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INTEGRATED CONSTRUCTION PROJECT PLANNING USING 3D INFORMATION MODELS

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ABSTRACT: Although the evolution and deployment of information technologies will undoubtedly play an important role in the current construction industry, many engineers are still unsure of the economic value of using these technologies. Especially for the planning of a construction project, a collaboration system to utilize the whole resources is a essential tool for the successful outcome. A detailed, authoritative, and readily accessible information model is needed to enable engineers to make cost-effective decisions among established and innovative plan alternatives. Most engineers rely on limited private experiences when they create solutions or design alternatives. Initial planning is crucial for the success of the construction project. Most construction projects are done through collaboration of engineers who have different specialized knowledge. Information technologies can dramatically enhance the performance of the collaboration. For the information delivery, we need a mediator between engineers. Object-based 3-D models are useful for the communication and decision assistance for the intelligent project design. In this paper, basic guidelines for the 3-D design according to different construction processes are suggested. Adequate interoperability of 3-D objects from any CAD system is essential for the collaboration. Basic architectures of geometry models and their information layer were established to enable interoperability for design checks, estimation and simulation. A typical international project for roadway was chosen for the pilot project. 3-D GIS model was created and bridge information models were created considering several requirements for planning and decision making of the project. From the pilot test, the integrated construction project planning using 3-D information models was discussed and several guidelines were suggested.

Keywords: collaboration; information delivery; object-based 3-D model; interoperability;, GIS model; bridge information model

1. INTRODUCTION

3-dimensional Information Modelling such as BrIM (bridge information model) is an emerging technological and procedural shift within the construction engineering. Construction industry has relied on 2D drawings on paper as the primary representation of construction documentation for centuries. Recently the AEC (architectural, engineering and construction) industry has made a rapid shift from 2D drawings to 3D information modeling, for example Building Information Model (BIM). Manufacturing industry has already documented and projected reduced costs, faster delivery, and improved quality as a result of implementing 3D CAD based integrated design and manufacturing processes along with accompanying interoperability standards [1-6].

In the planning stage of an international construction project, decision makers for each sector in a general contractor want to have enough information for the assessment of project risk. A detailed, authoritative, and readily accessible information model is also needed to enable engineers to make cost-effective decisions among established and innovative design alternatives. Most engineers rely on limited private experiences when they create solutions or design alternatives. Initial planning and previous risk treatment are crucial for the success of the construction project.

Due to the size and complexity of the project, a contractor wants to utilize their previous experience and facilities as much as possible for the aspect of risk and cost minimization. Before the stage of initial suggestion of design alternatives for a project, all participants in the project planning need to share the basic information of the target construction object. Essential information ranges from local political and social environments to the various trades and resources in the area of the project. 3D visualization of the construction site is useful tool to understand geological characteristics of the project. Information delivery between different sectors can increase the project cost and risk [7-8].

3D information models for civil engineering except plant construction are at the beginning stage for some specific processes [9-12]. Especially, bridge construction using modular, complicated members requires these new tools for collaboration and reuse of previous experiences. Digital mock-up including 3D shop drawings showed excellent advantages for owners, contractors and designers [10-11].

In this paper, the 3D information models including bridge models and GIS models are applied to the planning stage of an international roadway construction project. Current processes of the planning in a general contractor for the international project were investigated and To-be model using new technologies was proposed. The concept of construction project lifecycle management was suggested to enhance the whole processes of the construction project. Existing data for the project was used to build 3D information models for planning and decision makers evaluated the usage of the models. Especially, bridge information models were focused on for the collaborated decision of the best choice.

2. USER CASE STUDY

2.1 Initial Planning Stage for International Projects

Effective and detailed planning of large-scale, complex construction projects is of great importance to fulfilling project cost and time objectives. Recently, the level of risk exposure is gradually expanding and the bid competition also becomes more highly intensive. The most of the key input data for the decision making process was constructed from subjective opinions or relative ratings surveyed by the experts' individual responses. Data such as level of experience, financial capability, technical capability, and potential profitability are likely to be elicited differently and easily biased based on their personal background and perceptions to the specific level of risk exposures [13-14].

Current process of the initial planning stage in a Korean global contractor was investigated by interview of participants. From the interview, input and resources for each sector to produce output were surveyed and information delivery between different sectors was carefully investigated. Two international projects of roadway were chosen for the sample cases before the decision of participation of final bidding. The sea link project has 3.85km length and should be finished in 36 months. Because the contractor has a previous experience of similar bridge construction with rapid construction methods, they decided to consider the project bidding. Because of the large scale, decision makers want data as much as possible by sharing knowledge of participants of the planning stage.

As shown in Fig. 1, most processes are based on documents with 2D drawings and individual knowledge based on experiences. The collected information is simply lost because of the nature, of the handoffs between phases. There is a big drop-off as that information becomes extracted and handed off. Target structures are not clear for participants because of different individual background. It is difficult to have close collaboration for the decision by current document based process. Sharing the same target object and individual knowledge is crucial for the successful bidding and even for the actual construction. Accumulated information need to be stored in the company for next project bidding because a contractor has strategy of construction market for some region.

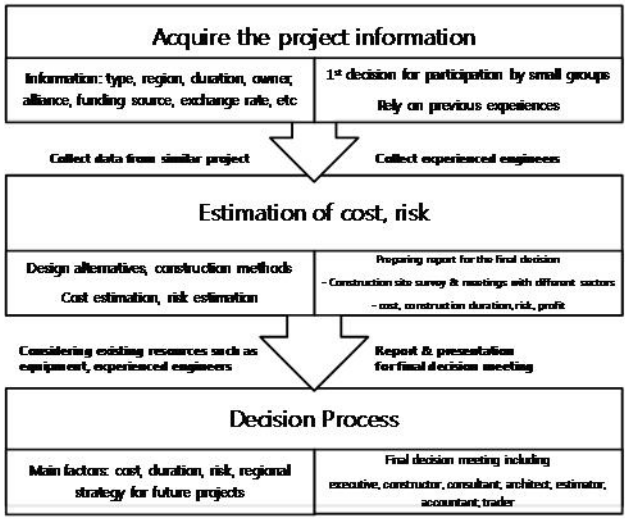


Fig. 1 As-is process of decision making

When the first basic information of the project was provided, 3D information models were decided to use for the visualization of target structures and GIS data. Simultaneously, A To-Be model for the international project planning was proposed and initial version of 3D information models were utilized not only for the meeting but also for the accumulation of data. Design and construction method alternatives were also considered by modifying the 3D models. Especially, estimation process closely linked with 3D model was developed for the fast cost estimation for different alternatives.

2.2 To-Be Model

Through the interview for the participants in the project planning, the most frequent request for the information model was the objects for the information sharing and evolutional process of the objects. A project management system in a company is commonly used to identify roles and schedule of each participant. Therefore, the mail role of the 3D information models is to replace the document based process and to integrate the whole resources for the better plan. As shown in Fig. 2, the 3D models have to be added and changed according to the accumulated and decided information for the bidding plan. When there are revisions of 3D models with new decisions from a sector, the revised models are delivered to the participants by a project management system.

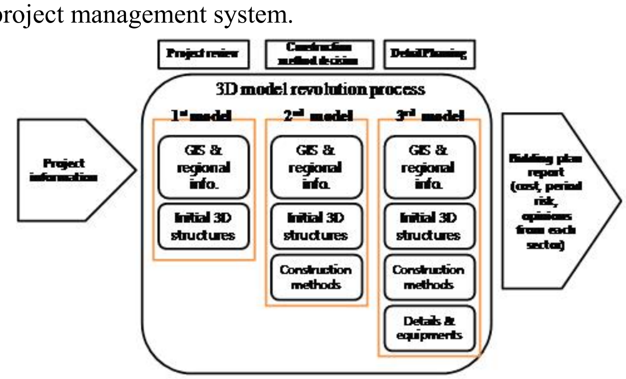


Fig. 2 To-be model of decision making

In the project review stage, engineers need information on where(geographical features), what(target structures), when(construction period) and cost and have to create the construction methods, how. Appropriate review process is very important for successful bidding and construction.

For the initial application of 3D objects to practices, a basic training to deal with 3D programs was done and supporting engineers are provided for the revision of 3D models and information. Decision makers are allowed to check the process and to add their opinions in the system at any time.

2.3 ICT for Collaboration

Information and communication technologies for collaboration are essential in recent construction project planning. For example, 3D GIS such as the google earth provides important information on geographical features for the planning. Without visiting the site, many participants can obtain regional information and the information can be accumulated in the 3D GIS model. Because of the large scale, several technologies such as an image pyramid method and tiled level of detail method are needed to enhance the data process as shown in Fig. 3.

Shared 3D objects can be effectively utilized in the collaboration software as presented in Fig. 4. A multi-user telepresence program enables participants to show their suggestion on 3D models and to invite opinion from the other professionals. Especially, regional characteristics should be shared between engineers to understand non-engineering risks for their proposal.

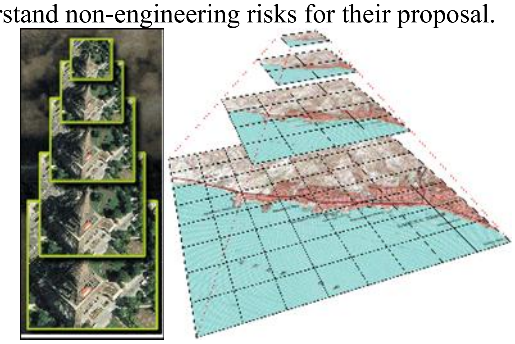


Fig. 3 Image Pyramid and Tiled LOD

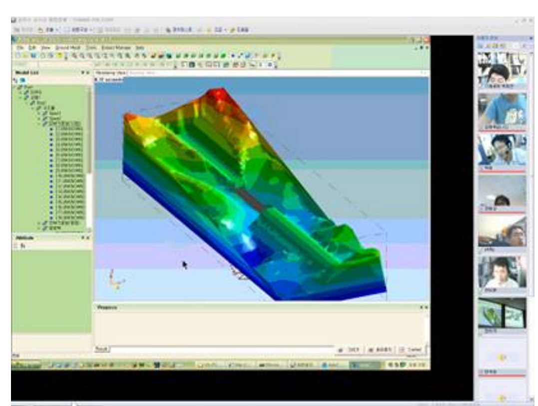


Fig. 4 Collaboration software

3. CONSTRUCTION PROJECT LIFECYLE MANAGEMENT

The international Alliance for Interoperability (IAI) developed the Industry Foundation Classes (IFC) standard for the sharing or information within the engineering, architecture, construction and facility management disciplines. The specification is designed to consider the entire project life cycle. Based on the similar concept, a construction project life-cycle management system was proposed from a research group to develop a virtual construction system [9].

The research focuses on developing the CPLM system for managing construction project data, and the decision support system that makes the collaboration among the project participants based on 3D technologies and information. The system covers the pre-planning, the structural engineering, MEP, and the 3D based estimation system. It also focuses on developing a simulation system for the construction process planning and feasibility study with help of the virtual reality technologies. However, there are many obstacles to realize and to apply this system for the practices.

This paper deals with the planning stage including 3D based estimation and decision support. The models at the first stage will be refined during design, construction stage in terms of geometry and information as shown in Fig.5. Most of the CAD engines allow several ways to export the model for other solutions. However, it is still difficult to transfer information architecture with its geometry from one CAD engine to the other CAD engines. In this pilot application, a CAD engine and its related solutions were used. Metadata for objects were added to the geometry models directly but other information on the model was attached by various file formats.

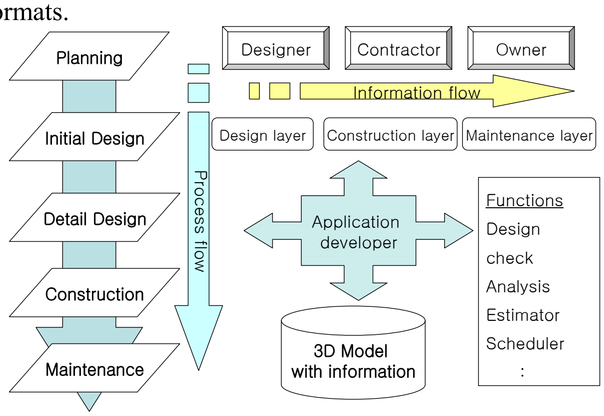


Fig. 5 Information and Process Flow for CPLM

4. APPLICATIONS

4.1 Project Outline

Two sealink projects were selected as pilot applications of 3D information models. As shown in Fig. 6, the 3.8km roadway of 8 lanes consists of concrete bridges of PSM, PC Beam and FCM. Near the site, there is another project of 20km sealink roadway. Bridges of PSC precast box-girders using PSM, FCM method and of cable-supported bridges.

The main reason why the contractor decided to participate the bidding was the previous successful experience on bridge construction in a short period. The contractor has their own technologies for fast and economic bridge construction. Initial design of the projects was already given. Non-engineering information for the bidding was collected through their regional office near the construction site.

Section		Number of the segment	Length (m)	Width (m)	Method (super/sub/foundation)	Reference
MAILINE BRIDGE		144	7.160	15.5	F/C erection / Pile Bent /RCD	
Worli Connector	Marine section	46	2.226	10.0	F/C erection / Pile Cap /RCD	
	Land section	26	1.140	10.0	Erection truss / Pile Cap /RCD	
Haji Ali Connector	Marine section	43	2.087	10.0	F/C erection / Pile Cap /RCD	4l ines : 455m
	Land section	40	1.970	10.0	Erection truss / Pile Cap /RCD	4l ines : 90m
Toll Plaza		-	450	60.0	Erection truss / Pile Cap /RCD	
Total	299	299	15.033			

Fig. 6 Project-I outline

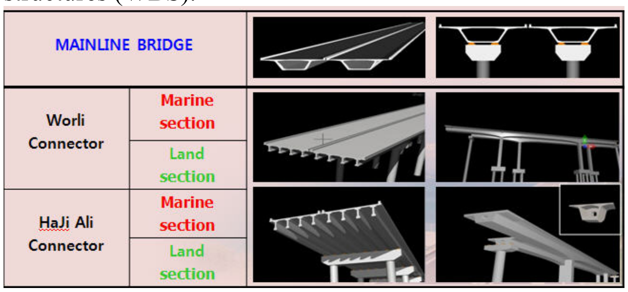
4.2 3D Information Model

Due to the large scale of the project, 3D models including GIS model need to be simple excluding details of reinforcements and prestressing tendons. Previous examples on concrete box-girder bridges were reused for the initial version of 3D information models. Parametric modeling technique is very effective to revise the 3D model [15].

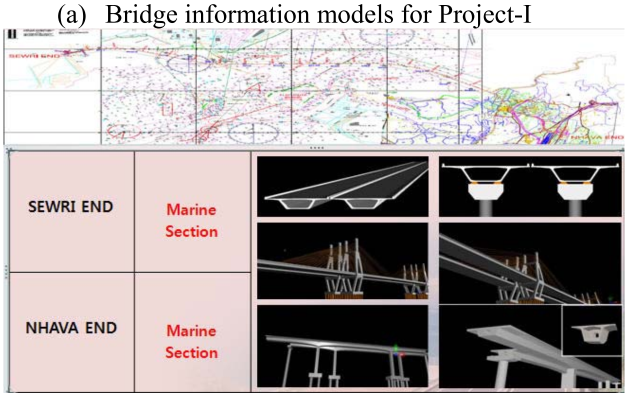
Basic digital maps for the design check of the provided conceptual design were converted to 3D GIS model. Existing infrastructures with geographic features of the site were visualized by an imported Google Earth map as shown in Fig.7. The map did important role to make participants understand the regional characteristics without visiting the site. More detailed information for the proposal was obtained through the local office of the contractor. Photos and documents were linked with the map.

Fig. 7 GIS model with existing infrastructures

Accurate estimation of the project is crucial for the bidding. According to the initial design, accurate volume of materials was calculated by 3D bridge models. The model does not have details but previous similar examples performed by the contractor provided relative steel ratio to volume of concrete. As shown in Fig. 8, 3D bridge information models for the two projects were built by Microstation. To make sure the reuse of the 3D models, the information models are constructed based on the customized information architecture and requirements. Product breakdown structures (PBS) are normally used for the architecture of the geometry model. Work process is considered in the building of work breakdown structures (WBS).



(a) Bridge information models for Project-I



(a) Bridge information models for Project-II

Fig. 8 Bridge information models for the planning

4.3 3D Bridge Information Model on 3D GIS Model

The 3D models for bridges structures were combined with the 3D GIS model by using adjusting coordinate system between two models as shown in Fig. 9. All the specific entities need to be placed relative to the road axis along the reference line for the section definitions at each point.

After building full 3D models for the planning, alternatives for construction methods, fabrication factory site, delivery route and traffic control were discussed. Digital documents including 3D models such as pdf files were provided for all participants. The documents allow active control of 3D models. This new way of information delivery received excellent response from the engineers.

Fig. 9 Combined 3D models

5. ENHANCED DECISION MAKING PROCESS

Due to limited time and resource for the project planning, concurrent engineering between different parts in a project is essential. Decision makers need fast feedback of their idea from different parts to derive better strategy. The most important constraints of the projects were construction period and cost. The team for the proposal gathered ideas from experts in the company and from accompanied consulting engineers. Accepted ideas were directly delivered to 3D modelers and the revised model and its information were noticed to all participants.

Especially construction methods and equipments significantly influenced on the period and cost. The location of fabrication factory was also important decision for the effective construction. For cable-stayed bridges as shown in Fig. 10 need specialists to derive optimal construction method and its schedule. Therefore, the 3D models for the bridge were shared between participants who had to submit their idea.

Estimation process normally located at the end of the decision. Fast feedback for the revised suggestion is important. The CAD engine can provide the volume of each part or material when the 3D CAD model has metadata for the estimation. As shown in Fig. 11, the 3D models can export every data for the evaluation of the cost by text or Excel file format. Indirect cost was also evaluated using the exported data by an estimation program based on experienced real cost. The enhanced feedback process of the estimation could allow many alternatives to be considered in spite of time constraint. Additional outcome from the estimation process is the optimization of rebar fabrication to reduce the loss of reinforcements. Fig. 12 shows the process.

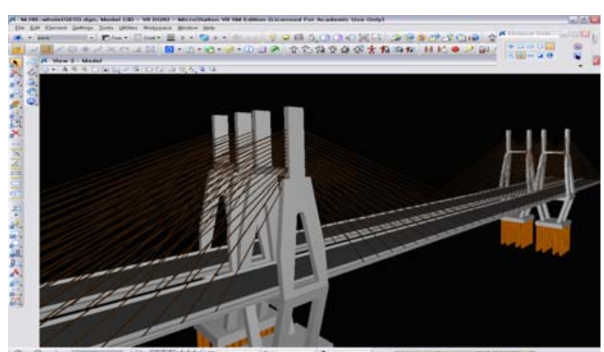


Fig. 10 3D information model for a cable-stayed bridge

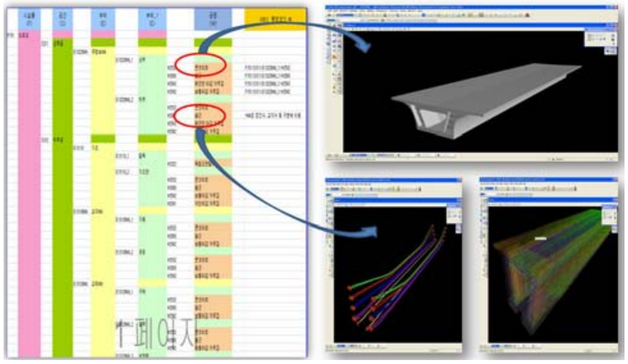


Fig. 11 Estimation linked with 3D detail model

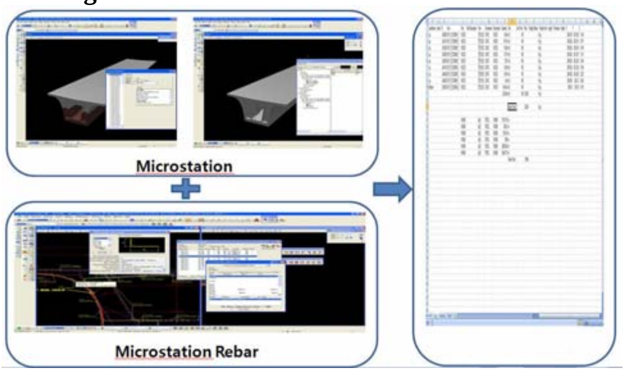


Fig. 12 Optimization of rebars

The 3D models can be built considering the construction schedule. Work breakdown structure (WBS) of each bridge construction was considered in the model to be used easily for 4D simulation as presented in Fig. 13. During the construction, this initial work can be reused for the construction management system such as 5D simulation.

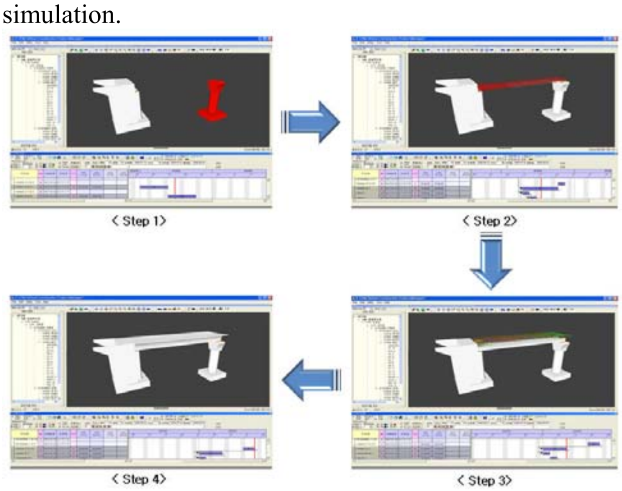


Fig. 13 4D Simulation

For the final decision of the proposal, a few alternatives were selected and digital documents including 3D models were constructed. As shown in Fig. 14, participants in the final meeting had the documents for the preparation of their opinion before the meeting. Interactive documents allow a user to open the linked information. In the meeting, the 3D models were also effectively used for the decision making.

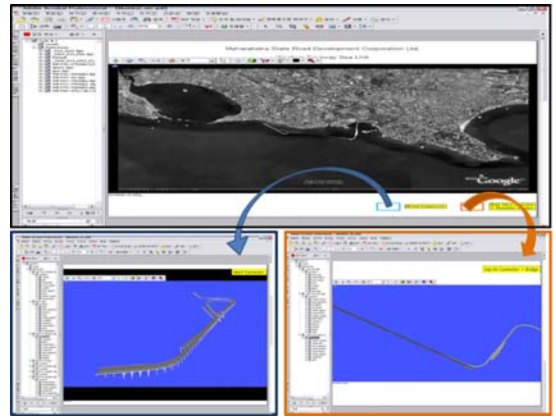


Fig. 14 Digital documents for decision making

After the pilot application of 3D information models for the planning of international projects, a brief survey was conducted on the advancement of the application. Most participants showed satisfaction of the new challenge using 3D models and training of the solutions for 3D models was an important concern across all experience levels. A 3D modeler needs to have not only drawing skill but also engineering experiences to build information for the model. Well-organized 3D models are crucial for the effectiveness of the whole process utilizing the 3D information model.

6. CONCLUSIONS

A new challenge in construction industry is the 3D information model. Even though the model seems to be excellent for the innovation of the current process, the actual application of 3D models to a practice needs significant effort to build well-organized models.

In this paper, two international projects were chosen for the pilot application of 3D information models. 3-D GIS model was also created and bridge information models were created considering several requirements for planning and decision making of the project. From the pilot test, the integrated construction project planning using 3-D information models can be a remarkable advance in construction industry. Most participants in the pilot application showed satisfaction and found a new challenge for the better environment of the big project bidding.

Training of engineers who are familiar with 2D drawings is the most important concern for further application. The 3D model needs to include several considerations for different processes in construction projects. Therefore, this pilot application can provide a good example for the planning stage and can be reused for the construction and management to build a construction project lifecycle management prototype of international projects.

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