GIS in urban planning

The use of the GIS in urban planning does not depend solely on the development of new GIS software and hardware. Indeed these considerations may be amongst the least important in influencing whether GIS is used in urban planning in a city (see Campbell, Chapter 44). The status and character of the organisation, data, state-of-the-art of planning, and staff are more important factors, and this section considers their importance with particular regard to developing countries.

4.2.1 Organisation

No matter how sophisticated and advanced it is, a decision support system is useless if it is not being used by decision-makers. Studies on the applications of GIS repeatedly show that staff and organisational factors are more important than technology in successful applications of GIS (Campbell 1994; Campbell and Masser 1995). There are three sets of conditions that are important in effective implementation of GIS:

1. an information management strategy that identifies the needs of users and takes account of the resources at the disposal of the organisation;
2. commitment to, and participation in, the implementation of any form of information technology by individuals at all levels of the organisation;
3. a high degree of organisational and environmental stability (Campbell 1994; Masser and Campbell 1991). GIS that are most likely to be used are those that can deal with identifiable problems. More complex applications are less likely to be developed than simple ones.

4.2.2 Data

The lack of available data remains one of the major hindrances in the use of GIS (Yeh 1991). As a type of information system, GIS needs graphic and textual data in order to function. There is no life in GIS without applications and there can be no application if there are no data. In short, data are vital to GIS. In the developed countries, a reasonable amount of geographical data are available thus making the establishment of a GIS relatively easy (Smith and Rhind, Chapter 47) if sometimes expensive (Rhind, Chapter 56). Unfortunately, data are not so readily available in the developing countries. The most readily available data are those from remote sensing which means that they are restricted largely to land *cover* information from which a very limited amount of information about land *use* can be extracted (Bibby and Shepherd, Chapter 68). Because of this it is not surprising to find that data contained in GIS in developing countries are primarily concerned with the physical environment and land cover. Socioeconomic data, which are vital to urban and regional planning, are generally lacking and often limited only to population census data.

Socioeconomic data require field surveys which are expensive and time consuming. In a study of information systems for planning in

Ghana, Akom (1982) found that there was a lack of up-to-date and reliable data for planning because some departments were slow in the acquisition of data, and coordination among various departments and institutions in the flow and exchange of information was weak. The lack of financial resources and trained personnel to collect data, and the unavailability of modern and efficient data processing equipment, were also cited as inhibiting factors. The relatively low price of microcomputers can help to alleviate some of the hardware constraints in electronic data processing facilities. However, the main obstacles still lie in the failure of developing country governments to recognise the need for statistical information for planning, and their willingness and ability to mobilise resources to collect it.

In many developing countries, the base-maps which are more essential than textual data to GIS are often lacking or outdated. There are usually many types of base-map, each compiled by different agencies with different accuracy and map scales. This makes them difficult to integrate into GIS (see Weibel and Dutton, Chapter 10, for a detailed discussion of this topic). Furthermore, there is a general lack of a standardised geocoding system which makes it difficult to link the textual data and graphic data. It is, of course, difficult to start GIS without the necessary maps, geocoding systems, and textual information (see Smith and Rhind, Chapter 47, for a discussion of the merits of so-called 'framework data').

It is not only the availability of data which is a problem in developing countries but their quality too. The currency of data is very important in planning because data will be of limited use if they are outdated. There is, unfortunately, a lack of institutional arrangements to determine, coordinate, and monitor the frequency of data updating by different departments. A fairly large amount of data used for planning in developing countries are collected by agencies over which the planning agency has little control (Batty 1990). Additionally, there are no procedures for verifying the quality of the data collected.

There has been a misconception that hardware, software, and human resources are major constraints on the use of GIS in urban planning in the developing countries. In fact, the availability of up-to-date data is the most important bottleneck in preventing GIS from being used effectively in the developing countries. There is an urgent need to establish an institutional framework to ensure that the required data are regularly collected and updated (Smith and Rhind, Chapter 47; Rhind, Chapter 56).

4.2.3 State-of-the-art of planning

The state-of-the-art in planning in the developing countries has not advanced much in comparison to GIS. The skills of planners and the planning systems may not be ready to utilise the data and functions provided by GIS. Planners could employ GIS in conjunction with new planning techniques so that they are better able to diagnose potential problems and assess the desirability of alternative plans. In spite of this, most planners in the developing countries are not yet aware of the benefits and potential applications of GIS. Furthermore, even though much effort has been spent on data collection, comparatively little has been spent on transforming data into information for making planning decisions.

4.2.4 Staffing

With the rapid growth of GIS, there is a shortage of human resources even in the developed countries. This shortage is more severe in the developing countries both in absolute numbers and relative terms. There are very few people who know about GIS in developing countries. The shortage of skilled personnel is currently very severe, especially given the number of cities and regions in the developing countries that can benefit from GIS.

The problem of training is very severe in the developing countries because of the lack of expertise and shortage of funds. In developing countries, GIS is often led by teaching and research in the universities. The reverse is the case in many developing countries where, very often, it is government agencies which buy and use GIS first through funding from international agencies. It can be several years later before GIS equipment is installed and courses are offered in universities and other tertiary institutes. Training of GIS personnel is often carried out by software companies by either sending their staff to run short courses on site or sending the operators and users to be trained in their headquarters. GIS courses and training programmes if available in the developing countries are normally carried out in the departments of surveying, remote sensing, and geography. There is also a general lack of GIS courses in planning schools. To use GIS more effectively in planning, planners must be trained not so much in the operation of the system, but in how to make use of the data and functions of GIS in different processes of planning and plan evaluation (Drummond 1995).

5 CONCLUSION

GIS are increasingly being used in planning agencies in the developed and developing countries (Worrall 1990; Yeh 1991). Many planning departments that have acquired mapping systems in the past have since shifted to GIS in lieu of mapping software (French and Wiggins 1990). With the increase in user friendliness and the number of functions of GIS software, and the marked decrease in the prices of GIS hardware, GIS is now an operational and affordable information system for planning. It is increasingly becoming an important component in the planning support system. Recent advances in the integration of GIS with planning models, visualisation, and the Internet will make GIS more useful to urban planning. Today, the main constraints on the use of GIS in urban planning are not technical issues, but the availability of data, organisational change, and staffing.

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