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BIM Application and Construction Schedule Simulation for the Horizontal Work Area

Hyeon-Seong Kim, Sang-Mi Park, Seul-Gi Kim, Seon-Ju Han, Leen-Seok Kang

***Abstract*—**The use of BIM, including 4D CAD system, in a construction project is gradually increasing. Since the building construction works repeatedly in the vertical space, it is relatively easy to confirm the interference effect when applying the BIM, but the interference effect for the civil engineering project is relatively small because the civil works perform non-repetitive processes in the horizontal space. For this reason, it is desirable to apply BIM to the construction phase when applying BIM to the civil engineering project, and the most active BIM tool applied to the construction phase is the 4D CAD function for the schedule management. This paper proposes the application procedure of BIM by the construction phase of civil engineering project and a linear 4D CAD construction methodology suitable for the civil engineering project in which linear work is performed.

***Keywords*—**BIM, 4D CAD, Horizontal work area, Linear simulation, VR.

I. Introduction

As construction projects grow in scale and complexity, and new construction methods and techniques are adopted, the quantity of data generated at each of the construction phases is becoming greater [1]. As such, practicality of using VR (Virtual Reality) and BIM (Building Information Modeling) based on three-dimensional design is expanding for the construction project. In recent years, there have been cases in which the application of BIM is mandatory in the case of building project by country and it is anticipated that 4D CAD will be applied to the actual field of the civil engineering project. However, use of BIM and 4D CAD in civil engineering project is relatively low compared to building works, which has led to insufficient application of BIM in real projects [2]. Many studies [3]-[6] on 4D CAD have been published, but most of them are 4D CAD application case studies focusing on building construction. This research proposes a practical operating process for BIM and 4D CAD with high practical applicability for civil engineering projects. Railway construction project consists of horizontal work area comparing with building project. It is difficult to simulate 4D object using existing systems [8]-[13] because they are focused on the interference management and 4D simulation for the building project which consists of vertical activities [7]. This paper suggests a function for simulating 4D CAD object of activities with linear type.

Hyeon-Seong Kim is with the Dept. of civil engineering, University of Michigan, USA (e-mail: wjdchs2003@gmail.com)

Sang-Mi Park and Seon-Ju Han are with the Graduate school, Dept. of civil engineering, Gyeong-Sang National University, Jinju, Korea (phone: 055-753-1713; fax: 055-753-1713; e-mail: gogf8585@naver.com, ioccom007@ naver.com).

Seul-Gi Kim is with the Graduate school, Dept. of civil engineering, Gyeong-Sang National University, Jinju, Korea (phone: 055-753-1713; fax: 055-753-1713).

Leen-Seok Kang, Professor, Dept. of civil engineering, ERI, Gyeong-Sang National University, Jinju, Korea (corresponding author, phone: 055-753-1713; fax: 055-753-1713; e-mail:lskang@gnu.ac.kr).

II. Composition of VR Operating Process in the Construction Phase

A. VR Operating Process

The goal during the construction phase is to reduce schedule, minimize cost and ensure construction quality through improved constructability and mitigation of abortive work. To achieve this, integrated management of construction phase information is required. However, there are further challenges against collection and sharing of construction data as projects have become larger and more complex, with greater work scope and increased need for collaboration between stakeholders including clients, designers, builders and subcontractors. In most BIM functions, including 4D CAD, the implementation of the output is represented by a VR object. In recent years, the use of AR (Augmented Reality) objects has increased in construction sites, and BIM has AR functions that can be simulated, and this trend is expected to further increase. As such, this research aims to propose an operating process for construction VR for collection and sharing of construction data during the construction phase. This process reviews the project information and designs, and on that basis establishes a construction plan that can enhance work efficiency through identification of information such as work sequencing errors, planned vs. actual progress and construction risks using 3D visual simulation applied to existing business workflows. In particular, this process allows for data extraction by sequence for expedited identification of and response to issues analyzed.

B. Operating Process by BIM Function during the Construction Phase

The functional operating processes were designed as shown in Fig. 2 for work sequence error analysis, construction risk analysis and progress monitoring and management. The work sequence review simulation can demonstrate hundreds of activities and their predecessor/successor relationships to visually identify errors in work sequencing. The module first generates a WBS (work breakdown structure), 3D model and schedule based on the project design, and integrates them around the WBS.

For 4D CAD simulation, 3D model and construction schedule are linked based on WBS code, so interworking between objects becomes convenient. Predecessor and successor relationships by process can be determined using

WBS code. By identifying the sequencing errors in advance and re-adjusting the predecessor and successor activities for each process accordingly, the process can prevent abortive works.

The progress simulation module allows effective progress management by visually simulating the difference between planned and actual completion over a large site area. Progress of each activity was calculated using the start date, end date and the required resource quantities. First, actual progress was calculated with the schedule module using the planned dates and actual resources spent. The calculated progress was categorized into normal, delayed and ahead vs. planned, and these results were linked to 3D models and displayed in blue, red and green to represent the progress status visually.

III. Case Study of BIM Simulation System

Based on the BIM operating process proposed above, a prototype BIM operating system is built. This system was applied on an actual bridge construction project to verify its usability in the field. First, the prototype generated the WBS, 3D model and schedule of the sample project. These were integrated and the functionalities developed through this research were applied as shown in Fig. 3. Fig. 3 shows a work sequence simulation visually for the construction sequences. Especially by linking the sequences with schedule, sequencing errors can be identified. Also, as the 3D model and the schedule are linked through the WBS, project manager can identify sequencing errors effectively.

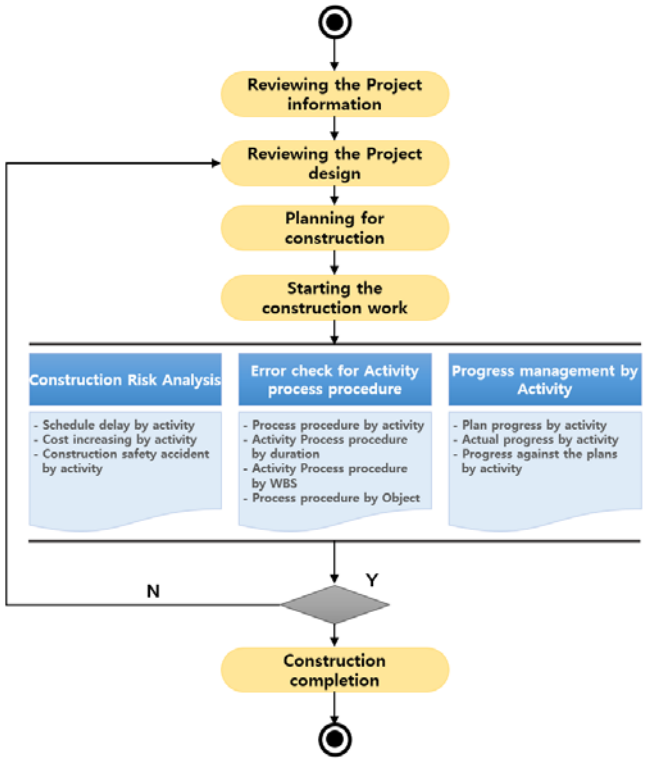

Fig. 1 BIM operating process during the construction phase

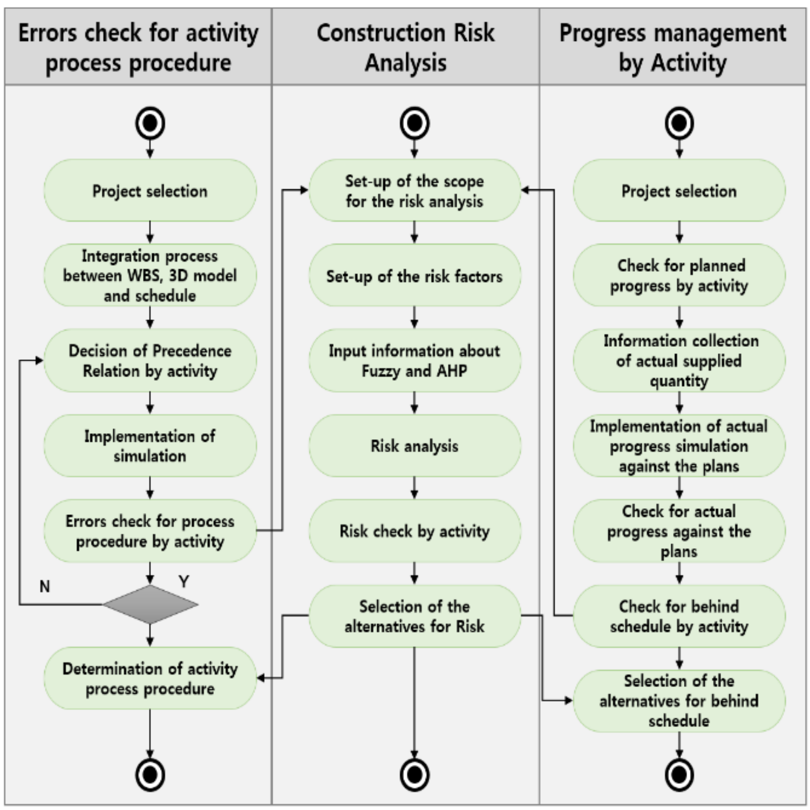

Fig. 2 BIM operating process by BIM function during the construction phase

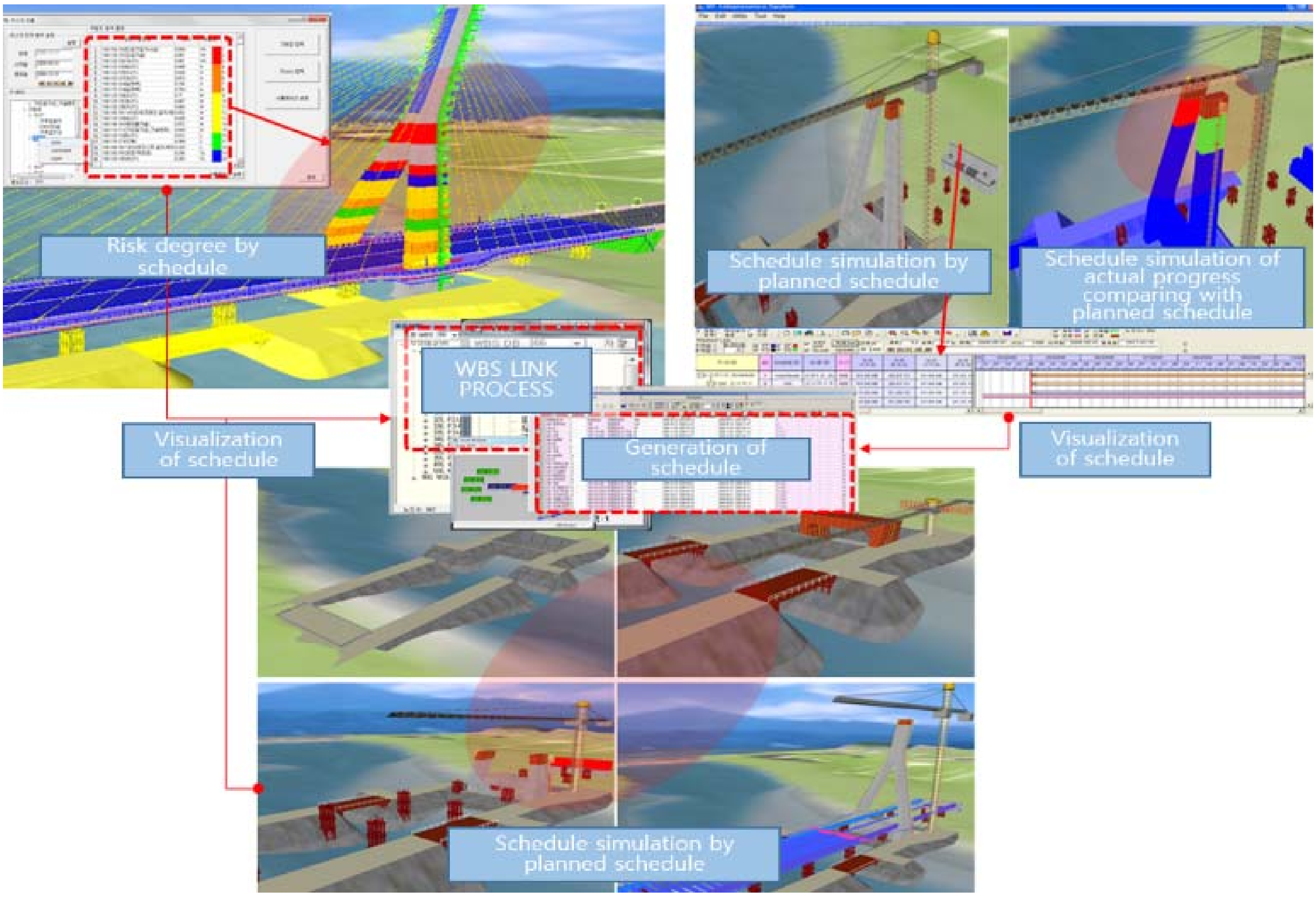

Fig. 3 Construction schedule simulation

The risk analysis module displays the results of analysis in color by priority using Fuzzy method. As seen in Fig. 3, the bridge tower is displayed red and is easily identified as the activity with the highest risk. Also by running the progress simulation using the actual resource spent by each activity, project manager get a planned vs. actual progress simulation as shown on top of Fig. 3. Through this, plans for each activity in accordance with the schedule and actual progress can be shown. Especially since the status of planned vs. actual progress is displayed in blue, red and green, the left side of the main tower has been delayed and the right side ahead of schedule.

IV. 4D CAD System for Horizontal Work Area

A. 3D Modeling of Earthwork

The existing 4D CAD researches [2]-[7] mainly consisted of the methodologies and system development for 4D simulation of the building work which is mainly carried out by vertical space, but the researches on the 4D simulation of the wide horizontal area for civil engineering work and the system development status are insufficient. For this reason, the field application of 4D CAD is actively applied mainly in building work. This is because it is easy to express repetitive activities within a limited range of vertical space due to characteristics of the construction work. On the other hand, since civil engineering projects are linearly progressing in horizontal space and non-repetitive processes including large-scale earthwork site, the utilization of existing 4D CAD system is deteriorated due to spatial wideness. Therefore, a 4D CAD system with specific functions for civil engineering works is necessary to express linear conditions of work and natural terrain conditions such as earthwork, and it must be expressed visually in relation to the construction schedule. Fig. 4 shows the earthwork modeling form that expresses from the representation of natural terrain to the cut and embankment work area through the geomorphic triangulation process.

B. Simulation of Earthwork with a Horizontal Work Area

In a construction project with horizontal work space such as road, railway, etc., there are many activities in which a plurality of activities is progressed in a complex type. In addition, since it is necessary to adjust manpower and equipment to be input depending on the surrounding environment due to external work, an appropriate schedule control method is required. However, existing 4D CAD systems have high efficiency for schedule control in repetitive process and limited work space, but it is difficult to be used in linear type project where process extension is more than several tens of KM, such as railway and road project including large amount of earthwork. Fig. 5 shows 3D modeling of excavation work at a certain interval (usually station number) between the start point and the end point of the railway roadbed construction progressing on a linear type.

Once the 3D modeling of the natural terrain is completed, 4D CAD simulation of earthwork can be done. Figs. 6 and 7 show the 4D simulation with the construction schedule linked to the 3D model of earthwork activity. Most civil engineering works with a horizontal work area include many earthwork operations. In the 4D simulation of such work, it is appropriate that the work schedule is linked with the location of the work because the work progresses on a long work site extension. If the earthwork activity is expressed in the existing system, it can be expressed only in the form of a mass of soil untreated with the topographical triangulation. For natural representation of natural terrain, it is necessary to change the geometry of terrain triangle according to the construction schedule and to make the 4D simulation.

C. Linear 4D CAD Functions for Horizontal Work Area

In order to simulate this linear type of work in a 4D CAD system, it is necessary to build functions that are specialized in the linear operations. In other words, it can be a useful tool to convert the schedule network part represented by the Gantt chart into a linear schedule network in the existing 4D CAD system.

Fig. 8 compares the 4D simulation with the linear 4D simulation and the existing 4D simulation. Especially, a railway construction project is composed of civil engineering, building, machinery, electricity, track work and dozens of KM construction sites. In Linear 4D CAD system, 4D CAD can simulate the construction position and construction time according to the distance coordinates at the same time, so 4D CAD can be used for practical process management. As shown in Fig. 8, in addition to civil works, the activities for the railway infrastructure are operated in parallel along the distance axis, such as electricity and track works, and interference control with these works is also an important factor.

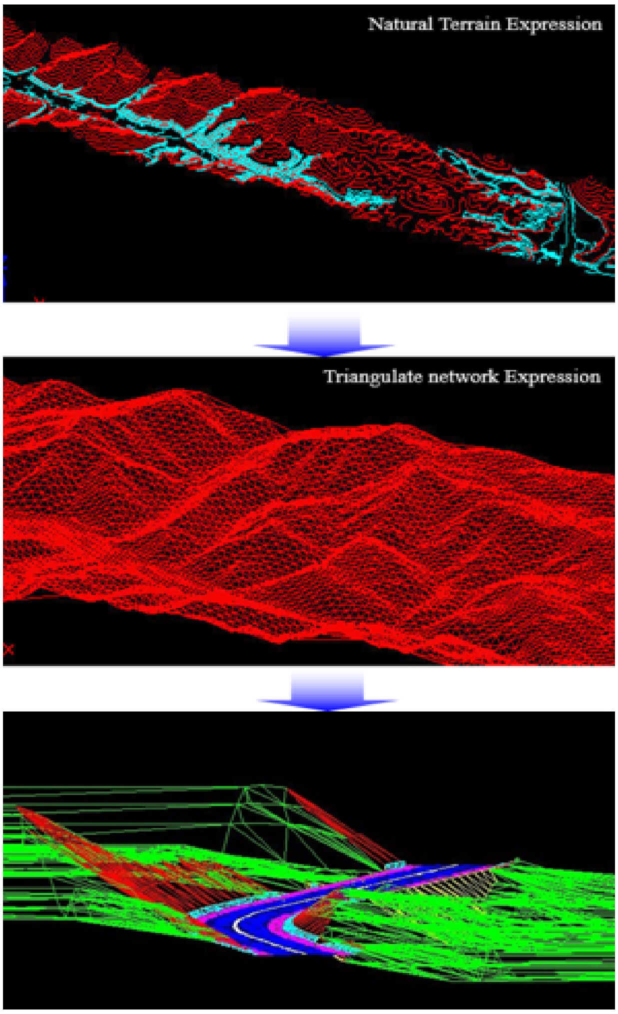

Fig. 4 Earthwork modeling process of natural terrain

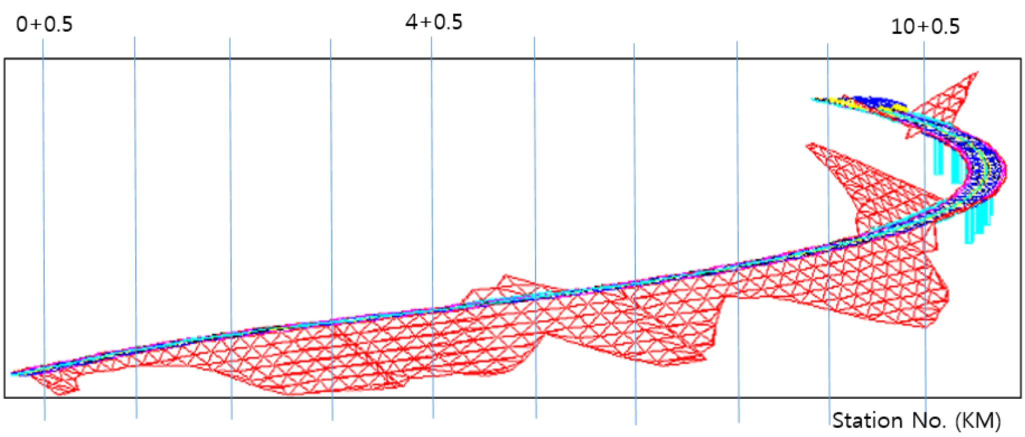

Fig. 5 Earthwork simulation by distance location

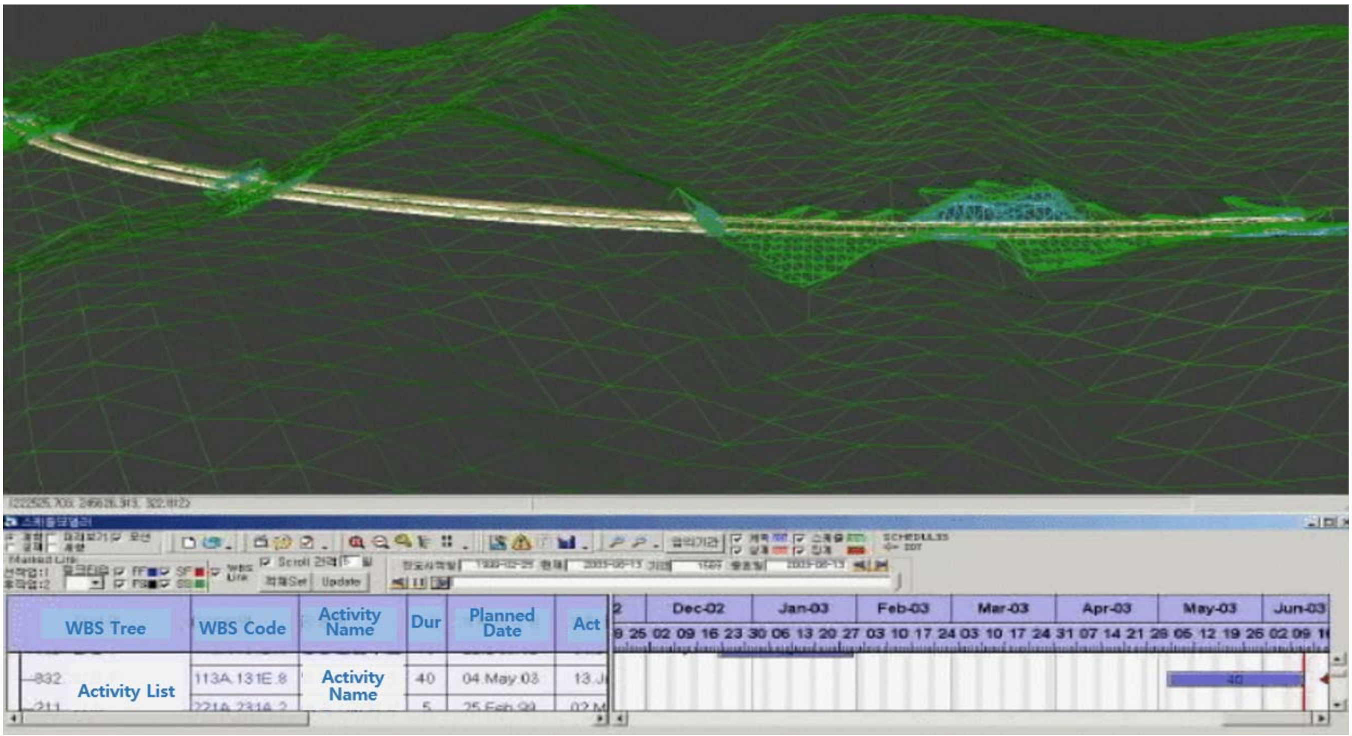

Fig. 6 4D simulation of whole horizontal working area

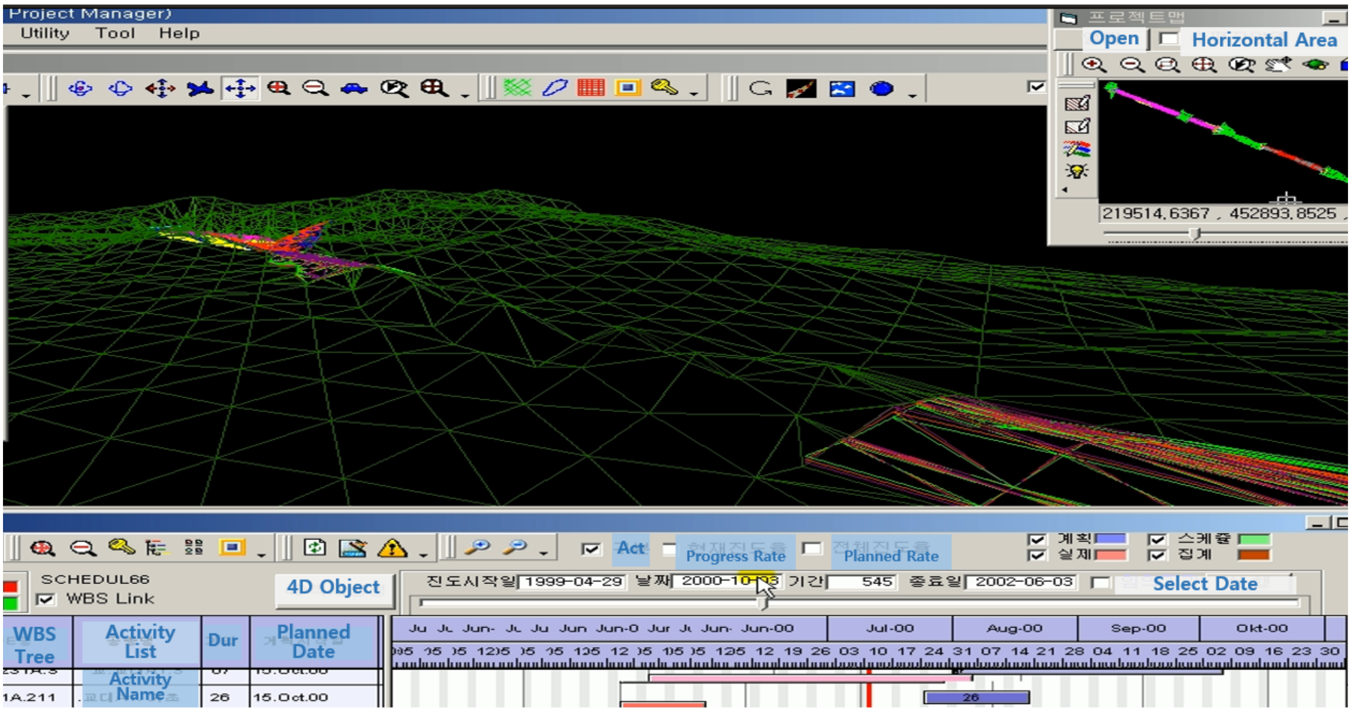

Fig. 7 4D simulation of earthwork area

Since the linear 4D simulation manages concurrent operations based on the position coordinates, it is more convenient to utilize the 4D CAD system. Considering that the existing 4D CAD system is used as the interference management for repetitive processes in the vertical workspace, this linear simulation function can increase the 4D CAD utilization for the field work in horizontal work in wide area field. Also, in case of practical application, it is necessary to prioritize processes that have characteristics of linear operation because representation of all linear works complicates the schedule chart. In the case of a railway infrastructure, earthworks, track work, and tunnel work, which the activities are progressed according to the distance coordinates of the X axis, can be representative processes.

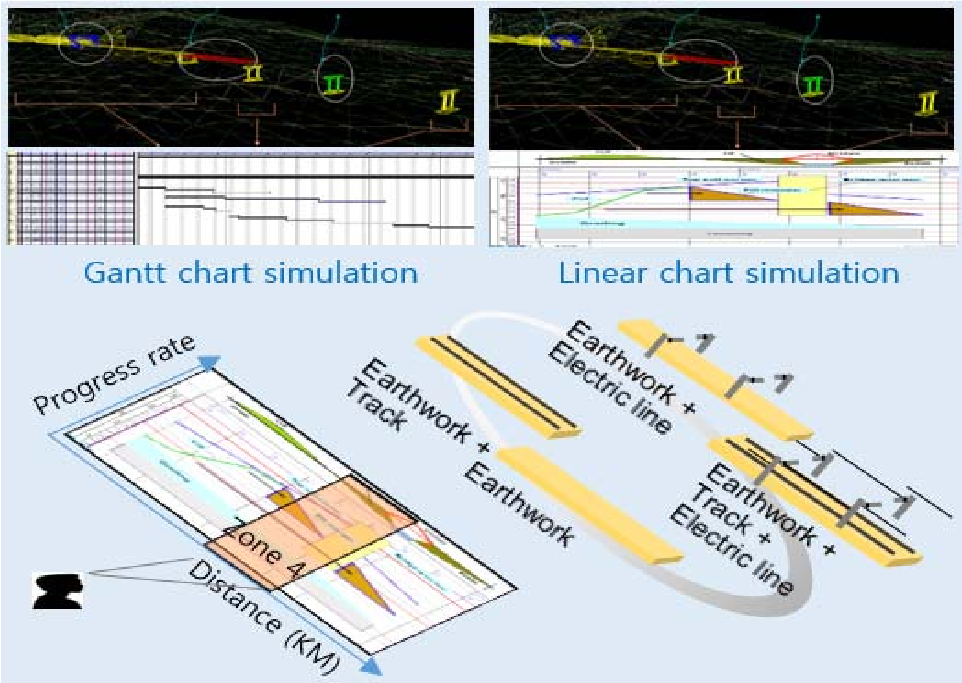

Fig. 8 Comparison of functions between existing 4D and linear 4D

V. Conclusion

This research suggested a BIM operating process and 4D CAD simulation functions for the construction phase that can increase the usefulness of BIM on civil engineering projects. In this study, the limitation of existing 4D CAD systems in civil engineering application is divided into earthwork of natural terrain and horizon of work in wide area. For this reason, it was stated that the functions of 4D CAD system suitable for civil engineering work with horizontal work space are needed. The study verified the applicability by applying prototyping process of earthwork simulation of 4D CAD system suitable for horizontal work space by these proposed functions. In addition, the research suggests the 4D CAD methodology of a linear construction project, and system development by this method can improve the application of 4D CAD system for the practical civil engineering project.

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