Application of GIS to Highway Infrastructure Management

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1. Introduction

Highway infrastructure management is a process with several highway related activities involving planning, design, construction, operation, maintenance, and research developments. Recently, in many countries, this process is carried out under certain levels of budget limitations. The adaptation of new technologies in this process can vastly improve the quality of related decisions and thus optimal use of the available budget. One of the new technologies which can be particularly promising for the management process is Geographic Information Systems, GIS.

In this paper, GIS elements, capabilities, its applicability to highway management process and the advantages added are discussed. An application example is also presented.

2. GIS: Definition and Elements

GIS is a computer system which can capture, store and manipulate data and produce outputs. The uniqueness of GIS comes from its ability to carry out these operations on both spatial and descriptive data. Accordingly, any GIS can be said to have the following major elements:

1. Spatial database module; in which locational and shape data are captured and stored in the form of coverages (maps).
2. Attributes database module; in which descriptive data associated with the spatial features are entered and stored.
3. Analysis module; in the form of a group of commands and functions which retrieve and manipulate both spatial and descriptive data to produce different forms of data and information in the forms of maps and/or tables.
4. Programming language; in which different user defined functions are written to run specific applications besides the general purpose analysis module.

3. Capabilities of GIS

GIS is not simply a system for producing maps, although it can easily create variety of 2D and 3D maps. GIS is an analysis tool with capabilities range from simple retrieving of data subsets, through statistical analysis to spatial analysis. Examples of spatial analysis are; relating different road-related features using location as a common key (overlay), aggregating adjacent features based on specific attribute(s) and data retrieval interactively based on the location (geographic queries). All these tools make it possible to analyze diverse, yet relevant, types of road data together to clear relations. Also large scale GIS softwares support network simulation which is particularly useful for managing road networks.

4. Why GIS for Highway Infrastructure Management

Road networks are inherently geographic as they are extended over a wide area and interacting with various land topography. Also, network components, e.g., links' extent and shape and intersections, and events taking place within the network, e.g., accidents and maintenance applications, are locational in nature. Thus, spatial consideration, relations between different geographic features, in the management process is essential and can vastly improve the decision making process.

However, highway infrastructure management systems are usually based on a central data bank in which only descriptive data are handled. More advanced systems are also supported by CAD systems for generating maps. Neither of the two systems permits spatial operations on the data. GIS as a system with spatial analysis capabilities besides having the attributes of the above mentioned systems is particularly matching the geographic nature of road networks.

5. Application Example

GIS can be introduced to almost all activities related to highway management process. For example, it can facilitate the planning phase in which preliminary route is selected by analysing several related factors such as land use and value, regulations, obstacles and etc. Similarly, the other activities of the

management process can be benefited from GIS spatial analysis capabilities. A case study was carried out in the area of maintenance management.

In this study, a highway maintenance management system, HMMS, was coupled with a GIS. The resulting system contained several maps for Nagoya city main roads, land use and value and main utilities networks. Also, road attributes such as inventory, traffic and pavement condition were included. Several user programs were defined to simulate deterioration and maintenance and evaluate condition. This system was used to evaluate the consequences of alternative maintenance strategies.

The coupling of the HMMS and GIS resulted in several merits. Some of these merits came from the capability of GIS to produce 2D and 3D maps to show data and results which is easier to understand and more suitable for high level decision makers. Also, optimal route finding capabilities could discover detour routes during maintenance applications. Interactive geographic queries made it easier to retrieve information to clear relations. Spatial overlays brought about the most distinct merits to the system by integrating diverse types of data. In Fig. 1, a road selected for widening was overlayed with land use to yield the amount, cost and details of the land to be acquired. In Fig. 2, a road scheduled for future rehabilitation was overlayed with the main water lines aiming at better coordination between timing of road maintenance and maintenance of other utilities.

6. Conclusions

GIS is a new technology which can vastly improve the quality of decision making in highway management process. The adaptation of GIS in highway maintenance management was illustrated. A HMMS was coupled with GIS. Capabilities of resulting system were investigated through out examining alternative maintenance strategies on a study road network. Several merits were added to the process. These merits can be summarized in the following points:

1- automation of maps generation for better display and understanding of system results.
2- easier queries through locational conditions.
3- network simulation such as in detour route finding.
4- spatial analysis in which diverse types of data are integrated.

This new technology if properly applied can insure better coordination among the different activities within road management and with the activities of other public authorities.

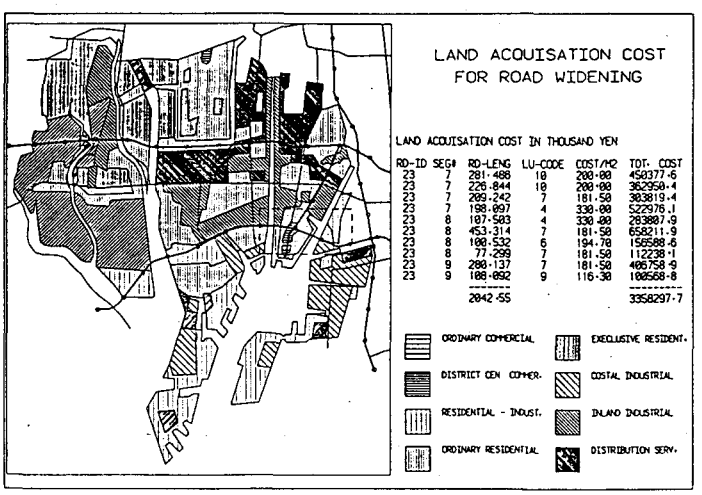

Fig 1: Land to be Acquired for Road Widening

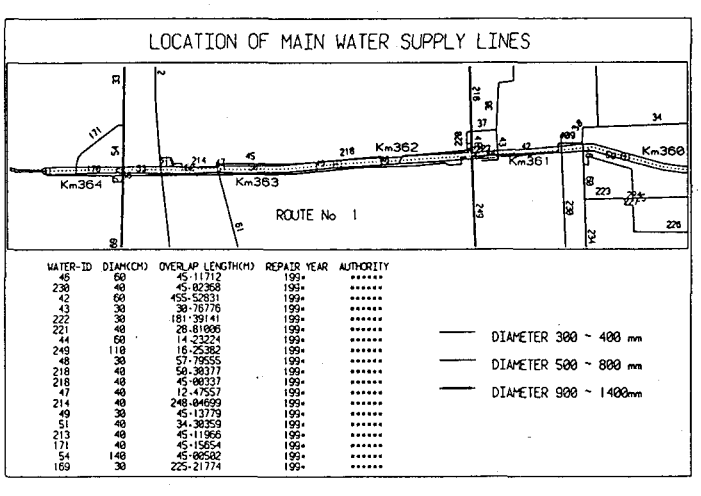

Fig 2: Road and Utilities Maintenance Coordination