A Framework for Collaboration Management of BIM Model Creation in Architectural Projects

Yu-Cheng Lin*1 and Hui-Hsuan Yang2

1Professor, Department of Civil Engineering, National Taipei University of Technology, Taiwan
2Ph.D. Student, Department of Civil Engineering, National Taipei University of Technology, Taiwan

Abstract

In recent years, the uses and applications of building information modeling (BIM) have become more common in construction projects. Usually, most general contractors (GCs) will use collaborative works for BIM model creation. GCs work together and complete BIM model creation at different locations and times, successfully reducing the duration of BIM model creation. However, BIM collaborative works cause numerous practical problems in BIM model creation, which include low quality BIM models, the need to rework the model creation, and incorrect model creation. To overcome these problems, this study proposes the BIM collaboration management (CM) framework to enhance the quality of BIM model creation work. Using the proposed BIM CM approach, the BIM team can reduce the time needed for model checking and improve the quality of BIM CM work. The proposed framework and approaches were applied to a case study of a building project in Taiwan to verify their effectiveness. The case study results show that the proposed frameworks and approaches are effective for collaborative BIM model creation for the GCs. Finally, the benefits, limitations, conclusions, and suggestions are summarized for further application.

Keywords: BIM; collaboration management; building information modeling; BIM management; general contractors

1. Introduction

The uses and applications of building information modeling (BIM) have become more common during the construction phase of construction projects. During the phase, general contractors (GCs) usually use BIM technology for various applications for construction management. If the architect uses traditional paper-based 2D drawings, it will be necessary for GCs to create a model to use for construction management (Eastman et al., 2011). However, one practical problem facing GCs is to achieve BIM model creation for large and complex projects within a short timeframe. Therefore, most GCs use collaborative works for BIM model creation, which requires having numerous participants working together to complete the elements of BIM model creation at different locations and times, thus successfully reducing the duration of BIM model creation. However, collaborative works also cause numerous practical problems.

According to interviews with BIM engineers and BIM managers of the GCs in Taiwan (Lin, 2012), collaborative works for BIM model creation have the following primary practical problems: (1) ineffective mechanisms for managing collaborative work, (2) failure to properly manage the BIM model creation problems and modifications, (3) difficulty sharing and noticing relevant modifications to related BIM engineers, (4) failure to properly manage BIM model creation self-inspections and results, (5) failure to properly control the versions of BIM model creation during the process where the BIM model must be updated and revised continuously, and (6) the ease of deleting BIM models created by other BIM engineers during the collaborative work process.

Despite considerable research and system development efforts in the academic and professional BIM-related literature, little research focuses on BIM collaboration management (CM) specifically for BIM model creation work. To resolve the above-mentioned problems, this study proposes the BIM CM framework to improve collaborative work for BIM model creation. The BIM CM framework is applied to a case study of a building project in Taiwan to verify its efficacy and demonstrate its BIM CM effectiveness for CM-based BIM model creation work.

2. Literature Review

BIM has been introduced in the AEC/FM industry, utilizing the technical developments of the IT industry to integrate the overall process of building from design to construction and management since the mid-2000s.
Collaborative work is very important for BIM model creation. There are many researches related to BIM-related collaborative work in construction. Munkley et al. (2014) pointed out that much of the research on BIM technologies and processes has focused on BIM file-based collaboration in recent years and proposed a low cost IT platform to execute BIM model-based collaboration. Das et al. (2014) presented a distributed cloud-based BIM framework to support collaboration and information sharing among project participants. Chen et al. (2014) proposed a system to enable Internet-based modeling collaboration among teams from multiple disciplines for the development of BIM. Wu and Xu (2014) proposed a collaborative framework of BIM information from the perspective of supply chain management. Oh et al. (2015) proposed an integrated design system for the improvement of BIM-based collaborative design to solve the use of different BIM-based software among collaborators during the design phase. Liu et al. (2016) explored project professionals' understandings of BIM implementation on collaborative design and construction and determined eight concepts influencing the development of BIM collaboration.

Recently, many national BIM standards and guides have been developed for BIM implementation, including the National Building Information Model Standard (NBIMS, 2015), Building Information Modelling (BIM) Protocol (CIC, 2013), Singapore BIM Guide (BCA, 2013), National Architectural BIM Guide (MLTM, 2010), and BIM guidelines (JIA, 2012). Some BIM standards and guides propose the concept and brief procedures for the CM of BIM model creation works. However, few BIM guides explain the framework and mechanism for a BIM model creation integrated BIM CM approach.

Currently, some commerce BIM CM software (such as Bentley ProjectWise and Autodesk 360) exists to support project teams who manage, share, and distribute engineering project content and review it using a single platform. However, few process management functionalities are considered for BIM CM work for BIM model creation. Furthermore, little research has discussed the framework and mechanism for the CM of BIM model creation in architectural projects.

3. Research Method

Most GCs adopt collaborative works for BIM model creation to reduce the duration of BIM model creation works, particularly in Taiwan. Moreover, the accuracy of the BIM model (such as the related information of the BIM model) should be inspected and confirmed for quality control of BIM models during collaborative work. It is important to develop CM approaches to ensure the quality and accuracy of the BIM model in the BIM CM process. Therefore, the main purpose of conducting this research is to develop a management framework and approach (forms and processes) to enhance the quality control of BIM model creation works. Using the proposed BIM CM approach, the BIM team can effectively enhance the planning and management of collaborative works for BIM model creation.

3.1 The Framework for Collaborative Work for BIM Model Creation

To enhance collaborative work for BIM model creation effectively, the study proposes four phases for collaborative work: the initial planning phase, the model creation phase, the model inspection phase, and the model integration phase (see Fig.1.). The following paragraphs explain each phase in detail.

3.1.1 Initial Planning Phase

Before beginning collaborative work for BIM model creation, the initial plan needs to be considered and developed carefully. Without careful consideration of the initial plan, collaborative work for BIM model creation will lead to many problems and produce low-quality output. To ensure that the BIM model can be created quickly and will be of superior quality, the work for the initial planning phase is proposed in this study (see Fig.2.).

After obtaining the 2D drawings during the construction phase, all related participants will hold meetings to discuss the requirements and schedule of the BIM model creation and confirm the scope of the BIM model. Further, the necessary considerations will include applications of the BIM model during the construction, the integration of different BIM software, BIM interoperability, and the major schedule and baseline of BIM model creation based on various professional participants.

The correctness of the BIM model is important for the various applications of BIM for GCs. Therefore, BIM managers and engineers should initially identify
all requirements of BIM model creation and develop the Standard Operating Procedures (SOPs) and rules for the collaborative work for BIM model creation. Then, BIM managers will assign the work to BIM engineers based on the identified requirements of BIM model creation.

To enhance the performance of collaborative BIM model creation for GCs, the present study proposes the following seven major SOPs and rules for the development of a BIM model during the initial work:

1. **The development of the BIM model mechanism**

   The framework of the BIM model files forms the basis of collaborative work for BIM model creation. The BIM model may comprise one or multiple files depending on the properties of the project. The framework of BIM model files needs to be planned and set up carefully based on the sizes and attributes of the BIM-related projects.

2. **Authority setup mechanism**

   The authority setup of the BIM model and related documents can be developed according to the authority of each BIM engineer to enhance the accuracy of collaborative work for BIM model creation. The major purpose of the use of the authority setup mechanism is to reduce the occurrence of problems associated with the unintentional deletion or revision of the BIM model.

3. **Backup management mechanism**

   The development of a backup management mechanism is proposed to prevent file damage resulting from human factors. Additionally, model information must be backed up at a fixed time and information maintenance management must be executed by a BIM manager or an authorized engineer. Furthermore, all BIM model files should follow set backup and naming rules to prevent damage to the model files.

4. **Model file naming mechanism**

   Based on Architectural, engineering, and construction (AEC) BIM Standard for Autodesk Revit, the letters A-Z, hyphens, underscores, and the numbers 0–9 should be used for all fields. The file extension shall not be amended or deleted (Woddy and Revit Sub-Committee Chair, 2010). Based on the model file naming reference BS1192:2007 (British Standards Institution, 2008), the file name should include three fields: project name, model type, and model area. Fields can be added if required.

5. **The BIM model template development mechanism**

   To ensure the model shows the best style based on the requirements of the owner or BIM manager in the BIM modeling process, the template is developed based on the BIM model requirements. After BIM model template development, all BIM engineers can reuse the templates for their BIM model creation work.

6. **The priorities of the drawing definition mechanism**

   A description of the priorities should be provided for the reference drawings. For example, drawing updates or Request for Information (RFI) files are supplementary information that should be prioritized over the original design. Furthermore, the BIM model needs to be modified based on the newest RFI result or the newest revised 2D shop drawing.
7. Level of detail of models and elements mechanism

The level of detail of each component should be defined based on the application requirements of the BIM model. Therefore, the requirements and related required information of the BIM model should be identified in advance by project participants. Obtaining and understanding the requirements is beneficial for BIM engineers to enhance the quality of the BIM model creation work.

In this study, the proposed SOPs and rules developed for the BIM model can be revised and modified based on project characteristic and requirements. The proposed SOPs and rules developed for the BIM model will help the BIM engineers and BIM managers to improve the quality and efficiency of BIM CM in the creation of BIM models.

After the initial work is finished, the BIM team must inspect the initial BIM model in the server. Furthermore, the BIM inspector needs to check the basic environment settings of the server to prevent errors in the BIM model creation.

3.1.2 Model Creation Phase

After the initial planning phase is complete, BIM engineers may obtain the basic BIM model linked from the BIM model of the server side to create the model. BIM managers can obtain and access any processing BIM model from the server side. To enhance the management and control of BIM creation work during the process, this study proposes the "model creation phase" process (see Fig.3.). During the process, BIM engineers will discuss any questions that arise with related project participants. To address design-related problems, it will be necessary to hold meetings or share RFI documents to confirm that the problems have been resolved before the BIM model creation. Finally, the entire BIM model creation needs to be revised and modified based on the design changes, updated information, or RFI results.

3.1.3 Model Inspection Phase

The present study proposes the model inspection mechanism to meet the accuracy requirement of the BIM model. The model inspection phase comprises two stages: self-inspection and final inspection. The self-inspection mechanism requires all BIM engineers to create and check the accuracy of the BIM model. As many problems occur because of BIM model mistakes during this process, check points should be set up to manage the BIM model inspection. All BIM engineers need to check the BIM model and find problems based on the defined check points. This study

Fig.3. The Procedure for the BIM Model Creation for the BIM CM Implementation
proposes a BIM model self-inspection form for BIM engineers to use during the self-inspection stage. BIM managers can also use this form to track the status of model modifications. Using this form should reduce the checking time and prevent cumulative mistakes in the final inspection stage. The related RFI documents will be used if any problems relate to the drawings and design (see Fig.4).

The final inspection mechanism requires the BIM inspector to verify the accuracy of the BIM model. The BIM inspector checks the final BIM model to ensure and confirm model requirements (such as constructability and practical application requirements). After any problems are identified, the BIM inspector will fill out the forms for BIM model modification requirements and send them to the relevant engineers. All BIM engineers will respond and revise the BIM model based on the BIM model modification requirements. After the BIM model modification work, BIM engineers will resubmit the BIM modified model for final inspection. All processes will be repeated until the final inspection meets all BIM model modification requirements (see Fig.5.).

### 3.1.4 Model Integration Phase

Usually, several different BIM models built by different professional participants are integrated to create a final, complete BIM model. The different BIM models are created for structure, mechanical, electrical, plumbing (MEP), architecture, and decoration. However, when different models are created, many serious problems can occur (such as conflicts and other time-consuming problems) during the integration process. To improve the performance of final BIM integration, the different BIM models should be integrated and coordinated earlier and integrated with checkpoints before all different BIM modes are created. For example, the first checkpoint should confirm the results for the self-inspection work of structural BIM models. After the BIM inspector accomplishes the BIM model inspection work, the BIM team negotiates and determines the points needing review.

### 3.2 BIM Model Version Management

During the process of BIM model creation, the different versions of the BIM model need to be traced and managed for all BIM engineers. Furthermore, it is essential to have regular meetings where collaborative work for BIM model creation can be discussed. All BIM engineers should submit their schedules and unfinished work to BIM managers before the regular meetings. After receiving the schedules and results of the collaborative work, the BIM managers can update and announce the newest integrated collaborative work for

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**Fig.4. The Procedure for the BIM Model Self-inspection for the BIM CM Implementation**

| Reference info. | Project participants |
|-----------------|----------------------|
| The requirement for owners and onsite use | BIM model requirements |
| To have discussion meeting |
| To confirm RFI documents |
| To confirm the accuracy of model |
| To create RFI documents |
| To modify model based on RFI |
| To modify/ revise model |
| To update model synchronously in the server |
| The process of model final inspection |

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**Table:** The Process of Model Self-inspection

| Roles | BIM engineer |
|-------|--------------|
| The process of model creation |
| Model self-inspection |
| To confirm the accuracy of model |
| To confirm the problems for drawing |
| To confirm RFI documents |
| To update model self-inspection form (fill out) |
| To update model synchronously in the server |
| The process of model final inspection |

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**Diagram:** The Process of Model Self-inspection

- **Reference info.** The requirement for owners and onsite use, BIM model requirements.
- **Project participants:**
  - To have discussion meeting
  - To confirm RFI documents
  - To confirm the accuracy of model
  - To create RFI documents
  - To modify model based on RFI
  - To modify/ revise model
  - To update model synchronously in the server
  - The process of model final inspection

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During collaborative work for the BIM model creation, one of the potentially serious practical problems is the BIM model files receiving damage on the server side, which usually causes rework or schedule delays in BIM model creation. To alleviate this problem, BIM engineers should back up the BIM model every day on the client side and save the new BIM model file only on the server side.

4. Case Study
The following case study involved implementing CM for the BIM model creation using the proposed approaches for the Mass Rapid Transportation (MRT) construction BIM project in Taiwan. The case study was performed over three months. This case study adopted the CM for the BIM model creation because of the serious time constraint for the BIM model creation. To reduce the BIM model creation time, the case study adopted CM for BIM model creation integrated with the proposed approaches. Therefore, 3 BIM managers, 6 BIM engineers, and 2 BIM inspectors were assigned to utilize the proposed approaches for the CM-based BIM model creation during the construction phase. The case study was conducted to verify the efficacy and effectiveness of CM in BIM model creation.

The entire BIM model creation in the case study was implemented based on the proposed frameworks and approaches in the study. BIM managers evaluated the station before executing the processes of the BIM the dispatch of 6 BIM engineers to create the BIM model. 2 BIM inspectors were assigned to check the model. Given that this BIM project was applied to the operation maintenance phase, requirements of operation maintenance and constructability were discussed with the owner and site engineers. The objective of the selected project using BIM was to create the structure, architecture, part of the decoration, and equipment of the station model. It was decided that one BIM central model file would be used to execute CM in this case, and certain work was decided upon based on the number of engineers in the central model. To prevent problems occurring with the BIM central model, the BIM manager was given the authority to add new information and backup the BIM model; BIM engineers did not have the authority to make such changes. After confirming this BIM project assessment and setting, the initial planning phase, model creation phase, and model inspection phase were executed sequentially to confirm that the BIM model could be applied to the construction site. Finally, the BIM model was delivered to the operational maintenance phase for maintenance work usage.

The over 92% satisfaction rate indicates its usefulness in providing CM-based BIM model creation work especially for the GC in the case study. This proposed approach enabled BIM engineers and managers to access the latest result and enhance management of the CM-based BIM model creation work. According to
to the case study survey results, CM-based BIM model creation work for the BIM manager reached 91% satisfaction rate and CM-based BIM model creation work for the BIM engineer reached 88% satisfaction rate using the proposed BIM CM approach.

Regarding BIM managers, the major advantages of the adoption and use of the proposed BIM CM approach based on questionnaire results are as follows: (1) to enhance management of CM-based BIM model creation work easily and effectively (86 percent agreed); (2) to refer all related results and check the self-inspection result of CM-based BIM model creation work effectively during the process (92 percent agreed); (3) to track and manage the latest status of CM-based BIM model creation work effectively (89 percent agreed); and (4) to access and refer the self-inspection results of CM-based BIM model creation work from BIM engineers (91 percent agreed).

Regarding BIM engineers, the major advantages of the adoption and use of the proposed BIM CM approach based on questionnaire results are as follows: (1) to reduce mistakes in BIM model versions effectively (92 percent agreed); (2) to avoid the occurrence of errors in the BIM initial model effectively (88 percent agreed); (3) to avoid the occurrence or errors in the model creation effectively (93 percent agreed); and (4) to understand the overall operation of collaboration based on SOPs easily (91 percent agreed).

The following problems and difficulties were identified from the case study. (1) When the BIM central model was deleted, the BIM manager had to spend time finding the latest BIM model file and setting it as the new BIM central model file to continue the CM-based BIM work. (2) Although plans were made for the BIM engineers' work range, their authority over specific work areas was not set up initially. Therefore, the work sets among the BIM engineers influenced each other during the BIM model creation process. (3) The BIM inspector spent considerable time managing the BIM model inspection because some junior BIM engineers lacked experience.

All involved participants (BIM manager, BIM inspector, and BIM engineers) were asked to evaluate the proposed approaches used in the case study. Table 1 presents a representative sample of their comments. Comments 1–8 stated that the proposed approaches were useful, informative, and potentially effective for the practical application of CM-based BIM model creation. Table 2 illustrates the evaluation results of the approach. Finally, the following recommendations are made based on feedback from the case study participants:

- The BIM manager requires not only BIM professional knowledge but also effective communication and coordination abilities with the team because poor communication decreases the performance of the CM-based BIM model creation.

- Upper management support and encouragement are essential for the implementation of BIM CM work. In addition, all involved participants should follow the proposed procedures of the proposed approach to improve the performance of their work.

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Table 1. Participants’ Evaluation Comments

| No | Comments |
|----|----------|
| 1  | When I encounter problems associated with CM-based BIM model creation during the process, I can easily contact and discuss the issues with the right people to solve the problems using the proposed procedures. (Provided by BIM engineer) |
| 2  | Without using the proposed approaches, it takes time and effort to find the backup BIM model. Therefore, I thought that this was one of the major benefits of the proposed approaches for CM-based BIM model creation. (Provided by BIM engineer) |
| 3  | It is very helpful for me to let BIM engineers inspect the BIM model by themselves in advance using the proposed checklists for BIM model quality control during the process. (Provided by BIM inspector) |
| 4  | Usually, there are many problems in BIM model creation after the first self-inspection process. Therefore, it is important for the BIM inspector to conduct a final inspection at the end of CM-based BIM work. (Provided by BIM inspector) |
| 5  | In integrating with CM-based BIM model creation, the phased BIM model creation and inspection may be enhanced to reduce errors and improve performance. During the phased process, it is easy for me to find and solve problems. (Provided by BIM inspector) |
| 6  | I think that all involved BIM engineers can follow the proposed procedures to handle the CM-based BIM model creation effectively to prevent the rework problems that arise in the event of incorrect BIM model creation. (Provided by BIM inspector) |
| 7  | I can manage CM-based BIM model creation effectively using the proposed approach. The benefit of using the approach for me is to enhance the process control and track interfaces effectively. (Provided by BIM manager) |
| 8  | With the use of the proposed approach, most engineers involved agreed that the performance of the CM-based BIM model creation was improved and was better than before. (Provided by BIM manager) |

Table 2. Approach Evaluation Result

| Title                                                                 | Mean score |
|----------------------------------------------------------------------|------------|
| Easy to understand the overall operation of collaboration procedures | 4.8        |
| Quickly create models according to uniform standards                 | 4.4        |
| Effectively avoid errors of the initial BIM model                     | 4.6        |
| Quickly solve problems of the model and 2D drawings                  | 4.6        |
| Model self-inspection can improve the accuracy of the model and quality| 3.8        |
| Systematic model self-inspection                                      | 4.0        |
| Final model inspection can improve the accuracy of the model and reduce rework | 4.6        |
| Enhances the effectiveness of problem management                      | 4.0        |
| Reduces the incidence of interface problems                           | 4.4        |
| Reduces mistakes in BIM model versions                               | 4.4        |
| Enhances the effectiveness of BIM model creation collaboration        | 4.2        |
approaches to meet the requirements of the BIM CM work.

- The BIM team usually comprises many junior and senior BIM engineers. As the junior BIM engineers usually need assistance from the senior BIM engineers, junior and senior BIM engineers should be assigned to work together on BIM CM work.
- The BIM engineers’ BIM-based and field-based experiences will affect the result of BIM model self-inspection. Further, BIM inspectors play a critical role in the quality control of the BIM CM-based models.

5. Conclusions

This study discussed the application of the BIM CM framework integrated with CM-based process management for the construction phase of building projects, and developed the novel BIM CM approach integrated with BIM CM forms and processes for BIM model creation work. The proposed forms include the BIM implementation for assessment form, BIM model self-inspection form, and BIM model problems form. Using the proposed forms and processes, the BIM CM approach allows BIM engineers and BIM managers to control the newest status and updated content of the CM-based BIM model creation work through effective process management and control. The proposed forms facilitate an updated approach to meet the requirements of CM-based BIM model creation work based on the results of interviews with BIM experts in Taiwan.

To assist the GCs with implementing CM-based BIM model creation work effectively, this study develops the BIM CM framework, which enables BIM-related participants to enhance the information sharing and process control of CM-based BIM model creation work through the proposed approach. Assisted by the proposed BIM CM mechanisms, BIM engineers and BIM managers can track and manage the CM-based BIM model creation work effectively. Moreover, the major characteristic of this study is to propose CM-based processes specifically developed for the process and control management of CM-based BIM models developed by different BIM engineers. The proposed approach for CM-based BIM model creation work is unavailable in the existing BIM tools and software.

Finally, the BIM CM approach was applied to a case study of a building project in Taiwan to verify its efficacy and effectiveness for CM-based BIM model creation work. Compared with the previous approach, there are many summarized benefits as follows: (1) to provide a managerial mechanism effectively for BIM managers and engineers to apply CM-based BIM model creation work; (2) to provide managerial flowcharts effectively for BIM managers and engineers to utilize CM-based BIM model creation work; (3) to reduce the occurrence or error and rework of CM-based BIM model creation work during the process compared with the previous approach; and (4) to provide information sharing effectively for BIM managers and engineers to utilize CM-based BIM model creation work. Overall, the case study results show that the proposed BIM CM approach is an effective mechanism for GCs to manage CM-based BIM model creation work. Future works will develop a collaborative management platform that uses the proposed BIM CM approach, which can be used as a server to store related BIM models. Furthermore, the related analysis can be illustrated based on the data and information saved in the system. The system will assist all BIM engineers and BIM managers to manage the BIM CM work effectively in the web-based environment.

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