A Planning of Spatial and Non Spatial Data for Highway Construction: GIS

Arun Kumar
Resource Person in UIET
MDU, Rohtak (HR)

Abstract: *Highway 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 highway construction planning. This paper proposes a GIS based system for improving highway 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.

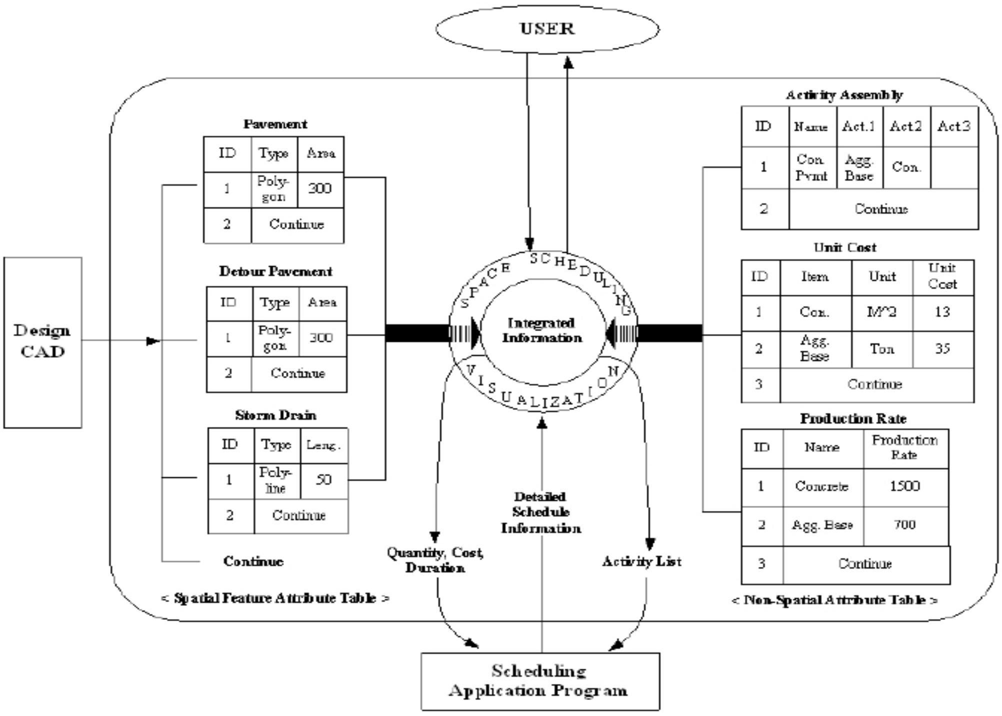
Introduction:

Highway 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 highway construction planning. The highway 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 attempts to utilize the digitized design data for construction planning was also taken up in civil engineering field recently. A GIS based system for improving highway construction planning is presented in this paper. The proposed system supports the highway 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.

GIS Based Information Integration for Highway Planning:

The highway 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 paper. Figure shows the overall structure of the proposed system. Two dimensional CAD drawings are converted to several shape files which are a type of

GIS formatted files according to geometry such as points, lines, and polygons. The converted shape files 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 commercial scheduling software. The system then can visualize the construction sequence.



Information Integration Structure of the System

Construction Elements Based on Geometry:

Classification of Construction Elements

Work Section	Shape file (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, the highway construction is composed of three work sections, ‘Pavement’, ‘Earthwork’, and ‘Drainage’. The construction elements of the work paper are classified and stored in separate shape files according to their geometry. For example, pavement area on design CAD drawings is converted to a shape file and named ‘Pavement’. The spatial attribute tables including the location and geometric information about each shape are automatically generated on converting to GIS formatted shape files. 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. 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 shape files. For example, as shown in figure, the polygons of graphic objects which represent ‘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.

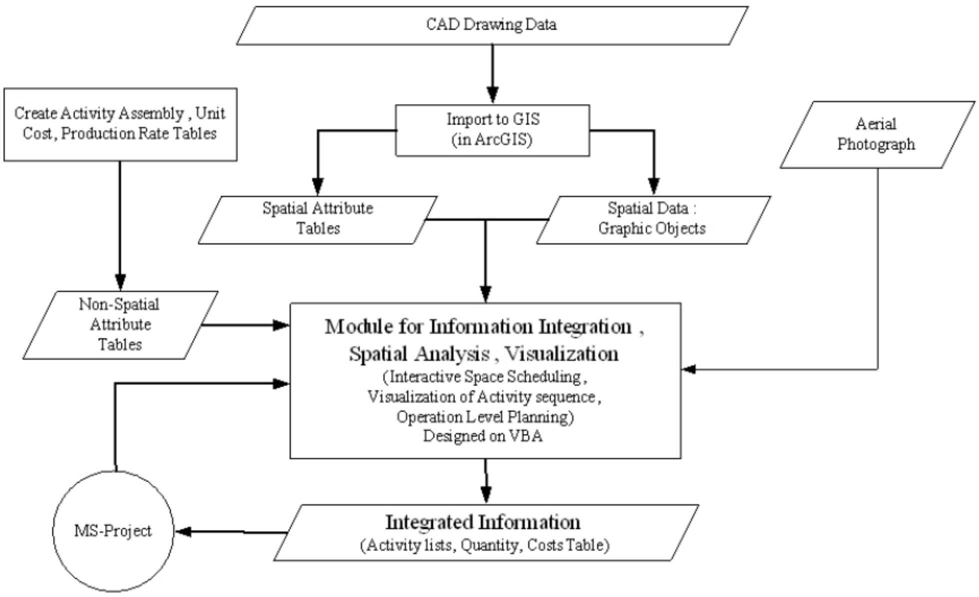
Information Integration Process:

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 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. Activity lists generated can be directly transmitted to a commercial scheduling application program. After detailed 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 achieved.

Interactive Space Scheduling:

Architecture buildings are easily modularized into construction elements like columns, beams, and windows etc. However, highway 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 shape file 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, 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 highway graphic objects in real time and directly connect them with construction information to create the activity lists for the modularized construction elements. This on-going research effort includes the development of the following system features to help planners plan highway construction. 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 highway 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 very 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. 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. 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.

(System Implementation)



GIS Solutions for Highway and Roadway Management:

Managing modern roadways is a complex business. From computerized traffic control systems and incident and safety management systems to effective capital improvement planning and maintenance activities, highway managers must draw on a wide array of technologies to effectively manage today's roadways. A comprehensive geographic information system (GIS) can help you integrate agency-wide information to achieve better operational efficiencies and results. GIS analysis and support through the infrastructure life cycle from planning and design through survey and construction management to operations and maintenance giving transportation professionals the ability to comprehensively manage their infrastructure.

Highway Asset Planning: Applied to asset planning, GIS not only facilitates data collection, processing, and display but also integrates asset mapping with project management and budgeting tools so that construction, operational, and maintenance expenses can be centrally managed and accounted for. Once established, asset management systems provide a framework to efficiently and equitably allocate scarce resources among competing objectives. Field personnel can take detailed GIS information with them on any number of mobile devices and quickly locate relevant facilities and perform detailed inspections. Deficiencies identified during inspection can generate new work orders for maintenance and repair. Maintenance and Work Order Management Modern highway management agencies have gained productivity and efficiency by integrating maintenance and work order management systems with GIS. Maintenance management systems allow more efficient scheduling of maintenance activities and tracking of work tasks, personnel, equipment, and material usage and help managers understand and report their complete maintenance activities.

Traffic Operations: Managers have come to appreciate the advantages of GIS based traffic and incident management systems to operate roadways at their peak efficiency. GIS can take a central role in developing effective traffic management strategies. The capabilities to integrate data feeds and share dashboard views make GIS ideal for viewing a comprehensive picture of current traffic conditions. For example, traffic managers can visually monitor bottlenecks and related information to quickly respond to vehicle incidents. In addition, these views can be shared with the public over the web, giving drivers the latest information on road closures and current travel conditions.

Transportation Planning: Finding the right balance between the need to accommodate demand on public infrastructure and the responsibility to preserve quality of life and environmental sustainability in your community is a challenge. GIS technology provides rich analytic and visual tools to help you meet this challenge. GIS provides a framework to inform models, such as those used to forecast travel demand and plan capital improvements, and to support strategic decision making. In addition, GIS applications that perform environmental evaluations shed light on the consequences of various transportation alternatives.

Transportation Safety Analysis: Recent transportation legislation strongly emphasizes achieving higher levels of safety on the nation's highways. GIS allows highway departments to accurately capture and analyze traffic accident information as well as identify dangerous highway segment locations with high accident rates. GIS, combined with complex statistical analysis and business intelligence tools, helps highway engineers better understand the causes of accidents at these locations and find ways of reducing them.

Environmental Management: Transportation planning and management require careful consideration of the impact that transportation activities have on the environment. GIS is uniquely capable of assisting transportation professionals to understand these repercussions and select the most environmentally sensitive solutions. GIS helps identify wetlands, drainage areas, and sensitive habitats as well as evaluate and manage the effects of storm water runoff on water quality. With GIS, transportation planners can understand the impact of land use decisions and evaluate smart-growth alternatives, leading to more livable communities. GIS integrates environmental factors with land-use and housing and employment density analysis to help communities address growth issues. The ability to visualize alternative options on a common platform allows differing parties to reach a consensus when dealing with an environmentally sensitive matter.

Conclusion:

The proposed system in this study could improve highway 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 highway 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 highway 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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