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Citation	Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan, B-3-3., B-3-3
Issue Date	2013-09-11
Doc URL	http://hdl.handle.net/2115/54245
Type	proceedings
Note	The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan.
File Information	easec13-B-3-3.pdf



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DEVELOPING BIM-BASED SHOP DRAWING AUTOMATED SYSTEM INTEGRATED WITH 2D BARCODE IN CONSTRUCTION

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ABSTRACT

The application of BIM (Building Information Modeling) has become the most critical and useful tool for communication management during the construction phase of a construction project. Managers and engineers usually utilize 2D shop drawings for construction works during construction phase. However, there are many problems of the 2D shop drawings regarding to communication in practice. By using BIM approach, users can get a visual overview of 3D BIM models and effective communications through 3D BIM models. In order to let onsite engineers review BIM models quickly and effectively, this study proposes a BIM-based Shop Drawing Automated (BSDA) system integrated with 2D barcode during the construction phase. This BSDA system later then been applied to selected projects in Taiwan to verify our proposed methodology and demonstrate the effectiveness of BIM-based shop drawing automation and integration in practice. By utilizing BSDA system, on-site managers and engineers can easily scan those 2D barcode that generated automatically by using this BSDA system to open 3D BIM models for discussion. The result demonstrates that the advantage of the BSDA system not only lies in improving communicating work efficiency in the 3D environment, but also facilitates easy BIM model approach to integrate with 2D barcode.

Keywords: Building Information Modeling, BIM, 2D Barcode, Shop Drawings Management.

1. INTRODUCTION

During the construction phase of construction project, 2D shop drawings are major information for the onsite engineers. Managers and engineers usually utilize 2D shop drawings for construction works. Currently, the way of shop drawing management usually names the folders and files to establish a set of management mode. However, it causes engineers spending a lot of time to search

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the demand drawing when the construction project contained a great deal of shop drawings. Furthermore, it relies on the engineer's experience to understand the content of 2D drawing. Building Information Modeling (BIM) was introduced nearly ten years ago to provide an environment where any related information on 3D entity models could be retrieved during the project life cycle (Tse et al. 2005 and Ding et al., 2012). Using BIM approach, users can get an overview of 3D BIM models and take visual and effectively communication through 3D BIM models. After the completion of the BIM model, engineers can quickly generate the 2D shop drawings from the BIM model; and the content of those drawings has been associated with the BIM model. One of the major problems is that most of the on-site engineers are not familiar with utilizing BIM software. In order to let engineers to refer 2D shop drawings and review the relational BIM models quickly and effectively, this study proposes a BIM-based Shop Drawing Automated (BSDA) system integrated with 2D barcode in the construction phase. 2D barcode is a graphical image that can store up to 7089 characters; the storage is greater than the 20-character capacity of a 1D barcode. Therefore, in this study, the 2D barcode is used as the drawing index and to store the web address of the drawing file. BSDA system is used to not only integrate the 2D shop drawings in BIM model with 2D barcode, but also automatically export sections of BIM model according to each 2D shop drawing. By utilizing BSDA system and scanning the 2D barcode of the shop drawing, managers or engineers can discuss and communicate through a corresponding 3D BIM models. The BSDA system is then applied in selected case study of a building project in Taiwan to verify our proposed methodology and demonstrate the effectiveness of BIM-based shop drawing automation and integration in practice. The combined results demonstrate that the advantage of the BSDA system lies not only in improving communicating work efficiency in the 3D BIM environment, but also in facilitating easy BIM models identifying integrated with 2D barcode.

2. LITERATURE REVIEW

Much research has shown the potential of one-dimensional barcode applications in various areas of the construction industry, such as data entry efficiency, labor management, productivity improvement, cost savings, and construction equipment and materials tracking, and electronic document management (Bell and McCullouch 1988; Blakey 1990; Stukhart and Cook 1990; Bernold 1990). Reference (McCullouch and Lueprasert 1994) illustrated how the two-dimensional (2D) barcode technology could be applied in the construction industry. Meanwhile, various researches on the application of barcode models have focused on the integration of other technologies. Reference (Shehab and Moselhi 2005) illustrated the use of barcode technology to develop an automated system for engineering deliverables such as drawings, reports and specifications. Reference (Saeed et. al. 2010) integrated GPS with RFID and 2D barcode technologies to provide the solution for pedestrian users accessing information about buildings and other artifacts.

There are many previously research publications regard to BIM issues in construction. Reference (Tse 2005) presented the core barriers, these factors and recommends using BIM technology for construction industries. Reference (Vanlande 2008) proposed an extension of the BIM technology to manage information during the entire lifecycle of an AEC project. Reference (Succar 2009) explored publicly available international guidelines and introduced the BIM framework, a research and delivery foundation for industry stakeholders. Reference (Umit and Jason 2010) proposed two design patterns as a foundation to formulate the design of information systems for BIM-based synchronous collaboration. During the construction phase, these benefits include less rework, reduction in requests for information and change orders, communication through visualization, improved productivity in scheduling, faster and more effective construction management with easier information exchange (Eastman et al., 2008; Hardin 2009; Azhar 2011). Despite many BIM articles and system developments in academic and practice literature, there is a lack of systematic approaches to search and manage the shop drawings in the BIM model environment. To solve this problem, this study proposed a new approach and system to enhance BIM-based shop drawings automation and integration using 2D barcode.

3. CONCEPTS UTILIZED FOR SYSTEM DEVELOPMENT

The proposed approach, which includes initialization phase and automated and integrated phase, shows how to integrate the BSDA system with the completion of the BIM model effectively. During the initialization phase, BIM engineer needs to import 2D barcode onto each shop drawing, exports the related section of BIM model to DWF (Design Web Format) file, and stores information from shop drawings into the database of BSDA system. During the automated and integrated phase, engineers and managers can scan the 2D barcode on shop drawing to review the related BIM model quickly using BSDA system. The following sections describe more detail for the approach.

BSDA system is based on a BIM model to develop a mode of shop drawing management. Therefore, BIM engineers need to complete the BIM model and all required shop drawings in BIM model before using BSDA system. When all is completed, BIM engineer then can begin to enter the operation process of initialization phase (See Fig. 1). During this phase, the user can scan the 2D barcode on shop drawing to open and review related 3D BIM model and get the drawing file to application phase. However, it is time consuming to repeatedly generate a 2D barcode then past on each shop drawing, so this study developed an API program of BSDA system in BIM software. The API program of BSDA system will automatically repeat the following step in each shop drawings to complete the operation process of initialization phase.

(1) *To transform 2D view plan into a new 3D section of BIM model*

In the BIM software environment, the shop drawing can set a lot of 2D views and 3D views but most of shop drawings are only set 2D views. Therefore, the API program needs to transform 2D view plan into a new 3D section of BIM model according to the boundary and range of 2D views.

- (2) *To export 3D section into DWF file and store information of shop drawing in BSDA system*
 In order to let user can review the related 3D section of shop drawing without using BIM commercial software, the API program will export the new 3D section into DWF file and then store information of shop drawing in BSDA system. Each DWF file will be set a web path in BSDA system when storing DWF file completed.
- (3) *To encode ID of shop drawing and publishing date in 2D barcode*
 2D barcode is a unique identification of shop drawing in BSDA system and so the information of encoding must be important and helpful. In this application mode, the 2D barcode will be encoding the ID of shop drawing and publishing date. Because BSDA system can identify the scanning shop drawing through the ID of shop drawing and determine the version of shop drawing is whether latest through publishing date.
- (4) *To import the 2D barcode in shop drawing*

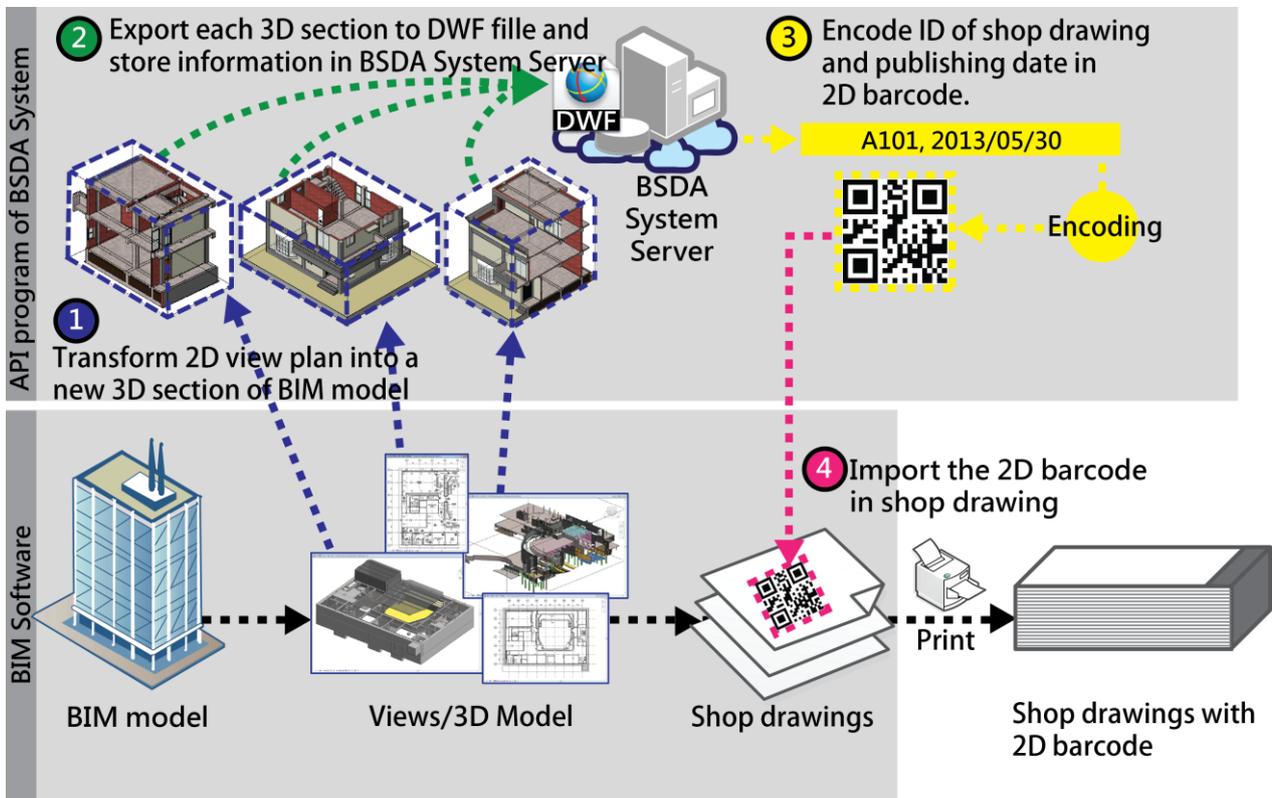


Figure 1: The operation process of initialization phase

After operating initialization phase, each shop drawing was imported the 2D barcode. If any misunderstanding occurs while discussing on unclear shop drawing, engineers can open the BSDA system and use the video camera with more than 30 million pixels or barcode reader to scan the 2D barcode on shop drawing. After read the 2D barcode, the BSDA system will decode the 2D barcode of scanning to get information of the ID and publishing date of shop drawing and then send barcode information to BDSM system server to search the related DWF file of BIM model. Finally, the BSDA system server will return the related DWF file of BIM model to engineers (See Fig. 2). Once

scanning, engineers not only can open BIM model of the related shop drawing, but also compare the publishing date of shop drawing with the nearest date in BSDA system server to check the latest version of the shop drawing.

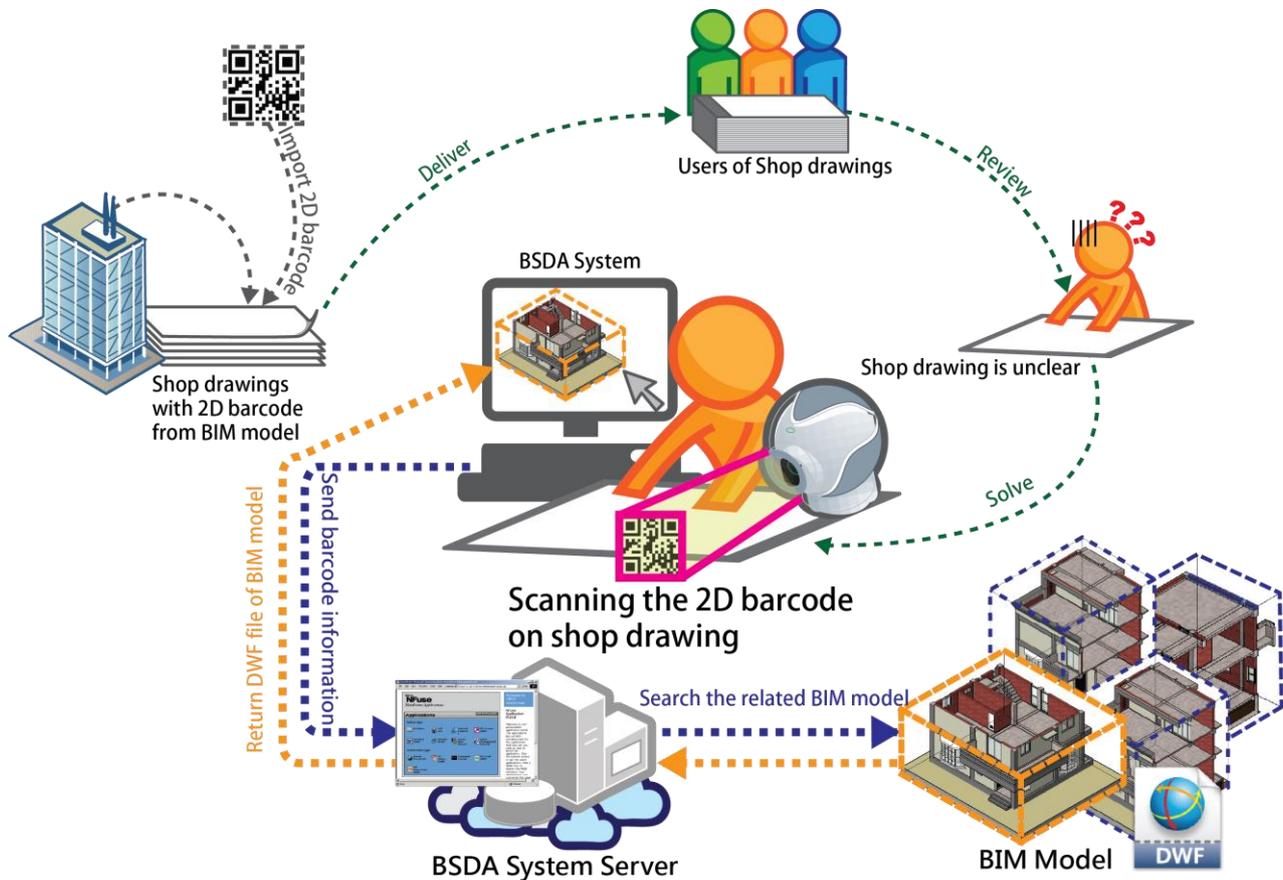


Figure 2: The operation process of automated and integrated phase

4. SYSTEM DEVELOPMENT

In the BSDA system, the primary function is to assist BIM engineers in integrating shop drawings in BIM model with 2D barcode and provide site engineers can quickly get the related BIM model of shop drawing through scanning 2D barcode on shop drawing. Therefore, this study developed five modules in the BSDA system, five modules are barcode encoding module, barcode decoding module, BIM model automatic sectioning module, DWF export module, DWF viewer API module and shop drawing management module respectively. Autodesk Revit 2013 was used to model the 3D CAD-based models and create shop drawings. Autodesk Design Review was used to read DWF files in the BSDA system. The 2D barcode integration with 3D CAD-based models was achieved using application programming interface (API) and VB.NET programming language. In the hardware, MS337-UG barcode reader was used to scan 2D barcode on shop drawing. When the BSDA system is completed, the BIM engineer can import 2D barcode into each shop drawing (see Fig. 3-a); the site engineer can scan 2D barcode on shop drawing using barcode reader (see Fig. 3-b) and then refer the related BIM model in the BSDA system (see Fig. 3-c).



(a) The 2D barcode is imported in the shop drawing

(b) The 2D barcode is scanned using barcode reader

(c) BIM model is referred in the BSDA system

Figure 3: The application of BSDA system in the polite test

5. EXPERIENCE AND DISCUSSION

This study compares the original BIM mode with the BSDA system mode, the result of difference as follow (and listed as Table 1):

- *Shop Drawing Automation and Search*

In the original BIM mode, the BIM manager and BIM engineers often utilize folders to manage files of BIM model and use BIM software such as Revit, ArchiCAD and Tekla to produce and manage shop drawings. Even though export shop drawings in the file of BIM model to other file type such as PDF and DWG, the BIM manager still utilize folders to manage those files so the user need very understand the architecture of folders. In the BSDA system mode, this study develops the API program of BIM software for the initialization phase in application mode. When BIM engineers execute the API program, the API program not only import 2D barcode to shop drawing, but also and export 3D DWF file and 2D PDF file to BSDA system server and then write information of shop drawing to the BSDA system database. Therefore, the BIM manager can clearly and quickly search shop drawings using the BSDA system even if the user does not understand the architecture of system database.

- *Operation Process*

The operation process is usually modeling, model integration, shop drawing producing and dimensioning in a BIM project. In the BSDA system mode, it still needs to do the same operation process of the original BIM mode because there are based on BIM model. In order to integrate BIM model with the BSDA system, the BIM engineer needs to execute the API program of BSDA system after the operation process of original BIM mode completed.

- *BIM Model Review*

The primary propose of this study is to enhance the efficiency of BIM model review. In the original BIM mode, the BIM engineer often needs to assist site engineers to review the BIM model if shop drawings unclear because site engineers cannot handle BIM model simply. In

the BSDN system mode, site engineers just open BSDA system and then scan the 2D barcode on shop drawing using barcode reader. The related and sectioned BIM model will be show at BSDA system automatically.

Table 1: Differences between the current approach and proposed system

<i>Task</i>	<i>Current Approach</i>	<i>Proposed Approach</i>
Shop Drawing Management	Folder-based or BIM software	BIM software and system database
Shop Drawing Search	Manual search	System search or 2D barcode scanning
Operation Process	Modeling, integration, shop drawing producing and dimensioning.	Executing API program of BSDA system after original BIM model
BIM Model Review	Open BIM model and manual sectioning the BIM model	Scanning the 2D barcode on shop drawing and then automatically open the sectioned BIM model.

There are some facing difficulties and limitations in the polite test, the details as follows:

- If the large BIM model (approximately 30MB) is presented directly to the client on the BSDA system, it will affect the smoothness and effectiveness of the system operation. Therefore, the large BIM model is necessary to split into parts of BIM model based on the user requirement to review BIM models effectively.
- BIM engineers do not built everything into the BIM model in the BIM project so they need to do a lot of extra work in details of shop drawings from the BIM model. Therefore, not everything that shown on shop drawing will be show to the related BIM model, detailed drawing especially.

6. CONCLUSIONS

This study proposes and develops the BSDA system for the BIM manager, BIM engineers and site engineers to enhance BIM-based shop drawings automation and integration using 2D barcode. The BSDA system provides BIM manager and BIM engineers to import 2D barcode into each shop drawings in BIM model. When a 2D barcode has been imported into shop drawing, the 2D PDF file, 3D sectioned DWF file and information of shop drawing will be export into the BSDA system server and database automatically. This study selected Autodesk Design Review which is free software as a BIM model (DWF file) viewer in order to simplify handling of BIM model and reduce the hardware requirement. Therefore, site engineers can scan the 2D barcode on shop drawing to get 2D PDF file, 3D sectioned DWF file and information of shop drawing through BSDA system. Compare with original BIM mode, site engineers can independent and efficient utilize sectioned BIM model to communicate with other participants through the BSDA system and scanning 2D barcode. Furthermore, the BSDA system can not only get related and sectioned BIM model quickly, but also discriminate the version of shop drawing weather is latest version or not because this study encodes the publishing date in the 2D barcode of the shop drawing and continuous records the latest publishing date in the BSDA system database. Through integration 2D barcode with shop drawing

in BIM model, site engineers do not need to use the professional BIM software such as Revit, Tekla or ArchiCAD. They just need to scan the 2D barcode on the shop drawing and learn how to use simply BIM viewer. When site engineers can handle the BIM model easily, they are willing to use BIM models to check further information of elements such as material, area, volume, and so on and discuss project issues such as complex surface, clash of interface, construction procedure, and so on.

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