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Enhance Construction Visual As-Built Schedule Management Using BIM Technology

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***Abstract*—**Construction project control attempts to obtain real-time as-built schedule information and to eliminate project delays by effectively enhancing dynamic schedule control and management. Suitable platforms for enhancing an as-built schedule visually during the construction phase are necessary and important for general contractors. As the application of building information modeling (BIM) becomes more common, schedule management integrated with the BIM approach becomes essential to enhance visual construction management implementation for the general contractor during the construction phase. To enhance visualization of the updated as-built schedule for the general contractor, this study presents a novel system called the Construction BIM-assisted Schedule Management (ConBIM-SM) system for general contractors in Taiwan. The primary purpose of this study is to develop a web ConBIM-SM system for the general contractor to enhance visual as-built schedule information sharing and efficiency in tracking construction as-built schedule. Finally, the ConBIM-SM system is applied to a case study of a commerce building project in Taiwan to verify its efficacy and demonstrate its effectiveness during the construction phase. The advantages of the ConBIM-SM system lie in improved project control and management efficiency for general contractors, and in providing BIM-assisted as-built schedule tracking and management, to access the most current as-built schedule information through a web browser. The case study results show that the ConBIM-SM system is an effective visual as-built schedule management platform integrated with the BIM approach for general contractors in a construction project.

***Keywords*—**BIM, Building information modeling, construction schedule management, as-built schedule management, BIM schedule updating mechanism.

I. INTRODUCTION

AN original schedule can be updated frequently, particularly as a construction project becomes larger and more complex. A general contractor typically requires access to as-built schedule information to control and manage construction projects. Updated as-built schedule management (SM) is essential to control and manage construction projects, particularly because it enhances communication and coordination among project participants. Promptly sharing the updated as-built schedule with other participants helps them make compatible decisions, which helps to minimize possible disputes. Therefore, updated as-built schedule monitoring and control among project participants should be necessary and important to the general contractor.

Consequently, collection of as-built schedules from project participants is ineffective, thus reducing efficiency and resulting in a lack of as-built schedule information. This process ultimately results in confusion. With the advent of Internet technology, web-based as-built schedule information management solutions have facilitated information distribution and sharing among project participants. Utilization of web technology enhances the sharing of as-built schedule information in construction projects and has recently become increasingly important due to the ease with which information can be shared through web solutions.

One of those problems is obtaining an accurate position and location from text-based illustrations of a traditional schedule. Building Information Modelling (BIM) is a new industry term referring to parametric 3D computer-aided design (CAD) technologies and processes in the AEC industry [1]. During the construction phase, effectively tracking and managing as-built schedule information integrated with BIM-assisted illustration in construction reduces mistakes. Effective BIM-assisted as-built schedule information sharing allows project engineers to identify a current as-built schedule and make accurate decisions in the visual environment. Despite many studies and discussions in academic and practical literature regarding the simulation of 4D approaches (3D computer model + time), few studies on the practical updating of as-built schedules, integrated with the BIM approach during the construction phase, have emerged.

The proposed approach is to enhance onsite updating of the as-built schedule integrated with BIM models for visual schedule management. To advance this notion, the study presents a novel approach called the Construction BIM-assisted Schedule Management (ConBIM-SM) system for general contractors to enhance as-built schedule information sharing and tracking. Furthermore, this study demonstrates that the proposed system is efficient in information sharing and enhances as-built schedule information implantation through the ConBIM-SM system. The ConBIM-SM system retains the as-planned and as-built schedule information in a digital format, and facilitates easy updates and shares updating as-built schedule information in the web environment. By using the ConBIM-SM system, project and BIM engineers can obtain an overview of the previous and current as-built schedule updated information for a given project. Furthermore, project engineers can access and utilize the most recent updates to the as-built

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models during the construction phase. The changes and problems with the as-built models can be made available to each project engineer via the markup-enabled as-built schedule. This research is a pilot study to apply the ConBIM-SM system for BIM SM work during a building project in Taiwan, and to analyze and discuss the entire BIM SM work. Many problems and limitations will surface when onsite updating of an as-built schedule is implemented. The main contribution of the study is to explore the experience of tracking and managing BIM-assisted as-built scheduling during the construction phase.

II. Background

To facilitate construction planning, visualization technology has become widespread [2]. BIM is a new industry term that refers to 3D illustration technology that incorporates parameters and processes related to the AEC industry [1]. Almost ten years ago, BIM was introduced as an environment in which any information on 3D entity models could be stored and retrieved throughout a project's life cycle [3]. A BIM model is a digital visual representation of all of a building's physical characteristics and relevant information on its life cycle [4]. In prior research, many different definitions of BIM have been proposed. BIM contains precise digital geometric measurements and data to support a project's design, procurement, fabrication, and construction activities to describe CAD [5]. BIM's main feature is that the complete model, with all of its parts, is saved in a single file. Moreover, any changes made to the model automatically affect any related data and drawings accordingly. BIM modelling allows users to create and update project-related documents automatically, and data on the building are attached to the model's elements [5]. BIM helps construction planners to make important decisions by providing a visual of the details of the project in the future [6]. BIM is a tool that allows for efficient delineation of the management and execution of construction projects.

All of the aforementioned research has focused on simulating the 4D approach (3D digital model + time). However, the idea of a 4D approach is hardly new. The 4D simulation approach is different from the BIM-based as-built schedule updating system, for which there have only been a few studies. In Taiwan, there have been many problems encountered with this system of scheduling during the construction phase [7]. One such problem is that it is difficult to clearly explain a project without a visual representation while the schedule is being processed. In recent studies, there have been attempts to update 4D CAD models with various technologies, such as Radio Frequency Identification (RFID) [8], [9], Ultra Wide Band (UWB) [10], 3D laser scanning [11]-[18], and digital image processing [19]. These approaches still have a multitude of limitations, such as a high cost, that need to be addressed before the methods can be put into practice. Therefore, in this work it was a challenge to provide for the general contractor and onsite engineers a platform with which they could track and manage the BIM-assisted information on the as-built schedule.

III. System Design and Development

To remedy the problems in the visual updating of the as-built schedule, this study presents the novel ConBIM-SM system to visually update the as-built schedule information for construction project participants. The proposed ConBIM-SM system improves project control efficiency and cost-effectiveness, enhances construction updating of as-built schedule information among project participants, and increases flexibility in updating the as-built project schedule and response time. The main objectives of this study are as follows (1) develop a web-based BIM-assisted as-built schedule management system; (2) apply the proposed system for onsite as-built schedule updating and explore its limitations and problems based on a real case study; and (3) improve project BIM-assisted as-built schedule control and management efficiency for general contractors. The system will enhance dynamic project tracking and management; therefore enabling project participants to access the most up-to-date as-built schedule.

Updating the as-built schedule during the construction phase is generally recognized as the most critical strategy for successful schedule management. This study focuses on the practical implementation of the as-built schedule for the general contractor at a jobsite. In this study, the proposed ConBIM-SM system facilitates different statuses of as-built schedule process during the construction phase. In order for the project manager and project engineers to track the visual BIM-assisted as-built schedule, the study proposes five types of process statuses for updating the as-built schedule in the ConBIM-SM system. The five process statuses include: (1) ahead of schedule with under construction status; (2) ahead of schedule with completion status; (3) behind schedule with pre-construction status; (4) behind schedule with under construction status; and (5) behind schedule with completion status. Various statuses have been developed for different purposes in order to meet distinct requirements for the as-built schedule.

The proposed ConBIM-SM system with BIM-assisted visualization allows all project engineers to access the most recent visual as-built schedule using the BIM model. Furthermore, the updated as-built schedule can also be shared with marked information related to changes (see Fig. 1). The primary advantages of the BIM-assisted as-built schedule are as follows: (1) it provides a BIM-assisted illustration for sharing the updated as-built schedule in the web environment; (2) it provides project managers and engineers with the ability to track color-assisted statuses of all virtual as-built schedule processes during the construction phase of a project; and (3) it gives project engineers the ability to respond to the updated or feedback content using the BIM approach in practice.

The study utilizes the BIM approach to apply as-built BIM models in the updating of the as-built schedule. In the study, Design Web Format (DWF) is the selected format of the BIM file for markup as-built schedule use. Onsite engineers may update the status and corresponding color of the progress using as-built BIM models (BIM DWF file), and upload it to the system for updated as-built schedule sharing. Finally, the system will convert as-built updated component units of BIM models under the BIM DWF file by API programming and upload them to the ConBIM-SM system.

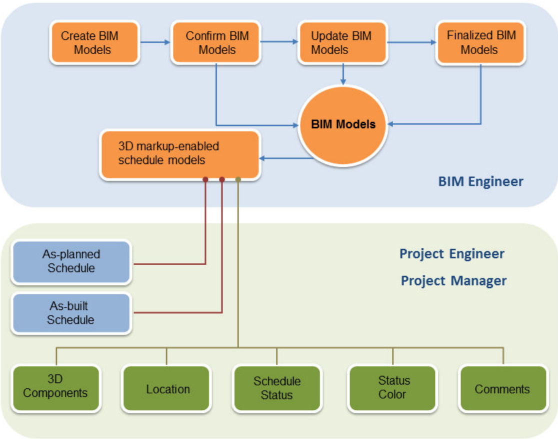

Fig. 1 Concept of BIM-assisted visualization integrated with the as-built schedule in the ConBIM-SM system

The study proposes a new innovative multi-field updated approach to the as-built schedule to enhance its management, which in turn allows engineers to update multiple as-built records of each activity or task in the field at various times. The main purpose is for engineers to build upon the previous updated content for each activity or task. This multi-field updated as-built schedule approach allows engineers to track past and present progress of the as-built schedule content. When onsite engineers also select a traditional single field for as-built updates, they need not use a multi-field progress update system.

The 3D markup-enabled schedule models can be defined as a 3D CAD graphic representation of as-built schedule activities linking relationships between CAD objects and attributes of schedule models. The BIM approach retains as-built schedule information in a digital format, facilitating easy updating and transfer of activities in the 3D CAD environment. The as-built schedule information with 3D BIM approach can be identified, tracked, and managed virtually during construction projects. The most recent as-built schedule status and comments can be acquired from onsite engineers and then shared and illustrated by way of the 3D BIM model for better understanding and communication.

The following section describes the development of the proposed ConBIM-SM system. The developed ConBIM-SM system runs on Microsoft Windows 2008 software with an Internet Information Server (IIS) as the web server. The ConBIM-SM system is developed using Activate Server Pages (ASPs), which are easily incorporated with HTML and JavaScript technologies. The ConBIM-SM system server supports four distinct layers: interface, access, application, and database. Each layer has its own responsibilities. The interface layer defines administrative and end-user interfaces. Users can access information via web browsers such as Microsoft Internet Explorer or Google Chrome. Administrators control and manage information via the web browser or using a separate server interface. The access layer provides system security and restricted access, firewall services, and system administration functions. The application layer defines various applications for analyzing and managing information. The database layer consists of a primary Microsoft SQL Server 2003 database. A firewall and virus scanning capability are used to protect the system database against intrusion.

The ConBIM-SM system is designed for all BIM-related project participants via a user-friendly portal, which serves as a real-time, updated as-built schedule channel for project engineers. All data are stored and classified using the visual schedule management dashboard in the ConBIM-SM system. Furthermore, the ConBIM-SM system is a solution that uses a single, unified database linked to the as-built models' files (DWF files) with different levels of access determined by user roles. Participants can access the BIM model SM information entry and updates, based on their responsibilities in the ConBIM-SM system. When information is updated in the ConBIM-SM system, the server automatically sends e-mails to the project manager, and the project engineers associated with the issue. One purpose in this study is to extend BIM to the construction phase and provide as-built schedule updating service for general contractor. The as-built model is applied in the ConBIM-SM system to capture and store as-built model information. Autodesk Revit Architecture and Revit MEP were used to model the BIM management dashboard and create BIM files. Autodesk Design Review was used to read as-built model files from the BIM management dashboard. Information integration with the BIM management dashboard was achieved using the Autodesk Revit application programming interface (API) and Microsoft Visual Basic.Net (VB.Net) programming language. The ConBIM-SM system was developed by integrating the BIM SM-related information using Autodesk Revit Architecture and Revit MEP software. All APIs in the ConBIM-SM system were programmed in VB.Net using Revit API. A program in C++ was written to integrate acquired data from different software programs and all interface information, such that as-built model files could be exported to an ODBC database for connection with the ConBIM-SM system.

IV. Case Study

The case study was a 4-months construction project. The case study involves a general contractor with 25 years of experience in constructing office buildings in Taiwan. The construction phase of this office-building project also involves three subcontractors and five suppliers. The general contractor wanted to take full advantage of using the visual approach to enhance onsite construction management (aspects of which include schedule management, visual discussion, and so on). In the general contractor's previous experience, there have been serious problems with onsite as-built schedule updating and tracking. One such problem has been obtaining an accurate position and location from the text-based illustrations of a traditional schedule. Therefore, the general contractor had assigned project engineers, project managers, and BIM engineers to utilize the ConBIM-SM system to solve the problems related to the onsite as-built schedule during the construction phase. The ConBIM-SM system was used in the office-building project to demonstrate its efficacy and that of the visual BIM-assisted updating and management of the as-built schedule.

During the case study, responsible onsite engineers updated their as-built schedule, and updated the status and content of the BIM model in the ConBIM-SM system. The BIM engineers needed to prepare and convert all BIM models into DWF files in the initial phase. After the BIM models were converted, the onsite engineers linked the as-built activity with the read-only BIM model (DWF files) and uploaded the submission via the ConBIM-SM system. The attached files with selected components of the BIM model included digital documents and photos. The BIM engineers assisted the onsite engineer in the creation and conversion of the BIM models for use in future as-built scheduling. Furthermore, BIM engineers will revise the BIM models based on the as-built situation, if necessary. All onsite engineers were required to update the as-built schedule using the ConBIM-SM system. Onsite engineers updated the status color of the current schedule's components that corresponded with the BIM models (DWF file), and updated their discussions and comments via the ConBIM-SM system. Finally, all BIM-assisted schedule information was centralized and stored in the central database to prevent the collection of redundant data. The ConBIM-SM system automatically sent a message concerning any updated information to the onsite engineers and project manager after saving the new content.

In the case study, the decoration engineers attempted to utilize the BIM approach for illustrating the as-built updated schedule regarding the installation of windows and doors. The decoration engineers and BIM engineers utilized the as-built BIM models and linked the BIM models to the activity in the ConBIM-SM system. After the as-built BIM models were revised and linked with related activities, the decoration engineers were invited to update their as-built schedules with the BIM approach (DWF file). All decoration engineers were required to update their own as-built schedules regarding the activities for which they were responsible. The as-built schedule information with the corresponding components of the BIM models included the as-planned schedule, as-built schedule, descriptions and comments, and as-built photos (when they were necessary). When the submitted as-built schedule document set was approved by the project manager, the system illustrated the process automatically. In other words, users could find and read the related as-built schedule directly simply by clicking on activities and referring to the appropriate components of the BIM models. Finally, all submitted as-built schedules whose components corresponded with the BIM models had to have their performance quality approved before the final as-built schedule could be published. All of the validation needed to be executed by the project manager.

The decoration engineer identified and updated the as-built schedule records of selected decorations (such as descriptions, as-built videos, and documentation) provided by the responsible engineers (see Fig. 2). The decoration engineer continued to update and provide comments on the as-built schedule in the portion of the project assigned to the installation of windows and doors using the multi-field as-built schedule records. Additionally, the decoration engineer provided additional suggestions and feedback pertaining to any delay problems after the work was completed. Subsequently, another decoration engineer updated the new as-built schedule and selected the status of the as-built schedule in the ConBIM-SM system after personally completing the installation of the windows and doors. Furthermore, the engineer uploaded the as-built photos and descriptions of the components corresponding to the BIM models in the ConBIM-SM system. Moreover, the decoration engineer republished the updated as-built schedule from the approval section to the published section of the ConBIM-SM system after the approval process was completed, and a notification was sent to authorized members.

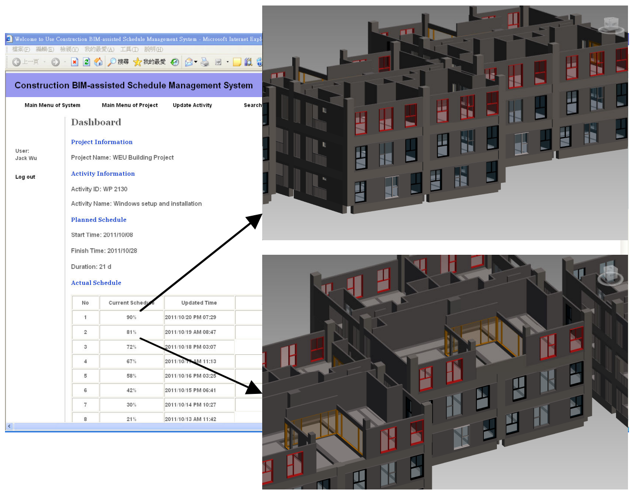

Fig. 2 As-built schedule update information with BIM-assisted visualization in the case study

The findings of this case study revealed several limitations of the ConBIM-SM system. The following are inherent problems recognized during the case study.

- An initial plan or discussion to integrate the BIM models in BIM-assisted schedule management is necessary at the project's onset to avoid ensuing problems with the as-built schedule updated with the BIM approach.
- Generally, BIM at different levels of detail (LOD) will affect the results of the visual updates to the as-built schedule. For example, a BIM model with LOD400 makes it easier to update the as-built schedule than one with LOD100. The corresponding components of a BIM model with LOD100 will require more detail for schedule updating than a BIM model with LOD400.
- In the case study, project engineers who were unfamiliar with the use of 3D BIM models initially required additional

time to apply the corresponding BIM-assisted as-built schedule in the ConBIM-SM system. Therefore, more time was used with this system than the current approach. After the users became more skilled and familiar with the 3D BIM models, the amount of time necessary for the current approach was almost identical to the time necessary for the proposed system in utilizing 3D BIM models.

- Usually, onsite project engineers did not have sufficient time and assistance to update as-built schedule if they had a pressing schedule. Another problem was that not all involved project engineers had the same attitude regarding using the ConGASM system for updating the as-built schedule. A few onsite engineers were unwilling to use 3D BIM models for updating the as-built schedule. The development of systems that satisfy all involved parties and the needs of the various project engineers depends on the different viewpoints and attitudes.

V. CONCLUSION

This study presented the ConBIM-SM system to construction project participants so that they could update and share any information about their as-built schedule in an enhanced visual way. The proposed system effectively improves the efficiency and effectiveness of creating a visual of the updated as-built schedule, thus enabling the general contractor to control and manage progress at the jobsite. The ConBIM-SM system improves efficiency in tracking the as-built schedule information collected visually from onsite engineers, and provides monitoring services for project participants. This study shows that the ConBIM-SM system significantly enhances control of the visual aspect of a construction project's as-built schedule. The system also enhances construction management when it is integrated with the application of BIM. Furthermore, the BIM-assisted visual illustration of real-time as-built information from all project participants helps the general contractor's manager to visually monitor and control the construction project's as-built scheduling process by using statuses of various colors. One of the main characteristics of the ConBIM-SM system is that there is no requirement for updating the BIM-assisted as-built schedule to install any BIM software at jobsite. All that any individual needs to do is to install the free Autodesk Design Review software and access the ConBIM-SM system directly through Microsoft Internet Explorer or Google Chrome. Project participants and managers can access the ConBIM-SM system to track the BIM-assisted as-built schedule anytime and anywhere, based on what they are permitted to do by their authorities.

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