GIS in Urban Management

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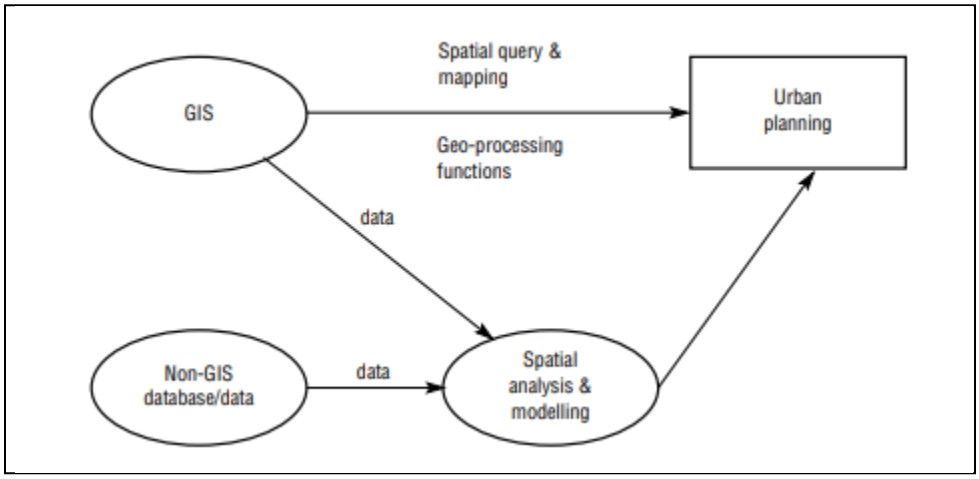
Introduction

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



GIS in Urban Planning

Database management, visualization, spatial analysis, and spatial modeling 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.

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). Data management, visualisation, and spatial analysis are used more in 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.

Visualization, spatial analysis, and spatial modeling are the most frequently used GIS functions in plan making. Webster (1993, 1994) discusses the advantages of using the data management, visualization, and spatial analysis and modeling 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 citywide 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 modeling 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 modeling and development of planning options than in the determination of planning objectives. The different stages in the urban planning process can be generalized as the determination of objectives, resource inventory, analysis of existing situations, modeling 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.

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).

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).

Modeling 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 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.

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).

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).

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.

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).