CHAPTER 1

INTRODUCTION

1.1 Background

Identifying the suitability of particular sites for urban development is one of the critical issues of urban and regional planning. The evaluation is usually made by means of identifying a complex array of physical and socio-economic factors, influencing the suitability of a site for urban development. The cumulative effect of these factors determines the degree of suitability and also helps in further classification of space into different priorities for development.

The determination of site suitability can also be accomplished by analysing the interaction between three sets of mutually related factors: namely ***locations, development actions and environmental effects*** (J. Lyle, P. Stutz, 1990). This means that when carrying out certain development actions and control of specific environmental effects, it is possible to identify the most suitable location for these actions and also the potential environmental effects (conflicts) that could result from these actions. This approach incorporates a close connection between ***site suitability assessment and environmental impact prediction***, introducing environmental compatibility criteria as one of the fundamental determinants in the site selection process. It assumes that variation in environmental character of a landscape renders some areas more suitable for supporting certain development actions than others and that the difference can be very important to environmental quality.

Environmental compatibility assessment in site selection processes, as described above, is a task that requires consideration of a comprehensive set of factors. Therefore, its effective use requires a flexible system capable of storing; manipulating and transforming a large volume of spatially oriented data into usable information. With the recent development of computer hardware and software technology, Geographic Information System (GIS) has emerged as a useful computer-based tool in supporting a variety of location and planning tasks. The major benefits of GIS come from their powerful capabilities in the fields of spatial data management, spatial analysis and visualisation. These advantages are reflected in two general areas:

1) Improved and flexible management of location-related data and,

2) Effective and faster data manipulation and preparation of information to facilitate location-related decision making tasks.

The latter is manifested primarily through the ability of GIS to support more precise and faster spatial overlay analysis, and consequently, the effective testing of a greater number of possible options. In contrast, the traditional manual decision-making processes often skipped this part due to the tedious nature of developing and testing alternative solutions.

Many researchers in planning and environmental management tend to define GIS as a decision support system (DSS). There is however little agreement on what a DSS is and what a DSS actually constitutes. The more widely accepted definitions of DSS identify it as an interactive system, providing the user with easy access to data and decision models in order to support semi-structured or unstructured decision-making tasks. As the above definition implies, the interaction between user and the system is very important in DSS. The system provides the tools (database management tools, application specific models and modelling capabilities) along with a user-friendly interface, while the user (decision-maker) incorporates objectives, criteria, judgement and relevant data to solve the problem at hand.

In terms of these definitions of DSS, it seems that GIS cannot be regarded as a fully developed DSS. In spite of the significant capabilities, GIS lacks support for the use of problem oriented decision models usually required by planners and all others with interests and responsibilities in planning and environmental management. Common to all definitions of DSS is the requirement that they must provide explicit models and capabilities to support particular types of decision. In other words, while GIS systems may contain data and information that can be more readily accessible and more flexibly modified to meet the needs for location-related decision-making tasks, they are usually general-purpose data management and analysis systems. As a result, few current GIS systems provide any particular problem related models usually needed to fully support decisions in various fields of human activities, including site selection and environmental compatibility assessment.

Another reason why a GIS is not completely suitable as a DSS is connected to the complexity of the GIS technology built upon a variety of scientific disciplines (cartography, remote sensing, computer science, statistics, etc). Consequently the use of GIS requires not only expertise for problem solving but also an extensive background in digital data management and mapping science as well as the technical knowledge to use the available GIS system. Because of this complexity, standard GIS tends to divert the process of decision making away from decision makers into the hands of the GIS specialist and a host of other highly trained technology experts.

To improve the above-mentioned situation the concept of a GIS based Spatial Decision Support System (SDSS) is receiving increased attention. The reason for this is the acceptance that GIS has the potential to assist spatial decision-making. This concept extends the present use of GIS as a DSS, to a situation where GIS can be used as a generator to build DSS for a specific spatial problem domain (P.Keenan,1997). As defined by Densham (1990), a SDSS can conceptually be thought of as providing an integrated set of flexible capabilities in supporting semi-structured or ill-defined location problem solving tasks. The key to a useful SDSS is basically the integration of GIS and its analytical capabilities with statistical and other application specific models. Such integration seems to have the necessary power and flexibility to assist decision-makers in the process of solving various specific spatial problem-solving tasks.

One example of integration is the linkage between GIS and expert systems (ES), often referred to as an intelligent SDSS, or a knowledge based GIS. Expert systems (or Knowledge based systems) have evolved as a branch of Artificial Intelligence (AI) and from a GIS perspective they seem to be the principal area of AI applications in GIS. In general, an ES can be regarded as a kind of computer system that attempts to behave in an intelligent manner by the explicit incorporation of human knowledge for the problem at hand (S. Openshaw, 1997). The essence of ES is that it attempts to incorporate the judgment, experience and intuition of human experts into problem solving. What actually makes ES a powerful approach is an appropriate use of heuristics or heuristic rules as a set of tools for problem solving whenever mathematical, statistical and other formal methods would be less effective or impractical for deriving optimal solutions (Ignizio, 1991). One of the typical characteristics of heuristics is its screening, filtering or pruning mechanisms by the use of IF...THEN statements that represent knowledge or guidelines through which the system may operate (Ignazio, 1991).

Incorporating a knowledge-based approach to enhance GIS has been found particularly valuable in site suitability assessment, specifically in the environmental domain. This is because the decision-making process in these spatial problem-solving areas is very often ill structured, requiring heuristics, and therefore knowledge based techniques to be applicable. The idea is to use GIS as a proper tool for visualisation, manipulation and analysis of spatially referenced data and their attributes for the problem at hand, while ES would provide a basis for catching the essential information from database and converting it into practical advice.

1.2 Research Objective

The purpose of this research is to see how GIS can be used to support site suitability analysis for urban development. This is done by using an existing manual decision-making process developed by UNEP-UNCHS (Habitat) and converting it into a spatially enabled decision support system – a Knowledge Based GIS (KBGIS). The UNEP model is essentially based on a checklist of problems and can be seen as a screening and diagnostic process for the identification of interactions between three sets of mutually related factors, namely location, development actions and environmental settings. It involves the assignment of qualitative labels to site-specific development-environment conflicts based on the available data on the physical environment and the planned development action, as well as a set of generic rules (facts) for assessing and grading the likely consequences. The UNEP model was developed to promote environmentally sound planning and management. It has been implemented on several occasions, but within the framework of manual processing techniques.

This proposed prototype system is intended to function as an intelligent - computer-based consultant in assisting screening and diagnostic processes in site suitability assessment and development-environment impact prediction. The purpose of its development is twofold, namely:

1) To present a practical example of using GIS in automating problem specific and ill-structured decision making tasks, and what is even more important,

2) To illustrate the usefulness of incorporating the elements of knowledge based techniques to enhance the level of intelligence of current GIS systems and their ability to assist decision-makers in the process of deriving facts from existing data and conditions.

This research is based on the recognition that the usefulness of a "conventional" GIS in automating the above-mentioned model for development-environment compatibility assessment could be improved by incorporating (embedding) the elements of knowledge based systems (KBS). The model and the evaluation approach it supports are in that regard seen as an appropriate problem domain that can be facilitated by integrating the strength of GIS and KBS. Such integration seeks to provide a decision-support environment that can be effectively utilized by both:

1) Users with limited (if any) knowledge of GIS at a practical level, and

2) Users lacking the experience in the area of site suitability assessment and environmental impact prediction.

1.3 Organisation of the Document

This document is structured into five chapters. The present chapter covers the introduction to this research. It provides the background, problem statement as well as the objective and motivation for the research.

Chapter 2 seeks to clarify the directions of this research. It is divided into four parts. The first part explains the strength of GIS technology in supporting spatial problem-solving tasks. The second part discusses the concept of a Spatial Decision Support System (SDSS). Emphasis is put on the role of GIS in providing a decision support framework for ill-structured spatial problem solving. This includes a review of the different approaches to the integration of GIS with analytical and modelling tools drawn from other disciplines as well as some relevant empirical examples. The third part is focused on issues concerning the integration of GIS and KBS in an effort to provide an intelligent decision-making tool for spatial problem solving. It starts with an overview or the basics of a KBS system and includes a description of its components and a summary of the essential steps involved in its development. Finally, the relevance of the different approaches as it applies to the purpose of this research is summarized.

Chapter 3 outlines the model for the identification of development-environment conflicts at the early (screening level) stage of the project planning process. The chapter starts with an explanation of the purpose of the model, and a description of its fundamental components. It ends with the presentation of a typical evaluation session supported by the model. The purpose is to illustrate the organisation of the information system as well as the evaluation approach and procedures. Material in this chapter constitutes the basis for the development of the proposed prototype KBGIS.

Chapter 4 explains the strategy followed in this research to develop the prototype KBGIS. It firstly deals with the components of the information system that supports the model, focusing on the issue of their organization, form and format within the prototype KBGIS environment. The second part of this chapter seeks to explain the GIS-KBS interfacing strategy. It also includes a brief illustration of the prototype KBGIS structure along with a description of its basic components and functions. The chapter ends with a detailed presentation of the system's modules and capabilities.

The final chapter provides a summary of the more important findings and achievements of this research.