DEVELOPMENT OF MOBILE BIM-ASSISTED DEFECT MANAGEMENT SYSTEM FOR QUALITY INSPECTION OF BUILDING PROJECTS

Jun-Xiong, Chang*, Yu-Chih Su*, and Yu-Cheng, Lin**

** Ph.D. Student, Department of Civil Engineering, National Taipei University of Technology, Taiwan*

***Associate professor, Department of Civil Engineering, National Taipei University of Technology, Taiwan*

ABSTRACT

Defect management (DM) for quality inspection of building projects is one of the major factors for general contractors to enhance construction management. However, there are serious problem regarding to the construction DM in practice due to time consuming, repeated data entry, misunderstanding, and inefficient information management. With the utilization of the Building Information Modeling (BIM), BIM digitally contains precise geometry and relevant data needed to support the facilities to describe 3D object-oriented CAD. This paper proposes a new and practical methodology to apply quality inspection and defect management by using BIM approach. Using 2D barcode and BIM technologies, this study proposes a BIM-assisted Quality Inspection (BIMQI) system for on-site quality managers in the construction phase. BIMQI System can collect defect data at a site in real time using 2D barcode and BIM technologies, and effectively manage statuses and results of the corrective works performed. The BIMQI system is then applied in selected case study of a building project in Taiwan to verify our proposed methodology and demonstrate the effectiveness of defect management practice in Taiwan. By developing BIMQI system, on-site quality managers can track and manage 3D BIM models with related maintenance record in a digital format. The combined results demonstrate that, a BIMQI-like system can be an effective visual facility management tool by utilizing the BIM and 2D barcode technologies. The advantage of the BIMQI system lies not only in improving defect management work efficiency for on-site quality managers, but also in facilitating easy quality inspection identifying and communicating in the 3D BIM environment.

Keywords: BIM; Building Information Modelling; 2D barcode; Information System; Quality Inspection, Defect Management.

1. INTRODUCTION

In recent years, several research and industry efforts have been focus on developing building information modeling (BIM) to support various projects of architectural, engineering, construction and facility management (AEC/FM). The construction DM in practice have serious problem including time consuming, repeated data entry, misunderstanding, and inefficient of communication that would resulted in significantly effects of the various aspect of quality control and construction

* Corresponding author: Email: taiwan@mail.syang.com.tw

* Presenter: Email l: taiwan@mail.syang.com.tw

management. Automatic identification procedures have recently become very popular in numerous service industries for purchasing and distribution logistics, as well as in manufacturing companies and material flow systems. By integrating automatic identification technologies (such as 2D barcode system), the effectiveness of defect management for quality inspection is enhanced and improved. In order to enhance the effectiveness of quality inspection work of the commerce building, this study presents a novel system called BIM-assisted Quality Inspection (BIMQI) system for the on-site acquisition and tracking of defect and quality inspection information and provides an information sharing platform for on-site quality engineers and manager using webcam-enabled notebook or webcam-enabled tablets. Integrating the BIM and 2D barcode technologies, information and data entry mechanisms can help to improve the effectiveness and convenience of QI information flow in the DM process. The primary objectives of this study include (1) applying BIM technology to increase the efficiency of QI work in the visual DM, (2) integrating BIM and 2D barcode technologies to link related BIM models effectively for QI and DM, and (3) developing a web-based portal for defect management and control, providing real-time information and wireless communication between a construction site and a main office. The BIMQI system is then applied a commerce building in Taiwan to verify our proposed methodology and demonstrate the effectiveness of the defect management in construction building. The combined results demonstrate that the BIMQI system can be a useful BIM-assisted QI and DM platform by utilizing the BIM and 2D barcode technologies.

2. BACKGROUND

Building information modeling (BIM) is a new industry term referring to parametric 3D computer-aided design (CAD) technologies and processes in the AEC industry (Taylor and Bernstein, 2009). Visualization technology has been widely adopted in construction to facilitate construction planning (Liston et al., 1998), conflicts analysis (Hu and Zhang, 2011), constructability reasoning (Mani et al., 2009), site layout planning (Ma et al., 2005), and defect management (Chan et al., 2012). The communication and discussion among all participants may be enhanced effectively by visualization (Hajdasz, 2008). Detailed as-built information is essential for process tracking, corrective actions, and schedule analysis.

Young et al.(2007). propose a PDA and wireless web-integrated system for quality inspection and defect management to improve communication efficiency among the related participants and help quality managers systematically manage and accumulate useful data that would be utilized as a reference in future construction project. Umit and Jason (2010) proposed two design patterns as a foundation to formulate the design of information systems for BIM-based synchronous collaboration. This research aims to address some of these limitations by developing an approach to support automated extraction and querying of construction relevant design information from a BIM. Madhav (2011) developed a novel approach to extract construction features from a given BIM and support the processing of user-driven queries on a BIM that builds on, combines, and extends previous

research on design relevant construction knowledge, ontological modeling, features and feature-based modeling, building product models (or BIMs), and product model reasoning. Chan et al. (2012) proposed a conceptual system framework for construction defect management that integrates ontology and augmented reality (AR) with building information modeling could enable proactive reduction of the defect occurrence during the construction process and that could greatly improve current defect management practice in the construction industry.

In summary, to solve this problem of defect management for quality section of a building project, we attempted to develop a BIMQI system for general contractor to enhance visual as-built construction information sharing and efficiency tracking during the construction phase of the projects.

3. THE DEVELOPMENT OF BIMQI SYSTEM

Recently, 2D barcode and tablets have become very popular in Taiwan. With the advancement of mobile technology, many mobile phones are equipped with cameras, which allow for 2D barcode scanning capability. When a barcode reader program is installed, the user can quickly access product descriptions, a web address, or e-mail address by scanning the barcode. For example, a mobile phone with the Google Android system can read one or two dimension bar codes like EAN, ISBN, or QR Code after installing the Zxing bar code scanner software. Tablets equipped with a camera also enable the application of 2D barcode scanning to facilitate maintenance management of building facilities. Therefore, this study integrates BIM and 2D barcode technologies to enhance DM work and provide detailed QI information communication. An integrated web platform can link all QI information on building to improve the effectiveness of the DM process. Figure-1 illustrates the flowchart of the progress used in the BIMQI system

The application of BIM/2D barcode technology in the management of facilities both inside and outside of the construction building focuses on its rapid identification and supports on-site quality engineers in handling QI work through the 3D BIM models. By scanning the 2D barcode label attached at the entrance location in the each floor, on-site quality engineers and manager can obtain the corresponding BIM model of the located floor and directly access defects tags of the BIM model for referring defect information such as defect topic, defect detail description, defect photos, QI history information, defect improved information. Furthermore, defects tags of the BIM model improve traditional 2D drawings that make it difficult to illustrate the vertical location or position of defects.

The BIMQI system consists of a BIM subsystem, 2D barcode subsystem, mobile devices subsystem and DM hub center subsystem. Significantly, the BIM, 2D barcode, and mobile devices subsystems are located on the client side, while the DM hub center subsystem is on the server side. Each subsystem is briefly described below.

In this study, BIM is used as an information model in the BIMQI system. The BIM is applied in the BIMQI system to capture and store basic information about the element of building, including basic descriptions, parameter-related information, QI-related records, and DM-related reports. Autodesk Revit Architecture was used to create BIM model files. Autodesk Design Review was used to review the defects tags of BIM models. Information integration with the 3D BIM models was achieved using the Autodesk Revit API and Microsoft Visual Basic.Net (VB.Net) programming language. The BIMQI system was developed by integrating the BIM models and defect-related QI and DM information using the Revit API programming. ODBC was utilized to integrate acquired data from different software programs and all QI information, such that BIM files can be exported to an ODBC database for connection with the BIMQI system.

Most people in Taiwan have personal smart phones and tablets and can easily access 2D barcode information. The case study uses QR code as the 2D barcode system since the QR code reader software is popular in Taiwan and provides the most suitable functionality for Construction DM. QR code also conforms to the ISO/IEC 18004 standard, has the largest data capacity and read speed, is very secure, can be read in different orientations, and has high tolerance for corrupted labels. The QR code label has high fault tolerance and its anti-corruption capability contributes to longer usage and better identification. One of the major advantages to using the 2D barcode is there is no extra cost required to buy software, since there is much free 2D barcode scanning software for smart phones.

The QI information storage will increase over time if the QI information is all recorded in the BIM model. Because BIM models cover a wealth of building information, system storage space should be reserved for crucial information, such as defect ID and title of defect, defect location and other critical information. In order to keep the system performance at an acceptable level, the information derived by other applications should be stored in an external location. Therefore, there are two databases designed in the BIMQI system, the BIM elements database and the DM database. The BIM elements database stores only basic information (such as ID and name of BIM components, and key parameter information of BIM components). Related QI data and information are stored in the DM database.

The tablet system adopts a Samsung Series 7 tablet as the webcam-enabled tablet hardware. The Samsung Galaxy Tab tablet runs on Windows 8. All data in the tablet module are transmitted to the server directly through the web via Wi-Fi or 3G.

4. TEST STUDY

This study is applied to a construction building in Taiwan for the case study. This study utilizes a BIMQI system as DM for QI work of building projects during the latter stages of construction phase. The BIMQI system is then applied in selected case study of a building project in Taiwan to verify our purposed methodology and demonstrate the effectiveness, applicability and practicability of defect management practice in Taiwan.

Table-1 depicts the progress simulated in the BIMQI system. We identified and ensured the reliability to component of 2D barcode in the processes of read and access. Then, the first need to test and analyze the component of 2D barcode to be aimed at optimum environment and limiting factors. Moreover, determined the finally way of install and the potentially difficulties and limitation. Duration the processes of quality inspection, engineers can use the tablet PC to scan the 2D barcode from a portal of spatial unit or public area that extracts the related basic information of defect inspection. Subsequently, directly adopted by tablet PC to record and describe the results of defect checking in turn and tracking the follow up states of renovate. Moreover, can understanding the states of conducting and accomplishing for all defects timely that by the markup of symbol and color. The related basic information of defect inspection would be returned pass to the terminating database of the home base synchronism. To assist make a communication template of information timely that not only need to perform the backup of information and quantitative analysis, but also to sharing with stakeholders of querying and extracting. But need to establish the controlling mechanism of assign and correct about these information. Also, maintain, renovate and finally recognition of accomplishing that to take charge of management center.

For checking, recording, executing, tracking and finally identification of the defects that subcontracts can extracting and querying the related to information of quality inspection by the terminating database of BIMQI system then have planed the schedules and contents of maintaining task. Consequently, the resolution and result of correcting would be returned pass to the terminating database of the home base synchronism. Engineers again based on these results of renovating to perform reviewing, approving, recording, analyzing and listing the states of defect examine. Furthermore, managers may also regard to the results of the foregoing that perform monitoring and identifying the accomplishing states of defect management tasks. Summarize, the processes would to assist acquire immediately and completely information for owners, managers, engineers and subcontractors of construction industry.

5. CONCLUSIONS

This study presents the BIMQI system that incorporates BIM and 2D barcode technology to improve the effectiveness and convenience of quality inspection and defect management of building projects for synchronous communication between the construction jobsite and a jobsite office. Applied toward defect management, the system shows potential for creating new practices for the construction quality inspection and defect management in visual BIM environment. The BIMQI system not only improves facilities defect management efficiency, but also provides a 3D BIM-assisted illustration service during the quality inspection process. In the case study, 2D barcode readings increased the accuracy and speed of BIM models link and searches, indirectly enhancing performance and productivity.

Engineers can extracting the 3D models and criterion from terminating database of BIMQI system by using tablet PC that is different from traditional manners which need to collect complex

and a large number of information, such as drawings, technical specifications, documents, checklists and tools. Therefore, it can simplify the schedule and the efficiency of arrangement, execution, examine, measure and so on then to promote the benefit and precision of defect management. To integrate the related to information into the same group of building information models which is added the markup within cross horizontal and vertical section of 3D drawings that compassion with traditional note of manuscript is more clarity and comprehensibility for inexperienced participants. The intent is to exemplify applicability of using sharing platform of BIMQI system for querying, communication, coordination, integration and review of defect management in construction site. In particular, the research aims to address the complexity problems of query process and enable to rapidly export the checklist for each group of defect items.

Although there are some challenges and problems, the proposed system has shown a great potential to be used in equipment and facilities defect management in construction building with the promising results shown in this study. By integrating automatic identification technologies, the effectiveness of quality inspection and defect management is enhanced and improved in a commerce building in Taiwan.

REFERENCES

Abdel-Monem, M. and Hegazy, T. 2012. "Enhancing Construction As-Built Documentation Using Interactive Voice Response." Journal of Construction Engineering and Management, 10.1061/(ASCE)CO.1943-7862.0000648 (Oct. 11, 2012).

Chan-Sik Park, Do-Yeop Lee, Oh-Seong Kwon, & Xiangyu Wang, 2012. A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template. Automation in Construction (2012).

Hajdasz, M. 2008. Visualizing simulated monolithic construction processes, Journal of Civil Engineering and Management 14(4): 295-306.

Liston, K.M., Fischer, M., Kunz, J., 1998 4D annotator: a visual decision support tool for construction planners, Journal of Computing in Civil Engineering, 330–341.

Mani, Golparvar-Fard, Feniosky, Peña-Mora, Arboleda, Carlos A., Lee, SangHyun 2009. Visualization of construction progress monitoring with 4D simulation model overlaid on time-lapsed photographs, Journal of Computing in Civil Engineering 11: 391–404.

Madhav Prasad (2011). Automated extraction and querying of construction-specific design features from a building information model. Ph. D. thesis, Department of Civil Engineering, The University of British Columbia.

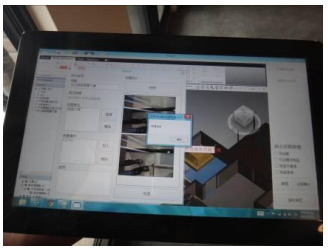
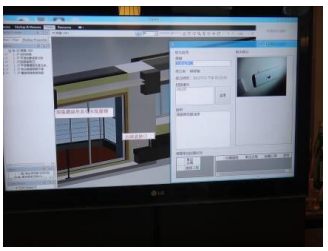
Taylor, J. E., & Bernstein, P. G. (2009). Paradigm Trajectories of Building Information Modeling Practice in Project Networks. Journal of Management in Engineering, 25(2): 69-76.

Umit, Isikdag and Jason, Underwood 2010. Two design patterns for facilitating building information model-based synchronous collaboration, Automation in Construction 19(5): 544-553.

Young S. Kim, Se W. Oh, Young K. Cho, & Jong W. Seo, 2007. A PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects. Automation in Construction 17(2008): 163-179.

Zhang, J.P. and Hu, Z.Z. 2011. BIM- and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies Original Research Article. Automation in Construction 20 (2): 155-166.

Table-1 The Description of the Progress simulated in the BIMQI System

Description	Processing Simulation
1. Using the tablet PC to Scan the 2D barcode from a portal of spatial unit or public area to load the 3D BIM models in the location.	
2. Take the photo attached with faults problem then to record and describe the results of defect inspection of a building project.	
3. The information of defect inspection would be markup in the 3D models and be returned pass to the terminating database of the home base synchronism	
4. The sharing platform of defect management enables to be used with each stakeholder.	
5. The content and describe for defect inspection of taxonomic in comparison with 3D models.	
6. The functions of filtering and identifying the states of defect management that is the sharing, communication and coordination platform with each stakeholder.	

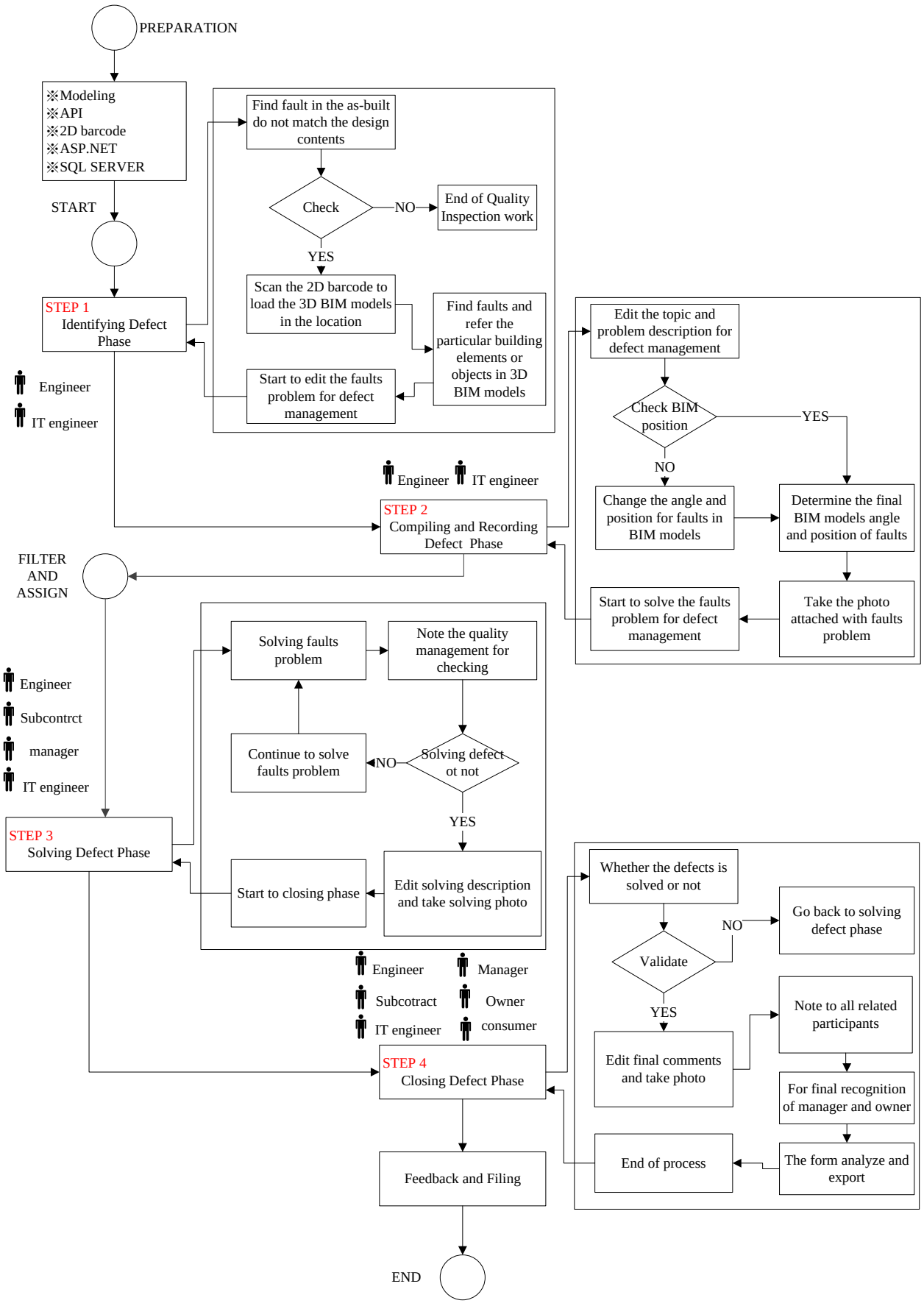


Figure-1 The Flowchart of the Progress Used in the BIMQI System