GIS-BASED ROADWAY CONSTRUCTION PLANNING

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Roadway construction planning processes involve a large amount of information regarding design, construction methods, quantities, unit costs, and production rates. GIS (Geographic Information System) is a very effective tool for integrating and managing various types of information such as spatial and non-spatial data required for roadway construction planning. This paper proposes a GIS-based system for improving roadway construction planning by integrating design and construction information. The proposed system can also help construction planners make a proper decision in a unique way with its 'Interactive Planning' function that supports the space scheduling and activity sequence visualization processes.

Keywords: GIS, Construction planning, Information integration, Space scheduling

1. INTRODUCTION

Roadway construction planning processes involve a large amount of information on design and construction. GIS (Geographic Information System) is a strong tool for integrating and managing various types of information such as spatial and non-spatial data required for roadway construction planning.
The roadway design process has been improved greatly by using CAD/CAE tools. Therefore most design data are created and stored electronically. However, the digitized design data have not been fully utilized for construction planning purposes. In recent years, in the architectural engineering field, there has been lots of improvement in integrating design and construction information for using design data at construction planning stage [Yau 1992 ; Marir et al. 1998 ; Koo and Fischer 2000 ; Cheng 2001]. Attempts to utilize the digitized design data for construction planning was also taken up in civil engineering field recently [Hassanein and Moselhi 2002].
A GIS-based system for improving roadway construction planning is presented in this paper. The proposed system supports the roadway construction planning with 'Information Integration', 'Spatial Analysis' and 'Visualization' functions. The application of the proposed system is limited to road construction among the highway construction components that include roads, bridges and tunnels.

2. GIS-BASED INFORMATION INTEGRATION FOR ROADWAY PLANNING

The roadway construction planning system proposed in this paper is based on integrating design and construction information within a GIS environment. The overall structure of the system and the methodology of integrating information are explained in this section.

2.1 Overall Structure

Figure 1 shows the overall structure of the proposed system. Two dimensional CAD drawings are converted to several shapefiles which are a type of GIS formatted-files according to geometry such as points, lines, and polygons. The converted shapefiles contain spatial feature attribute table with the conventional feature attributes and the shape features. The spatial feature attributes are integrated with the non-spatial attributes including construction information such as activity assemblies, unit costs, and production rates by the system's 'Interactive Planning' capability. The system then generates a table containing the quantities, the costs, the activity lists and their durations. This table can be transferred directly to a commercial scheduling software. After detailed scheduling (e.g. calculation of early start date and early finish date etc.) based on the data in the table with a scheduling application program, the date information is returned to the system and connected to the corresponding construction elements by the system. The system then can visualize the construction sequence.

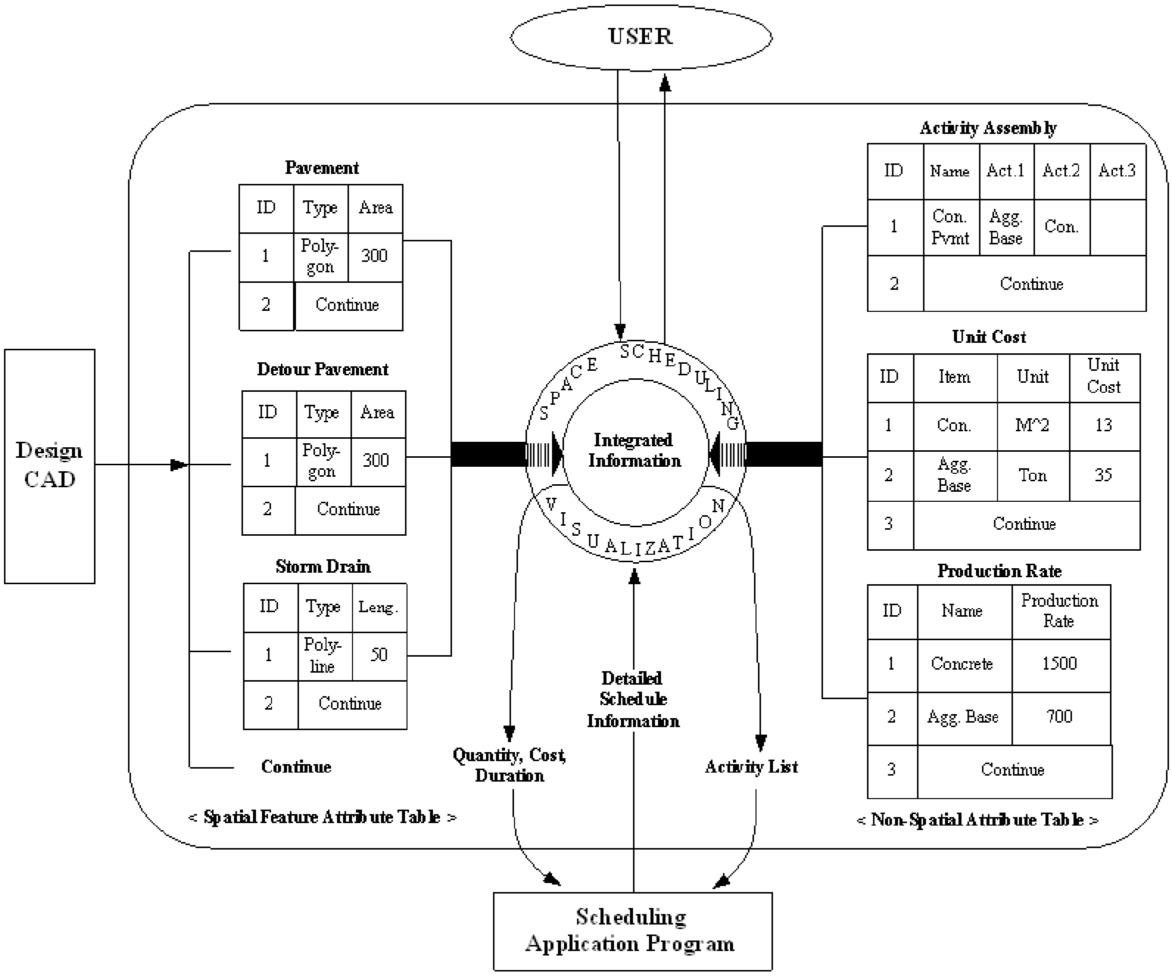

Figure 1. Information Integration Structure of the System

2.2 Classification of Construction Elements Based on Geometry

Table 1. Classification of Construction Elements

Work Section	Shapefile (Construction Element)	Geometry
Pavement	Pavement	Polygon
	Detour Pavement	Polygon
Earthwork	Cut/Fill boundary	Polygon
Drainage	Culvert	Polyline
	Pipe	Polyline
	Gutter	Polyline
	Inlet/Outlet	Point
	Manhole	Point

As shown in Table 1, the roadway construction is composed of three work sections, 'Pavement', 'Earthwork', and 'Drainage'. The construction elements of the work section are classified and stored in separate shapefiles according to their geometry. For example, pavement area on design CAD drawings is converted to a shapefile and named 'Pavement'.

The spatial attribute tables including the location and geometric information about each shape are automatically generated on converting to GIS-formatted shapefiles. The tables contain both the conventional feature attributes such as object id, area, and length etc. and the shape features such as the coordinates of the shape components. This data is the base materials for quantity take-off [Seo et al. 2002].

2.3 Non-Spatial Attribute Table

Additional data not included in the spatial attribute tables are required for calculating quantities, costs, and activity lists. The non-spatial attribute tables are composed of 'Activity Assembly' for each construction element, 'Unit Cost', and 'Production Rate'. The activity assembly table contains the detailed activity lists associated with graphic objects of the shapefiles. For example, as shown in Figure 1, the polygons of graphic objects which represents 'Concrete pavement' have two activities: 'Aggregate

Base' and 'Concrete'. These two activities are included in the activity assembly table to generate necessary activity lists for selected graphic objects.

2.4 Information Integration Process

Spatial data and non-spatial data are integrated by the customized module in ArcMap Visual Basic Application. A selected graphic object by the planners is connected to one of construction elements with an activity assemblies. The system aids the process with various construction element options so that the planners can easily connect the graphic object with proper non-spatial attributes.

The detailed data like unit costs and production rates in the prepared non-spatial attribute tables are used for estimating cost and duration of activities. All of the generated information is allocated to a new table. Figure 2 represents the process of quantity take-off, cost estimation, and calculating duration of activities. Activity lists generated can be directly transmitted to a commercial scheduling application program. After detatiled scheduling with the commercial scheduling software, the start and finish date information is returned to the system. This information is added to the spatial attribute table so that the visualization of the activity sequence can be achived.

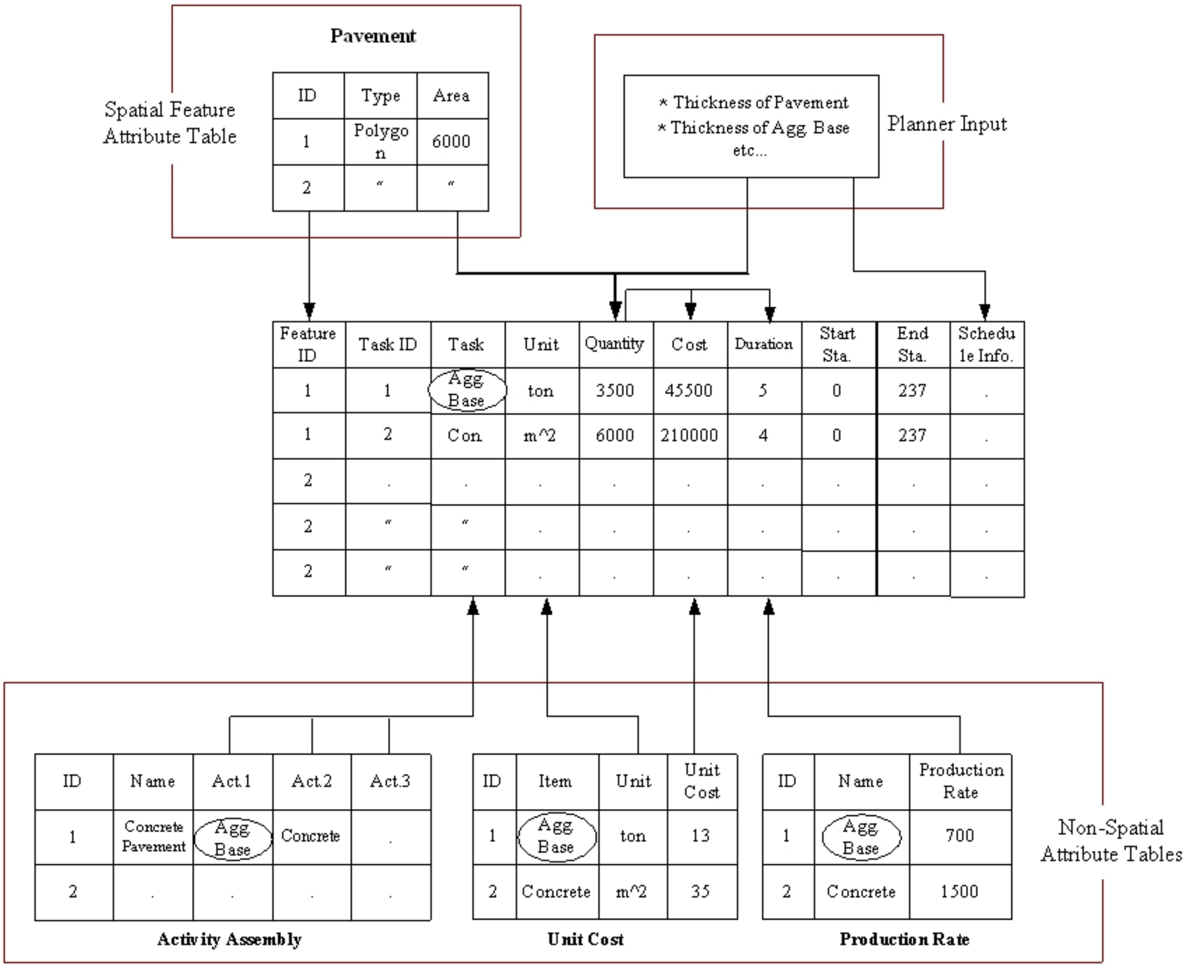

Figure 2. Data Flow

3. INTERACTIVE SPACE SCHEDULING

3.1 Space Scheduling & Activity Lists Generation

Architecture buildings are easily modularized into construction elements like columns, beams, and windows etc. However, roadway design components are not. The proposed system therefore provides the planners with 'Interactive Space Scheduling' function by which the planners modularize the design component in real time. After activating an interesting shapefile such as 'Pavement', the planners can divide graphic objects directly in real time. Then the system identifies the intersected region as a new graphic object, which means, as shown in Figure 3, it is possible that the system generates activity lists, quantities, and costs by connecting the divided graphic objects and non-spatial attributes. This function has an important meaning in that the planners are able to divide 2-D roadway graphic objects in real time and directly connect them with construction information to create the activity lists for the modularized construction elements.

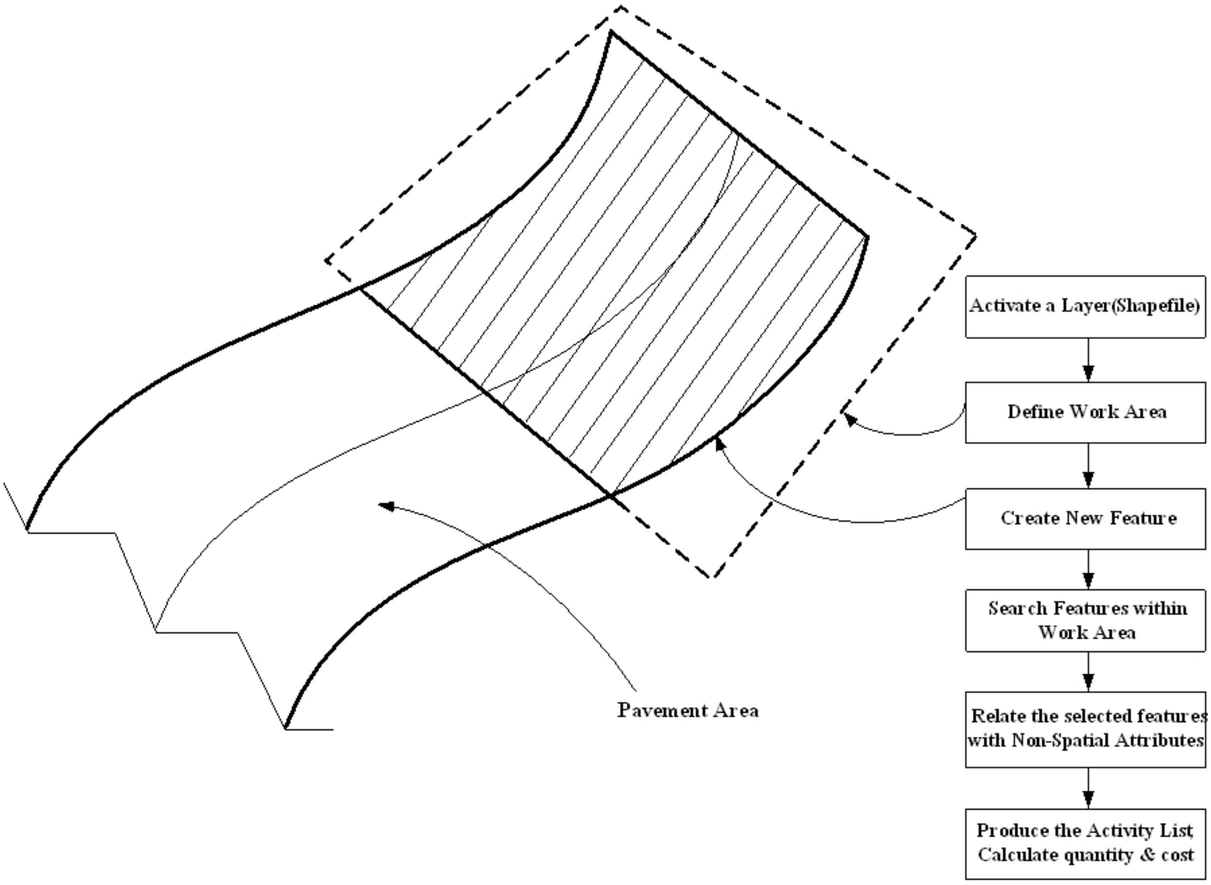

Figure 3. Space Scheduling Function

3.2 Interaction with Scheduling Application Programs and Visualization of Activity Sequences

The activity lists obtained through the process mentioned above are sent to a scheduling application program to complete detailed CPM scheduling. After that planners can get a detailed schedule table including the start date and the finish date. This detailed schedule table is connected again to the graphic objects by the system so that planners can visualize and analyze activity sequences. The system demonstrates activity sequences by changing the color of graphic objects. Planners can review the sequences immediately and intuitively, if there is something wrong with the sequences, planners can modify the detailed schedule in real time.

4. OTHER SYSTEM FEATURES

This on-going research effort at Hanyang University also includes the development of the following system features to help planners plan roadway construction.

4.1 Using aerial photographs

Arial photographs are utilized so that the planners can have the visual feedback on the construction site and the surrounding area while he/she is planning the roadway construction work with the system. The photographs are overlaid with the GIS spatial feature data. While the spatial and non-spatial data of the planning system provide the planners with the various helpful information, it was also found that the immediate and intuitive understanding on the site could be obtained by presenting the site condition through the photograph along with the spatial and non-spatial data of the proposed design work and the existing features.

4.2 Operation Level Planning

The system provides the route analysis and the equipment selection functions for the operation level planning. The planners can identify the best route from the construction site to the dump and/or loading site by comparing the distances between two points or by comparing the time required to destination.

Besides, the best combination of equipment (e.g. dump trucks and loading equipment) can be calculated based on the cycle time of equipment.

4.3 Temporary Road Design

Temporary roads for equipment's entrance to the construction site are often required. In this case, planners can design temporary roads with the system based on the analysis of the digital terrain model as well as the information provided by the spatial/non-spatial features and the visual feedback on the construction site. The system helps planners design temporary roads with its design tools.

5. SYSTEM IMPLEMENTATION

The proposed system in this paper was developed by customizing ArcGIS which is one of GIS application programs. The customized module for information integration and visualization was designed with 'Visual Basic for Application' which works as an integral component of the desktop ArcGIS applications with ArcObject library [ESRI 2001]. The GIS tables such as 'Activity Assembly', 'Unit Cost', and 'Production Rate' are also made on ArcGIS. MS-Project was used for detailed scheduling. Figure 4 is a schematic diagram explaining the system implementation processes.

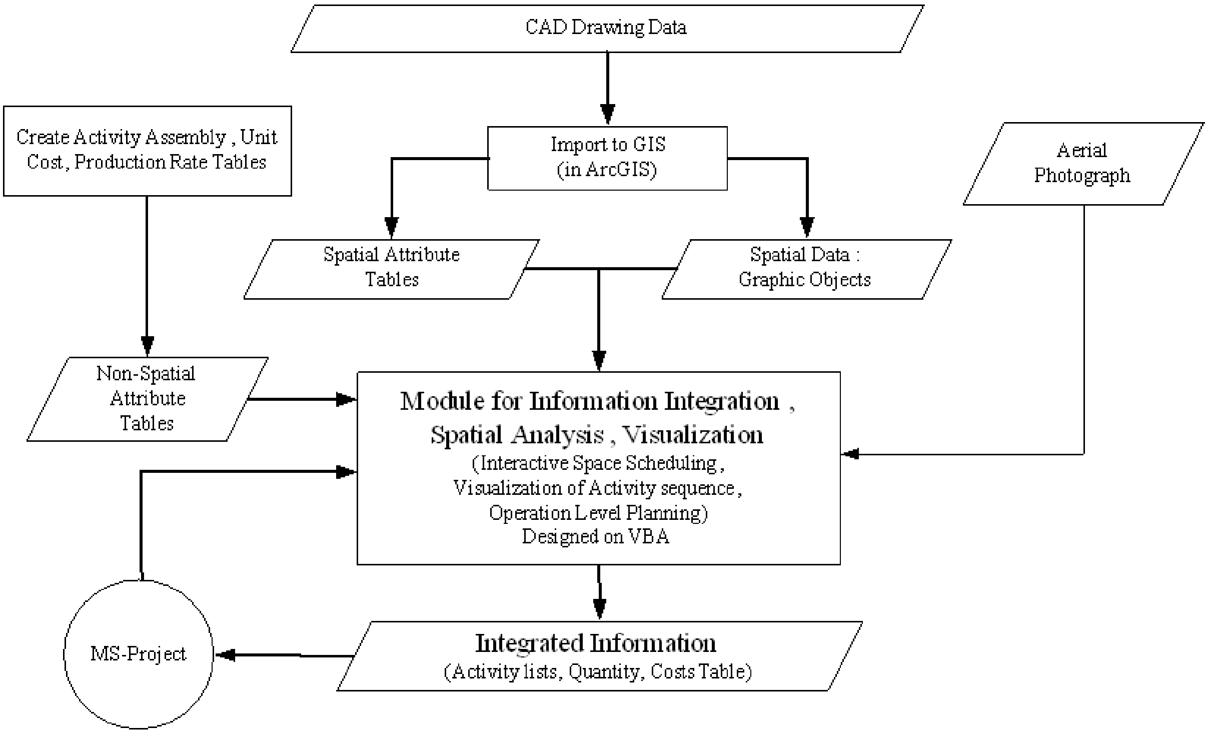

Figure 4. System Implementation

6. CONCLUSION

The proposed system in this study could improve roadway construction planning processes based on the information integration, the spatial analysis, and the visualization. The system provides construction planners with 'Interactive Space Scheduling' function with which the planners can divide 2-D roadway graphic objects not modularized into modules flexibly and integrate design information and construction information in real time. The system not only generates activity lists and calculates activities' costs and duration, but also visualizes activity sequences. Besides, the system performs the operation level planning through the route analysis and equipment selection features. The application of the proposed system is currently limited to the roadway portion of the highway construction projects. It is hoped that in the future the application of the system features extend to the structures such as bridges and tunnels.

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