Project Cost Estimation of National Road in Preliminary Feasibility Stage Using BIM/GIS Platform

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ABSTRACT

A preliminary feasibility study evaluates various aspects of a project such as environmental assessment, field study, technological validity, and economic feasibility. Among them, economic feasibility is the most important factor to use in selecting a road route in Korea. A proper preliminary feasibility study considers all costs incurred in the life cycle of the project, including construction costs, land acquisition costs, collateral expenses, and operation and maintenance costs. However, only construction costs are traditionally considered in the assessment of the financial viability of national road projects. In addition, while 3D modeling techniques have brought improved designs and engineering processes to the construction industries, their application in preliminary feasibility studies remains rare. We have developed a system that employs building information modeling and geographic information systems for estimating the cost of building a national road that can be applied in the preliminary feasibility stage. The proposed system is composed of three modules that estimate construction costs, land acquisition costs, and O&M costs. Based on the road route, the proposed system analyzes cross sections through the topography and subsequently determines the probable road, bridge, and tunnel sections, and their project costs. Overall, the proposed system could assist a reasonable decision making for best route selection and further facilitate improved project delivery.

INTRODUCTION

Building information modeling (BIM) and geographic information systems (GIS) are powerful technologies used in transforming construction project process information to 3D visualizations. As infrastructures have become bigger and more complex, there is an increased need for the BIM application to the areas of construction project management and engineering; however, conventional methods continue to be used in the initial stages of road construction. Improved engineering in these areas, such as preliminary feasibility analyses and alternative route analyses, is an important criterion for successful project delivery. To improve the initial engineering, this study develops a BIM/GIS-based system for the best route selection of national road, which can be applicable to the preliminary feasibility study and alternative route analysis as well. The proposed system estimates project costs for each route including construction costs, land acquisition costs, and operation and maintenance (O&M) costs, and further enables decision makers to select the best route for the project based on cost comparisons between alternatives. The GIS platform identifies the composition of a route (road, bridge and tunnel) and allows the estimation of earthwork and land acquisition costs. The BIM platform also enables the linkage between 3D images and the specifications of structures (bridges and tunnels). Consequently, the proposed system provides decision makers with improved project delivery.

CURRENT STATUS OF THE BIM/GIS APPLICATION TO ROAD INFRASTRUCTURE

BIM and GIS technologies have been widely used for various construction applications and their successes have proven that integration of BIM and GIS has great potential to improve existing practices for road infrastructure management. Isikdag et al. (2008) discussed the possible data transmission of BIM into the geospatial environment. They also examined two cases of application: site selection and fire response management. Bansal (2011) applied GIS technology coupled with 4D modeling to establish space planning. He identified spatial conflicts and resolved them by linking the work space with the execution schedule. Liu and Issa (2012) integrated BIM and GIS to properly implement facility management. They proposed a method for 3D visualization of the pipeline network to provide a clear impression of the underground conditions. Irizarry et al. (2013) integrated BIM and GIS to improve the process of construction supply chain management. Using the BIM/GIS system, they tracked the status of the supply chain by visualizing the flow of material and availability of resources.

While the 3D modeling technique coupled with GIS has brought improved design and engineering processes to construction industries, application of the BIM/GIS system to preliminary feasibility studies continues to be rare. The primary objective of our research was to develop a BIM/GIS-based system for the project cost estimation of national road, and to assure that it would be applicable in the preliminary feasibility stage.

DEVELOPMENT OF A BIM/GIS SYSTEM FOR BEST ROUTE SELECTION

System description. The project cost estimation system was developed on the commercial program *RD* (Pyeong Hwa Data System, Co. Ltd.) which was operated on the AutoCAD platform. The system was primarily composed of two systems and three modules, as shown in Figure 1. When the user-defined GIS information and associated data were inputted into the CAD system, the subsequent outputs regarding bridge and tunnel properties, earth work quantities, lot numbers, land boundary lines, and images could be used as inputs for the Web system. The Web system then estimated the total project cost for each alternative and provided 2D floor and cross section images for the project. Detailed procedures for the estimation and image generation are discussed in the following sections.

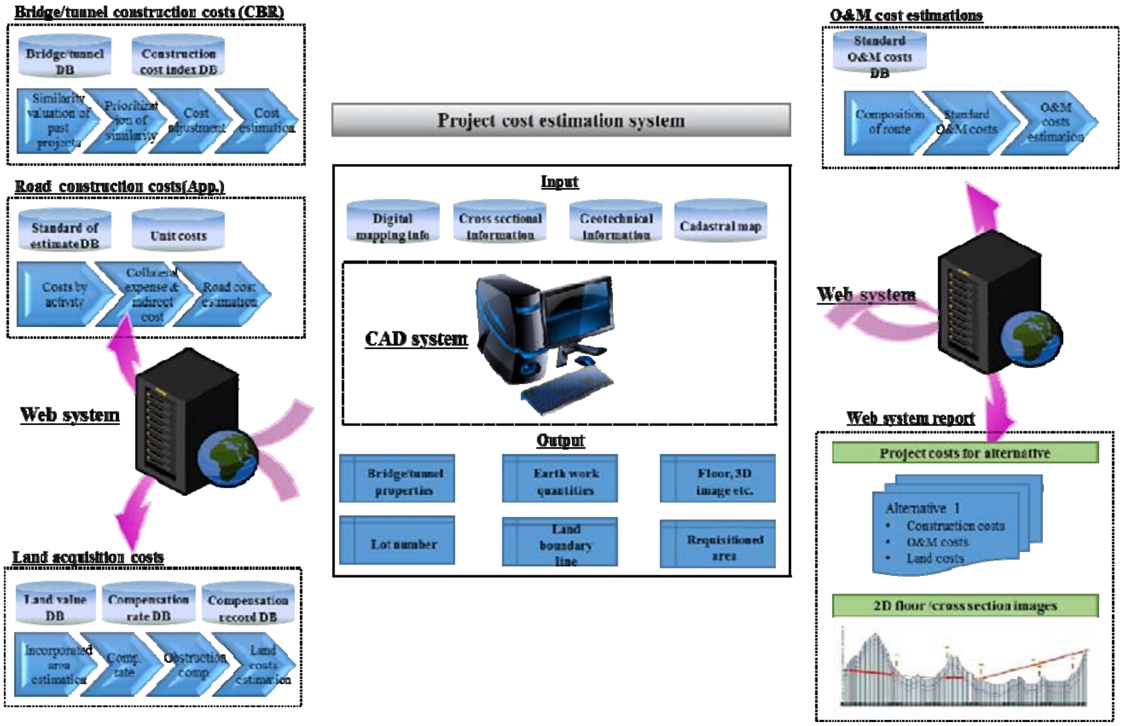

Figure 1. BIM/GIS-based project cost estimation system (Prototype).

Construction cost estimation module. Construction costs include the costs for constructing the road and associated structures (bridges and tunnels), and their collateral expenses. After a new project is registered, the user defines origin, destination and station points on a digital map. Based on these points, a CAD system uses an optimization algorithm to determine road, bridge, and tunnel sections. The user must then specify their types and designs, and the CAD system consequently estimates earthwork quantities as well as the widths and lengths of structures. These are delivered to the Web system where total project costs for the route are estimated. In this regard, road construction costs are calculated by multiplying the unit costs of the activities and quantity information, and collateral expenses are estimated based on the percentage of total road construction cost as specified in the regulation by the Ministry of Trade, Industry & Energy (MOTIE, 2012). On the other hand, the construction costs and collateral expenses for bridges and tunnels are estimated using case-based reasoning approach for the previous projects. These procedures are illustrated in Fig 2.

Land acquisition cost estimation module. Algorithms for estimating land acquisition costs are based on research by the Korea Development Institute (KDI, 2008). The costs are estimated based on officially announced average land values and the requisitioned land area. As shown in the procedure illustrated in Figure 3, when initial points are selected by the user, the CAD system designs the floor, cross section, and longitudinal section images. After the user registers the cadastral information into the system, it generates the right-of-way, calculates the requisitioned area, and finally, estimates the land acquisition cost.

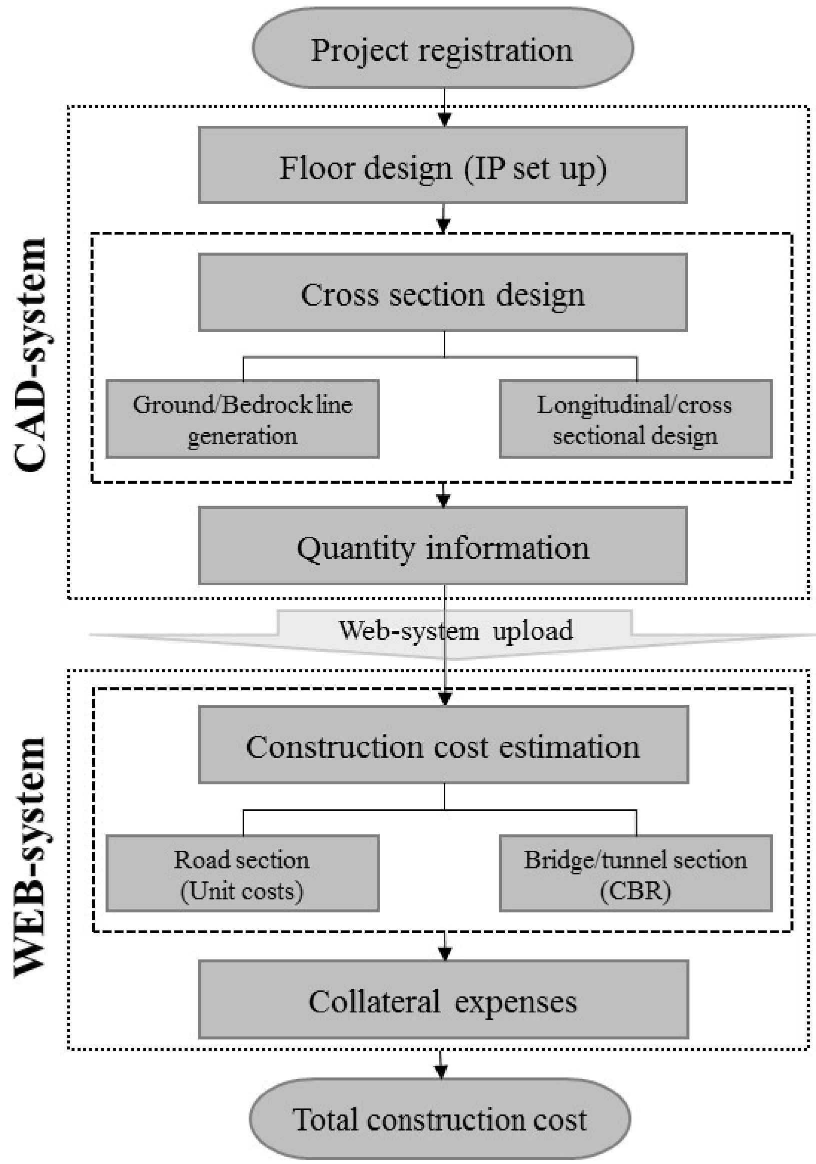

Figure 2. Construction cost estimation procedure.

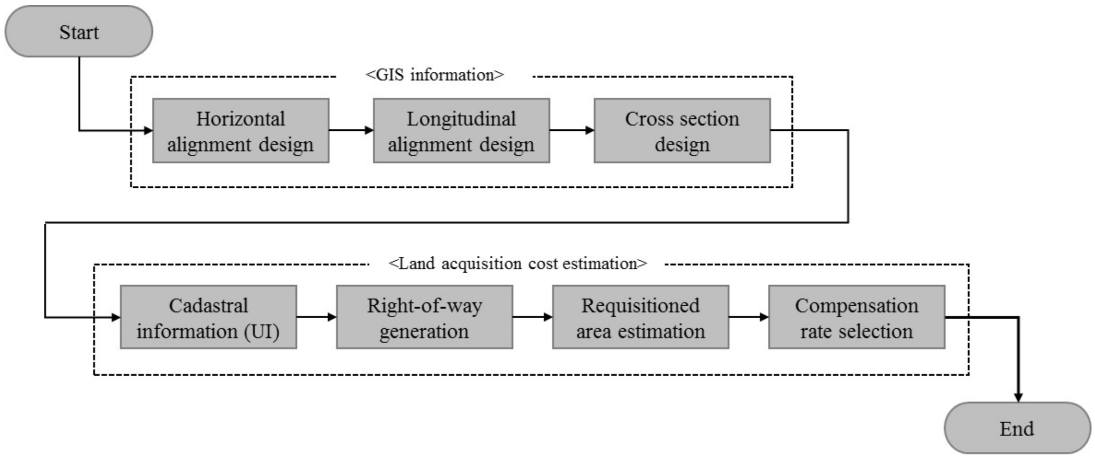

Figure 3. Procedures for estimating land acquisition costs.

Operation and maintenance cost estimation module. Previous studies showed that there was a huge gap between values predicted by regression analysis and actual O&M costs for road infrastructure, and that could be overcome by adopting the concept of a rehabilitation cycle (Korea Expressway Corporation, 2007; KDI, 2008). As a result, we assumed that the rehabilitation cycles for roads, bridges, and tunnels were 10 years, 10 years, and 15 years, respectively; these values were suggested by KDI (2009). To estimate the costs for each O&M item, we utilized five-year historical cost records of "Current state of the road O&M cost", provided by the Ministry of Land, Infrastructure and Transport (2008~2012). The estimated costs for a 4-lane national road are presented in Table 1.

Table 1. Estimated O&M costs for a 4-lane national road.

Structure	Category	Description	Period	Cost (Mil. Kwon/km/year)
Road	Repair	Surface treatment, patching, coating	Annual	6.5
	Resurfacing	Repaving	10 year	381.9
	Facility repair	Culvert, drainage	Annual	3.7
Bridge	Repair	Routine M&R	Annual	683.7
	Rehabilitation	Repaving, cable & anchor, etc.	10 year	1311.4
Tunnel	Repair	Routine M&R	Annual	261.5
	Rehabilitation	Repaving, ventilation	15 year	1363.4
General	Other repair	Security, road signs, lane paint	Annual	6.8
	Emergency repair	Emergency repair	Annual	3.4
	Operation costs	Labor	Annual	7.0

3D visualizations and reports. One of the important features of the system is that it can provide 3D visualizations of the road, bridges, and tunnels. The 3D modeling engine enables the user to identify components of the route including the banking and cutting parts of earthwork, bridge sections, and tunnel sections. A clear visualization lends to an understanding of the overall plan of the project. Figure 4 shows several 3D visualizations provided by the system. Each product is linked to quantity information. For example, the earthwork image is linked to the cutting, banking, and moving amounts that were automatically estimated by the system, and the bridge section image is linked to design specifications of that bridge. This information is uploaded to the Web system and contributed to the estimation of the total project cost.

The system also provides project reports that detail the design information, floor image information (Intersection point, and x- and y- coordinates), longitudinal image information (ground height and slope), structural specifications (type, length, and width), earthwork (banking, cutting, and moving), land acquisition costs (locational category, classification, lot number, and comp. rate), O&M costs (itemized lists of O&M, cycles, and unit costs), and total projects costs. Consequently, this option enables the stakeholders to compare alternatives and further to select the best route more easily.

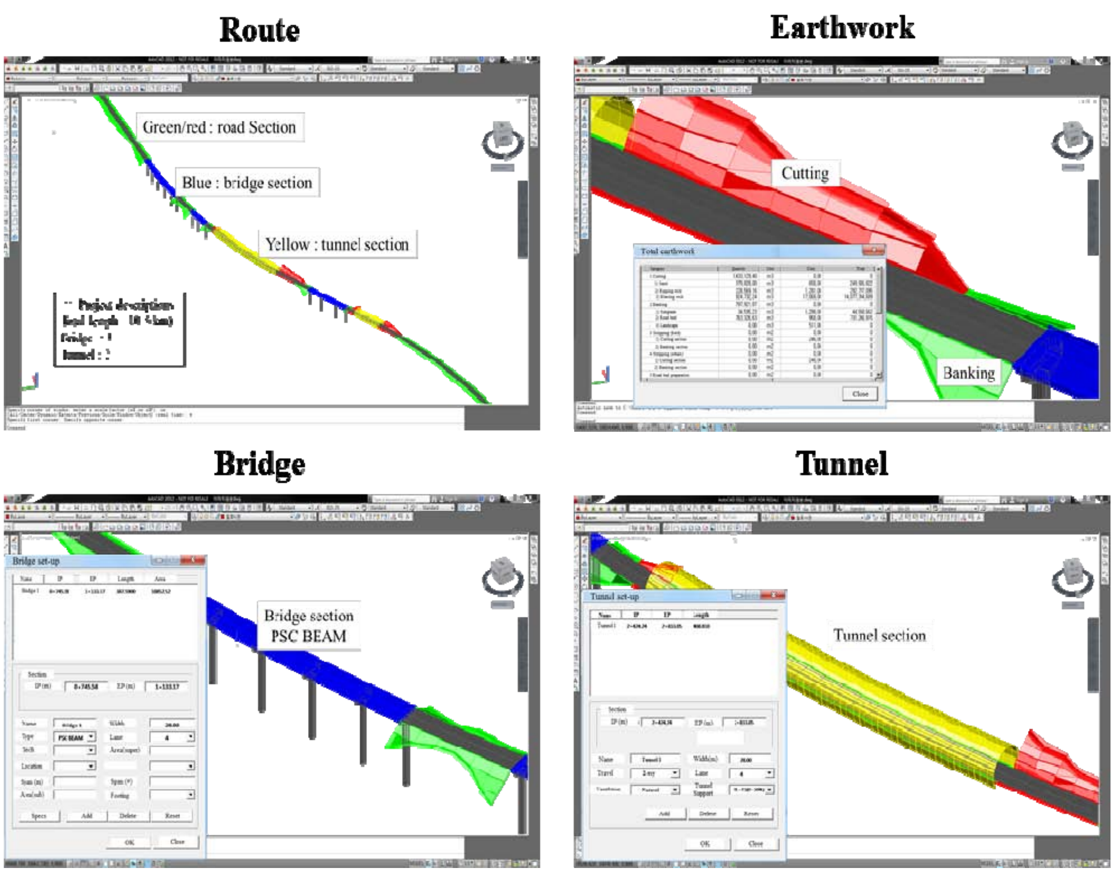

Figure 4. 3D visualization of the project.

CONCLUSION

Recent integration of BIM and GIS represents an unprecedented opportunity for construction stakeholders to manage an infrastructure project with improved design and engineering processes. This study developed a BIM/GIS-based system for project cost estimation of a national road, which can be applicable in the preliminary feasibility stage. A feasibility study using the proposed system has several advantages over a conventional feasibility study. First, the proposed system has flexibility which can enable the user to easily change the route upon a policy change in the national road network. Second, 3D visualization linked with associated information provides the user with a better understanding of the project. Third, the estimated project cost is consistent regardless of the user. Overall, the proposed system reduces the time, and resources used in the engineering process, and further provides an improved environment for selecting the best route.

ACKNOWLEDGMENT

This research was supported by “BIM/GIS Platform based Construction Project Management Technology.” The authors appreciate Korea Institute of Construction Technology for supporting the research fund.

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