Visualization of Numerical Information for Construction Project Management using BIM Objects

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***Abstract*— Construction projects are recently growing in size and a wide array of new construction techniques is being introduced, gradually increasing relevant project information. In most construction fields, however, project management operations are undertaken in a way that is heavily dependent upon the experience-based intuition of managers. For those reasons, 4D, 5D, and nD CAD systems are being applied to visualize construction progress information. Augmented Reality (AR) technique is also being an important factor for using Building Information Modeling (BIM) system for construction project. In addition, because the risk analysis information is provided as a mathematical analysis basis, the visualization system of construction risk information is being developed using the BIM tool. This study presents a various application cases of nD CAD objects for the construction project.**

Keywords-nD CAD object; simulation; building information modeling; project management.

I. INTRODUCTION

BIM (Building Information Modeling) based on 3-dimensional information models contribute most noticeably in the visualization of construction information throughout a lifecycle. The chief effects would be interference management at the design phase using 3D blueprint information and schedule management at the construction phase using 4D CAD. The visualization range has included cost and resource information to 4D objects to expand into 5D and 6D CAD systems. Fig. 1 represents a conference method transitioning from numerical information reliance to BIM-based visual information reliance.

The areas of improvement within construction using BIM can be divided into the technical (BIM function improvement) and policy-based aspects (BIM applicability improvement). This paper suggests a direction for function improvement, which requires a distinction between passive and active BIM systems.

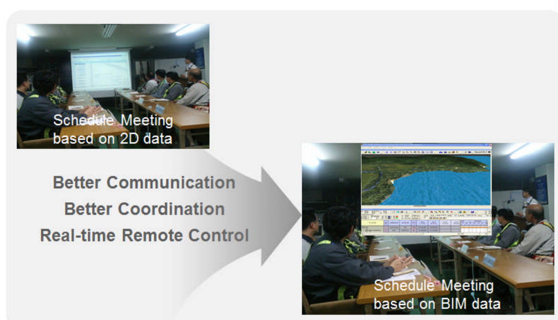

Figure 1. Using BIM to visually represent numerical construction information

Passive BIM that is the current BIM system is a tool that expresses the task situation visually. Active BIM goes one step further and contributes analysis that can help offer an optimized solution given task constraints. This paper uses a 4D CAD system, which is used mostly at the construction phase, to present an example of active BIM functions.

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Recently, there is much research for the visualization of construction information. Most of them are focused on building structures and plant project. Succar [4] suggests that BIM is an expansive knowledge domain within the Architecture, Engineering, Construction and Operations (AECO) industry. Zhang [5] developed an automated safety checking platform using BIM that informs construction engineers what safety measures are needed for preventing fall-related accidents before construction starts. For the risk information analysis, Carr and Tah [1] presented a hierarchical risk classification system as an official model for accurate risk evaluation and a prototype model for risk management system. Zeng et al. [2] proposed new risk analysis methodology based on the fuzzy theory to overcome the failure of conventional risk analysis methods to deal immediately with complex and diverse construction environments. These studies suggest mathematical interpretation-based analysis methods with limited practical applicability. Moon et al. [3] suggested a method to visualize construction risk information using BIM functions.

II. Construction Progress Management with Visual Information

For the 4D system to replace the existing construction management tools, a methodology to create and visualize 3D objects-based on plan versus actual progress is required. Such a progress management function is an essential part of schedule management visualization, and should be applied to 4D system. The system developed by this research team has both a general 4D implementation function and a 4D progress management function that allows analysis of progress state at each point. Fig. 2 expresses visual progress management distinguished by colors, shown in the 4D system.

The progress information visualized this way distinguishes delayed activities as well as activities ahead of schedule by different colors, making it possible for users to establish more advanced schedule management plans when compared to a schedule management tool based on numerical progress information. In Fig. 2, the actual progress versus plan is shown as ahead of schedule, delayed and normal operation, which are marked in colors blue, red and green, respectively. In other words, a methodology is introduced to distinguish ahead-of-schedule areas or delayed areas versus initial plan based on the progress rate calculated by schedule management module with each area shown in different colors, enabling visualization of the current progress state. This visualized progress areas can express detailed information such as ahead of schedule or delay in schedule with numerical information.

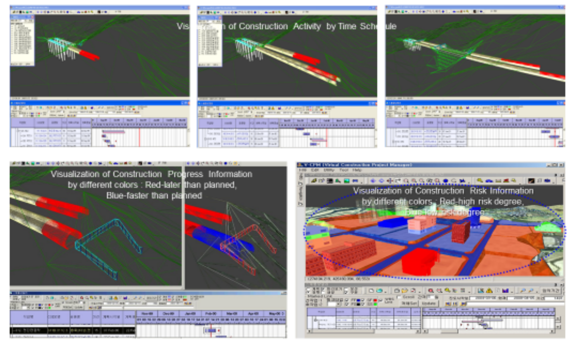

Figure 2. Application of BIM object for construction project

The progress status compared to planned progress is marked with green (ahead of plan), blue (normal progress compared to plan), and red (delayed compared to plan), to allow visual understanding of the overall progress status.

In particular, the progress information visualized this way lets users understand not only progress versus plan but also such specific items as scheduling information, location, and preceding and succeeding activities. Therefore it can be used as effective information when establishing revised plans for delayed activities.

III. 4D Application to Tunnel Construction Project

Of tunnel construction works, long tunnels often exceed 10km in length, and the case to which the system is applied to is a road tunnel construction site whose length is 10.965km long. Therefore, it is bound to limit intuitive management, unlike in the case of buildings, plants and bridge constructions, where users can see relevant structures on a screen. A function would allow management of tunnels by “section” in the process of actual construction, as in Fig. 3.

Figure 3. 4D process management function through “section” segmentation at a super long tunnel construction site

While it is possible to see a 3D model of the entire structure in one screen, it will be less efficient when compared to structures and bridge works which allow viewing of entire construction progress at one glance. For 4D process management of civil engineering structures involving a large or long site, effective division of functions into one that manages sections (manageable size) and another that manages the entire work as a whole is a key to enhancing the system's efficiency.

For this particular case, a function utilizing both measurement data and quality test data at a 3D model of the 4D system was developed and applied, in addition to the 4D process management function. Also, video image of CCTV was used in conjunction with 3D to implement the tele-presence functionality.

IV. 4D APPLICATION TO RIVER FACILITY CONSTRUCTION

River facility construction is extensive in nature, so application of a system that combines Google Earth's functionality with 4D for management may be of great use. In this case of application, a system that combines Google Earth with 4D system for management was developed and applied to an actual site (see Fig. 4).

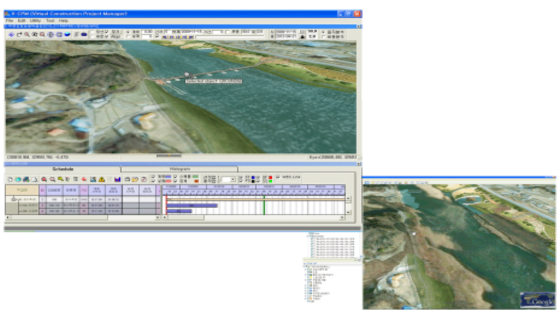

Figure 4. 4D application for river facility project

Fig. 5 shows the process of 4D simulation that includes temporary works that are assembled and dismantled afterwards (coffering works, etc. in this case). In other words, it describes the entire construction process that includes even temporary facilities that are built temporarily to help build permanent structures and then dismantled afterwards, rather than permanent works that are built consecutively and exist continuously.

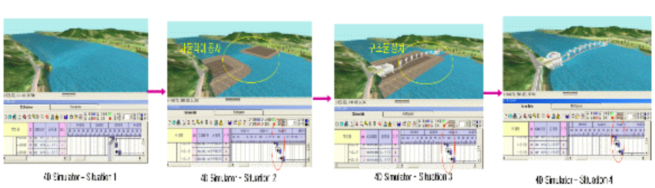

Figure 5. Simulation of girder structure installation process during river facility construction

In addition, in this case of river facility construction, 4D system was utilized as a way to visualize flood management. A system to visually predict and confirm flood levels based on anticipated precipitation was developed within a 4D system for application; such a technology can be utilized as a useful tool for disaster management during river facility construction projects (see Fig. 6).

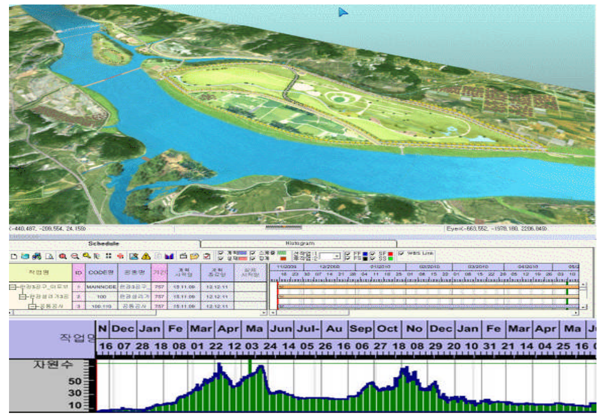

Figure 6. Prediction of flood levels using 4D CAD system

V. VISUALIZATION OF CONSTRUCTION RISK INFORMATION

The analytic hierarchy process (AHP) and fuzzy analysis can be used for the risk analysis of construction information, as described in Fig. 7. First, construction environment factors affecting risk criteria are analyzed and are selected as risk evaluation factors. For example, three risk factors - risk analysis on delay in the construction period (time), risk analysis on greater-than-planned construction budget (cost), and risk analysis on accidents during construction work (work condition)—are calculated in line with AHP analysis procedures. The results are provided for fuzzy analysis procedures to quantify risk criteria in accordance with evaluation factors. The quantitative analysis values of each risk factor are calculated on the basis of fuzzy procedures. For this purpose, linguistic variables are defined as very low (VL), low (L), moderate (M), high (H) and very high (VH). The analysis results of each risk criteria are thus suggested as risk level and comprehensive priorities.

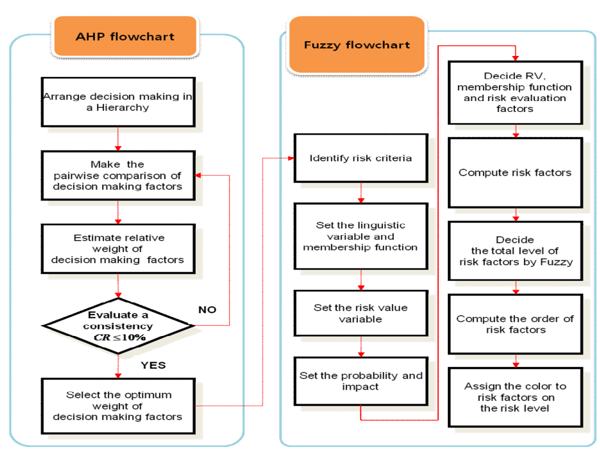

Figure 7. AHP and Fuzzy analysis Procedures

To visualize the process risk, a fuzzy method is used to link to the 4D object. The colors of each process are then changed depending on the level of risk, and the simulation is run for the 4D object. Project managers should be able to recognize which processes will have an especially high amount of risk, increasing their effectiveness. Fig. 8 shows an example of process risk simulation.

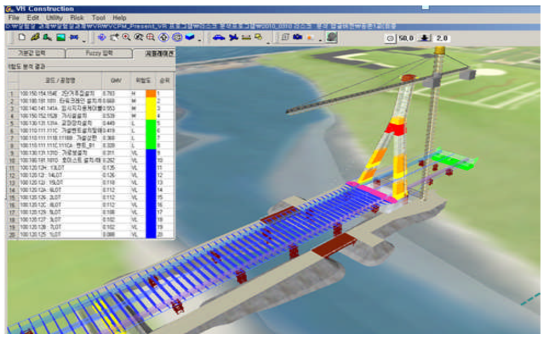

Figure 8. Active 4D CAD system(e.g., representing process risk levels)

The example used in Fig. 8 is a bridge construction project currently underway with 250 separate activities. For risk analysis, each task's possible risk of a safety accident was used as the basis, and further initial information was found through expert interviews and input into the system. Each process was given a probability P and an intensity I by the on-site experts. To objectify the subjective risk levels, a fuzzy analysis was used to set a priority order depending on risk, 5 levels were designated, and the 4D object was simulated. Representing tasks and processes with higher risks visually will allow high risk processes to be managed at a higher level of care by project managers.

VI. ENVIRONMENT IMPROVEMENT FOR BIM APPLICATION

Fig. 9 outlines the functions required to improve generation convenience in 3D and 4D objects. The first item required is a method to easily transform 2D objects into 3D objects. A possible method may be to create a library for important structure schedules to make schedule information composition of 4D objects a simpler process. The convertibility of 3D objects by parametric variables is also necessary.

In addition, the 3D objects that compose the design phase of construction are mostly single layer objects that are final products of separate complex processes. As a 4D object must be comprised of multiple objects with layers specified to the process level, a simple object disassembly function must be developed. Aside from these former improvements, creating a widely diverse library of 3D objects for vital structural parts is necessary.

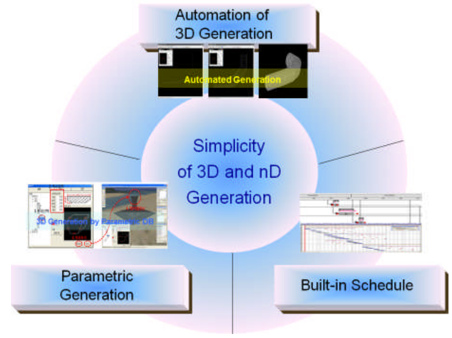

Figure 9. Establishing enhanced convenience in creating 3D and 4D objects

Fig. 10 presents the necessary functions for establishing compatibility with BIM objects including 3D objects. First, the comprehensive completion of IFC codes must advance for open BIM to be created, and developing IFC codes for civil engineering facilities must progress at a faster rate.

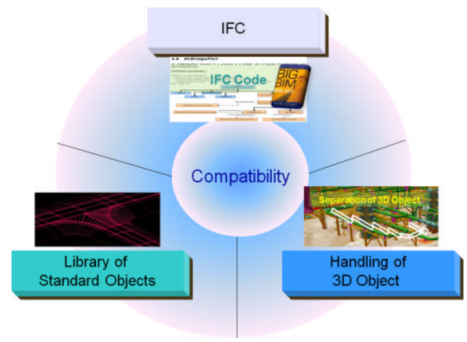

Figure 10. Establishing BIM object compatibility

Fig. 11 details the necessary diversification of specification of BIM tools and evaluation methods. For civil engineering work to move away from the established 2D-based management system to a BIM based system, application guidelines and regulations must be introduced. There is also a need for tools that can evaluate a specific BIM management system's applicability and select specific BIM systems based on the construction project's characteristic properties.

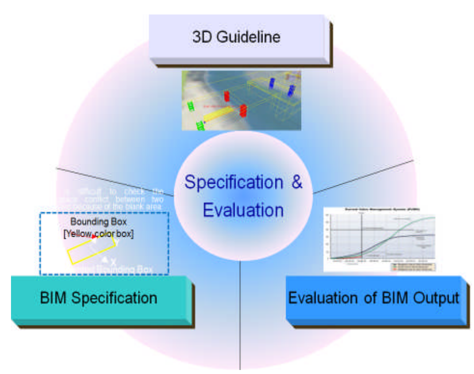

Figure 11. BIM operation system guidelines and product evaluation

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VII. CONCLUSION

This research presented a BIM operating process for the construction phase that can raise the usefulness of BIM on civil construction projects. The proposed BIM operating process enables integrated management of construction data through analysis of progress, sequencing errors and risks. Also as the system uses visual representation of complex and numerical information, it can be expected that the system will be actively used as an effective decision making tool.

To validate the system's applicability in real situations, a case study was carried out using bridge, tunnel and railway projects. Because the BIM functions can be used for visualizing the most information through the construction life-cycle, the application of information technology and computer science tools will be gradually increased for the construction project management.

ACKNOWLEDGMENT

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