Applications of Configuration Management in BIM Models Management during the Construction Phase

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Abstract:

Applications of building information modeling (BIM) become more and more common to enhance the effectiveness of BIM implementation for a general contractor in Taiwan. However, project changes are inevitable conditions as they are a fact-of-life during the construction phase. Actually, there are many problems on BIM model management when the project was changed. If the BIM model revision and announcement of updates are not control exactly, the results of as-built BIM models has differently from building. We need an approach to enhance an as-built BIM model change management that it should be complete and systemic including to identified, updated, announcement, and tracked. Configuration management (CM) is most of the project management tool that enables a project to effectively anticipate, manage and execute changes that are inevitable in any project. In order to solve the problems, the major purpose of this research is to propose the approach to enhance the BIM model management integrated with a CM approach for general contractor during the construction phase. The proposed approach includes BIM change control documents and the frameworks to follow change status quickly for the related participants. The proposed approach is then applied in the selected case study in Taiwan to demonstrate the effectiveness in practice. Finally, this study identifies the benefits and limitations, and conclusions are summarized for further applications.

Keywords: BIM, Configuration Management, Building Information Modeling, Construction Phase

1. INTRODUCTION

Building information modeling (BIM) quickly has emerged recently as a hot issue in the construction industry, and it is a new technique (Seo & Ju, 2014). BIM is an intelligent 3D model-based process with which to manage various products that can be help owner to plan, design, construct, and manage buildings (Autodesk Inc., 2015). The new technique not only changes how building drawings and virtual visualizations are created, but also intensely alters all of the key processes and building information transparency. It has dramatically become involved in putting a building together (Eastman et al, 2011). BIM can represent the virtual 3D building, carry detailed information, and identify their relationship with other objects. BIM itself contains huge potential that can be increased value and effectiveness during the construction life cycle of any project. The process means from initial plan and building-up activities to prospect of usage and facilities management and finally demolition. The owners' expectation is a real benefit from managing long-term projects, covering the whole life cycle in terms of sparing investment money and other resources. General contractors (GC) in Taiwan are increasingly adopting BIM approach that is currently managed as 2D in existing construction projects in 3D. However, most of users still use 2D-based products with the related guidelines required for the submission of 2D-based products. The reason for which designers and contractors have to perform 2D and 3D works at the same time, leading to increased construction cost and tasks. Many practical problems are still unsolved in the course of using BIM for a general contractor in Taiwan. Such as the subject of change management that the managing changes effectively is crucial to the success of a construction project, however, regarding to BIM model version uncontrollable and the announcement management of updates unexecuted exactly. Therefore, a manager needs an effective and systematical change management approach to combine with BIM. Managing changes to requirements is essential to minimizing cost and schedule overruns on projects. In order to solve the problems with the models, this study proposes an approach that is applications of configuration management (CM) in BIM model management during the construction phase. The basic purpose of CM is to keep the physical implementation of a product consistent with the documentation that describes how to build it and what it is supposed to do. During product development, manufacturers use CM to track the evolution of a product and its design. CM's ability to control changes to requirements is a major reason for employing it on its projects. The proposed approach doesn't only include the version control of BIM models. Furthermore, the approach focuses the control and management framework of final BIM models management during the construction phase. By summarizing a definition of CM, the research proposed documents and frameworks used in the BIM change management and to follow change status quickly

for the related participants. These are referred to apply CM documents and procedures in BIM. Finally, this study identifies the benefits, limitations, and emergent problems through real cases. Then, conclusions and suggestions are summarized for further applications. We expect the effective use of the proposed approach to significantly help GC develop as-built BIM model management work effectively during the construction phase.

2. BACKGROUND

The concept of BIM has existed since the 1970s. Eastman et al. (2011) defined BIM as a modeling technology and associated set of processes to produce, communicate, and analyze building models. Also, Eastman et al. (2011) purposed about BIM's characterization by four parts including building components, components' data, consistent and no redundant data. All of this is used to simulate and manipulate reality based models to manage the built environment within a fact based repeatable and verifiable decision process that reduces risk and enhances the quality of actions and product industry wide. (NIBS, 2007). Next, the review of the previous researches, as part of the survey of the integration of BIM models and CM, firstly focused on the researches on BIM model management phase that included as-planning management and as-built management. Then, review about CM's definition and the previous researches. Summary of application approaches CM to BIM management. Some of the previous researches focused on as-planning BIM model. To review previous research into automated code compliance, identifies the key issues for future development and examines the causes of information paucity for compliance checking in the current generation of BIM tools (Greenwood et al., 2010). In addition, more of previous researches focused on as-built BIM model to serve as an information repository to store and deliver as-built information. (1) This research group has developed a semi-automated approach, focusing on productive 3D as-built BIM creation for complex indoor environments. The test is feasible by application of the developmental approach to the case study in Korea (Yoon et al., 2015). (2) The research developed a web ConBIM-SM system for the general contractor in order to enhance visual as-built schedule information sharing and efficiency in tracking construction as-built schedule (Jan et al., 2013) (3) To make the as-designed BIM be updated with the construction changes. Proposing to use a laser scanner and a camera was used to capture the construction history and develop a more complete as-built BIM. (Liu et al., 2012).There is very limited research work addressing the BIM management process between as-planning phase and as-built phase. The BIM management process include model change management and version control issues specifically within the construction project management context. This paper provides an approach to help engineers decide on which progressively captured point cloud data to combine. Then using point clouds that captured by laser scans can be used as a reference to update an as-designed BIM into an as-built BIM (Gao et al., 2015).

PMBOK guide fifth edition defines Configuration Management as "A subsystem of the overall project management system. It is a collection of formal documented procedures used to apply technical and administrative direction and surveillance to: identify and document the functional and physical characteristics of a product, result, service, or component; control any changes to such characteristics; record and report each change and its implementation status; and support the audit of the products, results, or components to verify conformance to requirements. It includes the documentation, tracking systems, and defined approval levels necessary for authorizing and controlling changes" (PMI, 2013). The standard 649-1998 of American National Standards Institute and Electronic Industries Alliance (ANSI/EIA, 1998) delimit the CM that is a management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design and operational information throughout its life. There are four parts in the CM (see Figure 1). Only limited research has CM issues in construction. These reference topics have well-diversified. (1) To identify how configuration management is currently being developed and used by transportation systems. In addition, it is expected that this synthesis will serve as a resource document for transportation departments just beginning to apply configuration management (Smith, B. L., 2003). (2) The Turin Urbano is a mass transit system that has recently been constructed to serve the urban parts of San Juan, Puerto Rico. CM was employed in the later stages of the project to better manage project documents, and to provide an improved audit trail of change order work (Admire et al., 2010) (3) It is the request for proposal for the Portal Bridge Capacity Enhancement RBCE project that included a requirement to implement CM and to provide a records management and control system for the project (NJT/Amtrak PBCE RFP., 2007) (4) At the Los Angeles MTA, after experiencing significant budget overruns in the first segment of the system, a configuration management system was implemented to better control changes in the second segment. There are costs associated with CM implementation, including the purchase of a document management system and the costs of enforcing a formalized system (Steinberg et al., 2007).
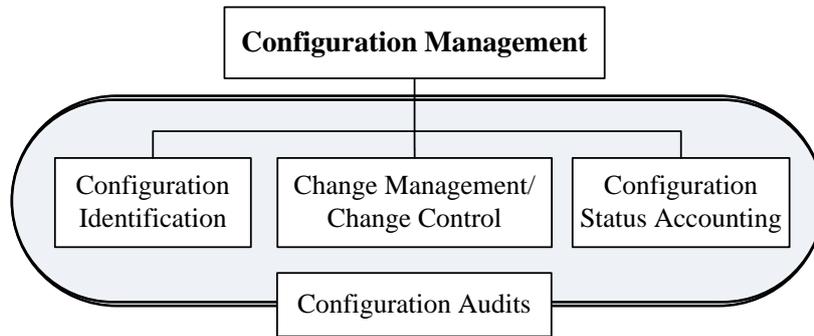
Figure 1. The CM process by transportation management center pooled-fund study project (FHWA, 2003).

3. RESEARCH CONTENT

As shown in Figure 2, there is a framework of the BIM model with phase change. The BIM models are created by GC. There are three phases of BIM model that includes as-planning drawings, as-built drawings and final as-built drawings. The as-planning drawings will be going to the next phase through to update and revised the BIM Model. After that, Inspection and revised the BIM Model ensures the completeness and accuracy of a final as-built model. The study is a proposed approach that application CM to manage the BIM Model change course during the as-planning drawings phase to the as-built drawings phase for GC.
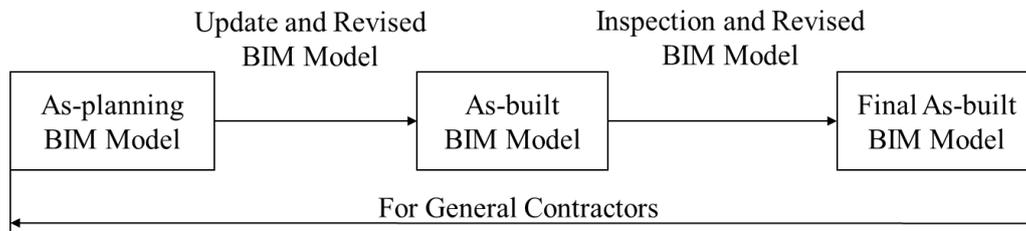

Figure 2. The framework of the revised as-BIM model for the owner.

According to the discussion of the CM definition, the study process of the proposed approach for BIM model management includes identification, change control, status accounting and audit. The process definition and introduction are shown in Table 1. The focus of this study will be on identification and change control for BIM model management during the construction phase.

Table 1. The framework of proposed CM approach to BIM model management

Denomination	Description of definition
BIM- configuration identification	Basis of the documents that including the summary table of BIM issues, the BIM correction confirmation form, BIM correction of change record, etc., for identification of BIM model requirements and correction.
BIM- configuration change control	According to the documents to manage consistency the BIM model of functional and physical, and establishing the frameworks.
BIM- configuration status accounting	BIM model change status documents and the frameworks to be executed in the simple and easy way to follow change status quickly for the related participants.
BIM- configuration audit	To confirm consistency of the BIM model performance, functional, and physical attributes with its requirements, design and operational information.

The BIM model management relationship includes on-site engineers, BIM engineers and BIM managers. The on-site engineer will return problems, when the first of construction detail drawing submitted by the department of BIM. The hypothesis in this research paper of construction detail drawing revised by BIM model. If the BIM model need change, BIM engineer needs to revise correction the BIM models. However, before revising the BIM model, the BIM manager needs to make a decision whether the BIM objects should revise or not. The BIM objects, correction include modifying and creation. The three parts may discuss about the BIM model correction one another, and BIM manager summarizes a resolution afterwards. If the BIM model needs to revise, it will be going to change control of BIM model. The relationship of responsibility each three posts (see Figure 3).
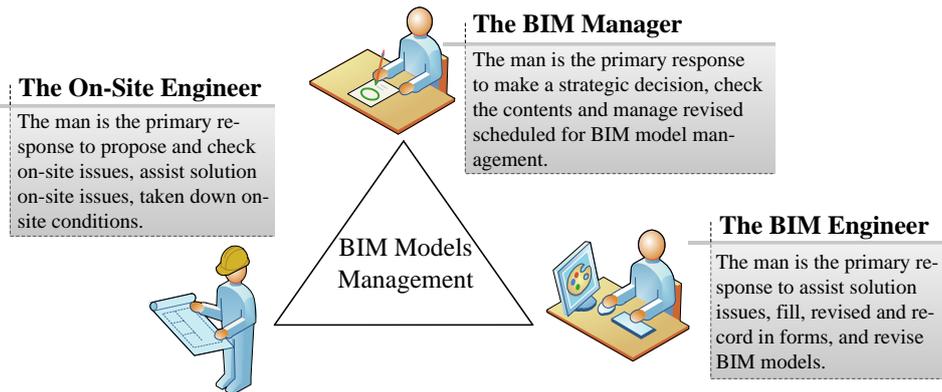
Figure 3. The relationship of BIM model management.

Engineering change and/or adjustments are inevitable as they are a fact-of-life during the construction phase. (Hao, Q., 2007). However, if the construction detail draws are not correction, construction change may cause of wrong direction. Furthermore, the final as-built BIM model would be deviating original as-planning BIM model. In order to shorten correction time and communication gap of BIM, the research has assumed that the BIM engineer need to dispatch on site. In addition, the correction should be to delete before constructing. The shop drawing should be the basis of BIM model. All of the construction plan and process should base the shop drawing. BIM model applies CM procedures, as described below and as shown in Figure 4.

Step 1: Identification problems and requirement.

The construction detail drawing submitted by the department of BIM, but it may still many problems. These kind of problems are uncertain. When the problems are discovered, the problems discoverer needs to fill issue in the Summary table of BIM issues; Then, the BIM manager makes a decision whether the BIM objects should revise or not. This discoverer includes on-site engineer, BIM engineer and BIM manager. If the issues need to revise BIM models or create the BIM objects, the BIM manager would message the problems discoverer that would be an applicant. The applicant needs to fill in the BIM model change application and propose some suggestion. Moreover, the BIM manager could message others ask some suggestion and the applicant assists to fill others suggestions in the form of the BIM model change application. When the application has done, the next need to differentiate between on-site engineer and BIM engineer who the applicant is. If the applicant is an on-site engineer, the application can go to the next step immediately. When the applicant is BIM engineer, the application need to determine whether the on-site engineer need to check or not.

Step 2: Confirmation revised or creation the BIM objects

The BIM engineer needs to according to the application, and fill in the BIM correction confirmation form. This form has to explain the BIM model correction and new items that include scope, change information and so forth. Then, the BIM manager needs to confirm the contents of the form that is identical to the BIM model change application. If the BIM correction confirmation form has a few doubts, the BIM engineer should review and correct until clear.

Step 3: Inspection the BIM objects

When the BIM correction confirmation form is approbated, the BIM can start to change activities. Then, the BIM engineer fill in the BIM correction of change record, after the BIM models has corrected and completed exactly. The next need to differentiate check scheme between A and B. The A check scheme need both of the on-site engineer and the BIM manager to check. The B check scheme just needs the BIM manager to check. This discrimination way can refer to an applicant of the BIM model change application. If the BIM correction models haven't matched the BIM correction confirmation form, the BIM engineer should review and correct until conformation.

Step 4: Announcement and updated

The BIM engineer response to update the BIM model news, after the BIM model correction has done. Then, the on-site engineer can basis the new version of BIM models to build and fill the construction process in the construction required for BIM models change. This record is unnecessary if no constructing.

Step 5: Closed

The BIM engineer can base on the form which is the construction record or the correction of change record. When the BIM engineer to fill in the BIM change final report, announce the closed news.
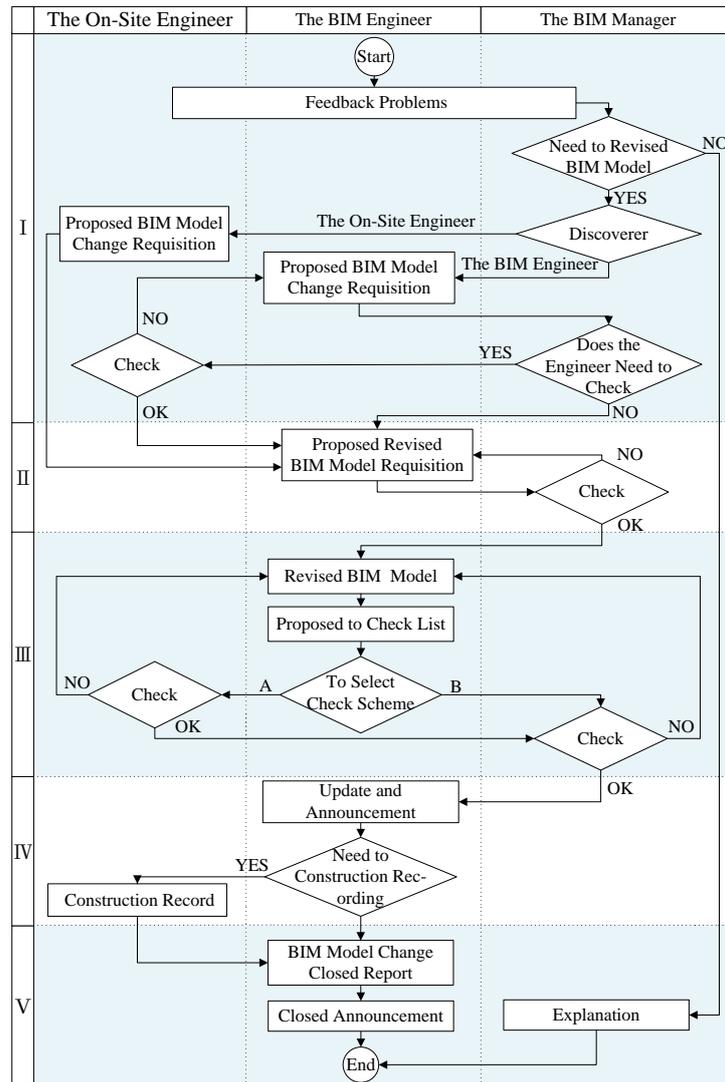

Figure 4. The process of apply CM for BIM Model Chang Management.

There are six type documents described are in the Table 2.

Table 2. The documents apply CM to the BIM model management.

phase	Name	Type of Code	Description
1	Summary table of BIM issues	SUM. Code_Date	The table summed up the BIM model problems. It can understand elementary conditions, and follow up the issues.
	BIM model change application	0. Code_Date _ Issue Code _v. Version No.	The applicant needs to according to the approved problem, to fill in the form, and to propose some suggestion.
2	BIM correction confirmation form	A. Code_Date _ Issue Code _v. Version No.	The BIM engineer need to according to the application, and fill in the form. This form has to explain the BIM model correction and new items that include scope, change information and so forth.
3	BIM correction of change record	B. Code_Date _ Issue Code _v. Version No.	The BIM engineer fill the form, after the BIM models has corrected and completed exactly. Then, the auditor need to confirm this correction that is matched the BIM correction confirmation form.
4	Construction record for BIM models change	C. Code_Date _ Issue Code _v. Version No.	The on-site engineer can basis the new version of BIM models to build and fill the construction process in the construction required for BIM models change. This record is unnecessary if no constructing.
5	BIM change final report	1. Code_Date _ Issue Code _v. Version No.	The form recorded the BIM model change courses for reference.

4. CASE STUDY AND DISCUSSION

As shown in the Figure 5, the case study relates to an educational building project made up of concrete reinforced steel that has 2 floors of roof protrusion and 7 floors on the ground; it is located in a college in Taipei,

Taiwan. The GC needs to utilize BIM and submit final as-built BIM models in this case. The scope of the BIM model includes mechatronic engineering and civil engineering. We would like to check the study propose an approach that is, an application of CM in BIM model management during the construction phase. The case study primary discussion anything wrong conditions. It could happen when this study's method is introduced into the case study. According to the experience of introducing in this case, we have some reviews of the application process.
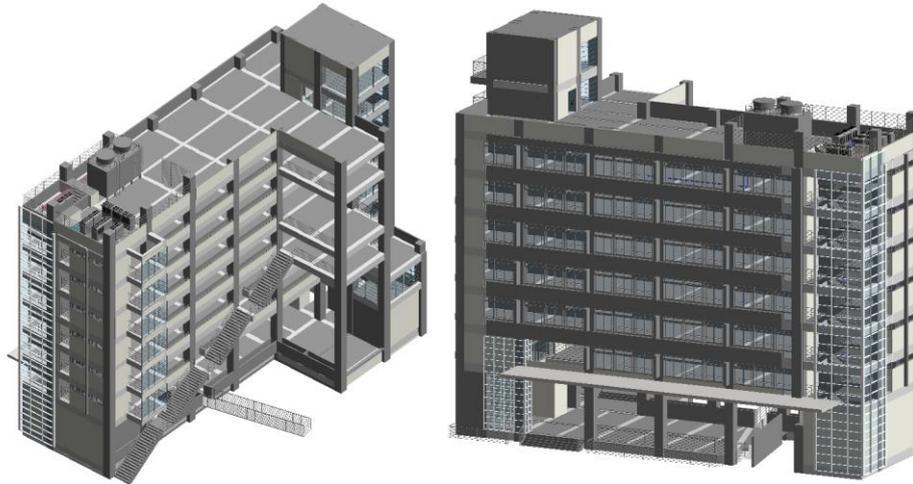

Figure 5. The BIM model using the case study.

In order to assist the document's introduction of the study approach in this case study, the study uses different drawing that has an angle of views of the BIM model, and importance of annotation. As shown in the Figures 6 and 7 are the result of the case study tours are the summary table of BIM issues and the BIM correction confirmation form.

BIM CORRECTION CONFIRMATION FORM	
Document code: A. SEB_080715_8RFQ01_v1.02	Page 1 , total 1
Basic information	
Project/ Type: The six education building/ Building	Submission date: 2015 / 07 / 08
Applicant / Status: Mr. Hwang / BIM Engineer	Due date: 2015 / 07 / 20
Version: SEB_010715_v5.07	
Problem description: The roof ventilator area is not enough to put the main equipment. Does it need to correct the stairs that are connection the roof ventilator area? Dose other plan?	
Problem location：	
Information of correction confirmation	
Check	
☑ Pass, suggest: none. ☐ Correction, suggest: Auditor sign / Status / Date:　BIM manage / Mr. Lin / 20150711	
Note	
An annex of the change requisition documents by architect	
Applicant　sign　/　Date：　Hwang　/　20150708	

Figure 6. The BIM correction confirmation form used in the case study.

<table>
<tr><td colspan="2" align="center">**SUMMARY TABLE OF BIM ISSUES**</td></tr>
<tr><td colspan="2">Name/ Code：The six education building / SEB10411   Page 1 , total 1</td></tr>
<tr><td colspan="2">Question 1</td></tr>
<tr><td>Name / Status: Hu, H. T. / On-Site Engineer
Date: 2015 / 07 / 03
Version: SEB_010715_v5.07
Problem description: The roof ventilator area is not enough to put the main equipment. Does it need to correct the stairs that are connection the roof ventilator area?</td><td>Re. date: 2015 / 07 / 04
Result:
☑ Agree, application code: SEB_(Date)_8RFQ01
, recommend: around of Stairs on the roof will correct together.
☐ Not agree, Suggest:</td></tr>
<tr><td colspan="2">Question 2</td></tr>
<tr><td>Name / Status: Mr. Huang / BIM Engineer
Date: 2015 / 07 / 04
Version: SEB_010715_v5.07
Problem description: On floor of 2 to 7 and face to east, the window of the classroom need to change type of sash style.</td><td>Re. Date: 2015 / 07 / 06
Result:
☐ Agree, application code:
, recommend:
☑ Not agree, suggest: the issues is not influence that has few different in function.</td></tr>
<tr><td colspan="2" align="right">Final Update：2015 / 07 / 06</td></tr>
</table>

Figure 7. The summary table of BIM issues used in the case study.

When the case applies, we firstly met the form that is the summary table of BIM issues, and discovered some issues. When the same problem appeared on different BIM model, location or BIM issue summary tables, it may cause difficult to manage plenty of documents and to revise the BIM model frequently. These of large documents will cause not easy to track, manage and integrate with all. Furthermore, it could happen to human errors. The research of suggestion is for the BIM manager that is integration the same type of issues and filling in the same application, but these issues code should be annotated to the note of the application. When the BIM correction of change record has not checked with BIM manager, the form can increase the requirements. When the form increased requirements before it has check by BIM manager. The BIM manager needs to repeat and check new parts. The form of BIM correction of change record needs to fill in the due date that is not mean closed of project and case date but the BIM model correction by checking exactly. When the case has the construction record for BIM models change, the achievements of audit may not be good and real. Then, the revised scheduled may influenced by the unreal date. In order to use the version of BIM models exactly, beginning reviews the BIM model need to take notice whether someone has used and reviewed or not. If either of BIM objects also are waiting to review on different basis forms that is on the same floor and adjacent to the BIM correction objects, during the BIM model correction, it can correct at the same time. The other of BIM objects correct at the same time, but it needs to fill in the difference of BIM correction of change record and to note the form code in the required documents for the trail.

5. CONCLUSIONS AND SUGGESTIONS

The major conclusions are summarized as follows:
（1）The main purpose of this study is to enhance the effectiveness of BIM implementation. Then, in order to record and control the BIM model change management for practical cases, the research of proposed approach applies CM to BIM model management for a general contractor during the construction phase. It would be good to control and trace BIM models for owner. Then, this approach can use for inspecting the degree of completion for final BIM models. It could be used for deal disputes and treat as evidence.
（2）The BIM manager can amalgamate similarly issues to create lots of documents and to avert complex for document management. The suggestion about searching file is that need to note the code of issues.
（3）The form of BIM correction of change record can amalgamate similarly issues and application documents but the applicant need to note the form code of summary table of BIM issues. When the form has checking by BIM manager, If the new object increases on the form after the BIM manager has done to check, the update form would be note the new contents and check again.
（4）About the information of due date means to pass the inspection date that fill in the form of BIM correction of change record. It is different from reality correction completion and case closed. If the due date means the case closed that will affect the BIM manager to identify what is reality progress and achievement.
（5）Before the BIM models are correct, the BIM engineer should check the version of BIM models and whether the presence of BIM models is revising or not. Furthermore, the chronicle's version of the BIM correction confirmation form maybe is different from the present one.
（6）If other BIM objects is nearby or neighboring the correction during the correction of BIM models, the suggestion of this study is revised simultaneously. These BIM objects need to fill in the differently of BIM correction of change records in accordance with the BIM correction confirmation form, and to annotate the correlation between these BIM objects for checking.
（7）The primary proposed approach of this research primary is used to BIM model management for a general contractor that is no consideration about exterior change management, but the change request can fill in the

note about the code of documents for the owner that is convenient to the trail and confirmed.
（8）Application of CM in BIM models management is different from versions control. This approach is not only consideration the versions change management but also integration of administration and technique, documents control and trail, and etc. Moreover, the plan of CM has to include scheduled management, contract management, training and etc. for BIM models management.

This paper makes some suggestions for further research, as summarized below:
（1）The suggestion of this research proposed approach about the final as-built BIM modes management that is an application of CM.
（2）Further research can focus on the differing organization; for instance, the CM management and BIM model management is not a general contractor but a proprietor. The kind of further research can base on this study of the proposed approach to apply to the other case study.
（3）Further research can develop APIs about the proposed approach of software to replace manual operation, assignment, and thus enhance BIM model management process and manage work effectively.

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