Mapping Work Process and Information Exchange of Construction Entities for BIM Implementation: Case Study of an Academic Institute

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ABSTRACT

Building Information Modeling (BIM) represents modern construction management concepts that can be integrated in every phase throughout the facility lifecycle. Not only can BIM enhance the performance and efficacy of the construction project delivery process, but it can also improve the quality of the delivered products and reduce various forms of project waste. The principal concept of BIM is the collaboration among all stakeholders in different phases of the facility lifecycle to manage relevant information efficiently. However, this data sharing concept is extremely challenging for the construction industry where the project delivery process is unstructured and fragmented. Thus, the primary step for implementing BIM in any construction entity is to assimilate current organizational conditions, especially its work processes and information exchange. This paper investigates the work process and information exchange in construction projects by focusing on the project owner. The Office of Physical Resources Management (OPRM) at Chulalongkorn University (Thailand), which is responsible for developing the university's construction projects, was chosen as a case study to illustrate an application of the proposed methodology. General information about the OPRM as it relates to facility design and construction was first gathered, including organizational structure, the stakeholders involved, their roles and responsibilities, and current information exchange. The phases of a construction project were defined by adapting from those in the *OmniClass Construction Classification System* (OCCS), which is used widely in the construction industry. The collected information was analyzed and organized to map important work processes and information exchanges among the stakeholders throughout the project lifecycle. Due to the complexity of workflows, the Business Process Model and Notation (BPMN) was adopted to illustrate and

communicate the results. A key feature of the BMPN is the formal documentation of information exchange requirements among the stakeholders in terms of paper and electronic documents. The results of this formal mapping has proven instrumental in helping all parties, especially project owners, comprehend the project delivery process thoroughly so that the appropriate elements can be modified to support and accommodate the transition to BIM implementation.

INTRODUCTION

Building Information Modeling (BIM) represents modern construction management concepts that integrate information technology with construction business procedures (Succar 2009). BIM exploits Computer Aided Design (CAD) technology to interconnect all building elements (objects) together, each of which is designed to contain necessary information (Smith and Tardif 2009). Several countries have issued BIM standards or guidelines, such as the National Building Information Modeling Standard (NBIMS) of USA, for the exchange of information in building construction to support construction business processes. BIM can be applied to every phase throughout the facility lifecycle. Not only can BIM enhance the performance and efficacy of the construction project delivery process, but it can also improve the quality of the delivered products and reduce various forms of project waste (Arayici and Aouad 2010). In many construction projects, however, BIM has been adopted primarily for architectural design by creating 3D models used mainly for visualization. As reported, 3D visualization may not be the most effective application area (Khemlani 2007). Instead, better information modeling and comprehension of work processes may be more vital.

The principal objective of BIM is the effective collaboration among all stakeholders during different phases of the facility lifecycle brought about by the efficient management of relevant information. This goal of sharing information efficiently to improve effectiveness is extremely challenging for the construction industry because often the project delivery process is unstructured and fragmented. For this reason, it is the project owner (or its representative) who often plays the pivotal role in implementing BIM in a building construction project. The first steps that the owner must take in this direction are to assimilate its own organizational conditions, especially work process and information exchange (Sharif 2012).

This paper presents a proposed methodology and the results concerning the assimilation of work process and information exchange for a particular project owner—the Office of Physical Resources Management (OPRM) at Chulalongkorn University (Bangkok, Thailand). The collected information was analyzed and organized to map important work processes and information exchanges among the stakeholders throughout the project lifecycle. The outcome of this formal mapping has proven instrumental in helping all parties, especially project owners, comprehend the project delivery process thoroughly so that appropriate elements can be modified to support and accommodate the transition to BIM implementation.

MAPPING WORK PROCESS AND INFORMATION EXCHANGE

In this paper, construction work process and information mapping is divided into two main stages, as shown in Figure 1: (a) construction process development, and (b) verification. The *construction process development* stage consists of three steps:

(1) *Gather Information*. This step is to collect information that is relevant to construction project development from two main sources: documents and interviews. The information includes organizational structure, stakeholders involved, their roles and responsibilities, and current information exchange.

(2) *Establish Project Lifecycle*. This step is to establish the phases of construction project development, which are modified from those in the *OmniClass Construction Classification System* (OCCS). The building lifecycle is broken down into a number of stages according to the sequence of construction activities (Construction Specifications Institute 2006).

(3) *Construct Process Map*. This step is to create a construction process map based on the information gathered in Step 1 and the project lifecycle defined in Step 2. The information gathered in the first step will be analyzed and organized to illustrate important work processes and information exchanges among the stakeholders throughout the project lifecycle. In general, business entities create process maps as part of business process renovation, the results from which are used to support organizational changes and improve their business models, strategies, and goals (Trkman and Groznik 2006; Popovic et al. 2006). The Business Process Modeling Notation (BPMN) is a standard tool for developing such business process maps. The BPMN is considered a common language that allows all business entities to communicate clearly and efficiently (Business Process Management Initiative 2004). Herein, the BPMN diagram is used to depict workflow and information flow of construction entities. In a BMPN diagram, *horizontal swim lanes* are used to illustrate each entity's roles and responsibilities, whereas *vertical swim lanes* are used to define the timeline of project lifecycle.

Once construction work process and information exchange mapping is complete, the results will then be verified to ensure the completeness and correctness of the mapping results.

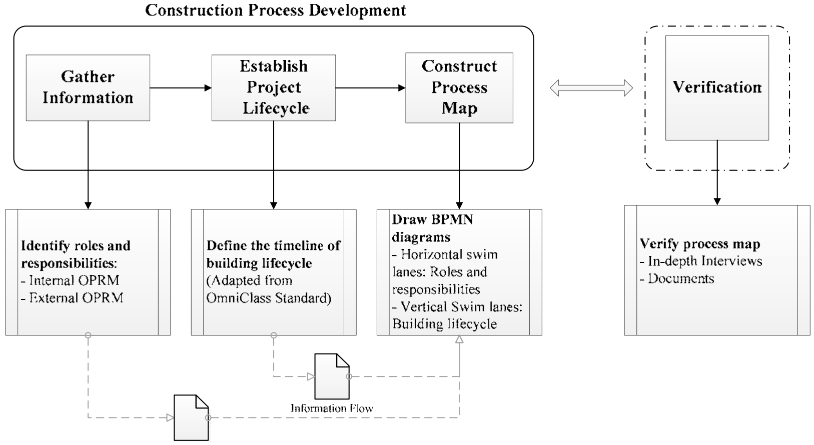

Figure 1. Steps of work process and information exchange mapping.

APPLICATION: AN ACADEMIC INSTITUTE

The Office of Physical Resources Management (OPRM) at Chulalongkorn University (Thailand) was chosen as a case study to illustrate an application of the proposed methodology. The OPRM is responsible for developing the university's construction projects with a total contract amount of about $80 million annually.

Gather Information. Various types of information were gathered to create a construction process map of the OPRM. The first steps were to identify all stakeholders in OPRM construction projects and to organize them into two categories: internal stakeholders and external stakeholders. The internal stakeholders are units within the OPRM, which include the Master Plan Unit (MPU), the Design Unit (DU), and the Construction Management Unit (CMU). The external stakeholder is the Procurement Section of the university. Once these stakeholders were identified, their roles and responsibilities were compiled and listed (last column of Table 1).

Establish Project Lifecycle. The lifecycle of OPRM construction projects was subdivided into four main stages, namely, the conception stage, the design stage, the procurement stage, and the execution stage. This project phasing follows *OmniClass* Table 31 − *Phases and Sequence of Work in Project* (Construction Specifications Institute 2006). Table 1 shows the roles and responsibilities of each stakeholder in each stage of the lifecycle of an OPRM construction project. For example, in the conception stage, the roles and responsibilities of the Master Plan Unit (MU) entail providing the project concept, estimating the budget, and surveying.

Construct Process Map. The project timeline and the information identified in the previous steps were mapped using a BPMN diagram. Two types of information were analyzed and organized to create this diagram: work flow and information exchange. As a result, the diagram displays both the sequence of construction activities that were performed throughout the project lifecycle stages, as well as the information exchange among the stakeholders for each construction activity.

The notation used to map information exchange in a BPMN diagram communicates the following two elements:

1) *Detailed information*. In a BPMN, the notation for each construction activity contains detailed information associated with that activity.
2) *Forms of documents*. Three forms of documents in the projects were:
   (1) *Official documents*. Official documents include those required by law or by the university's standard operating rules and regulations. These documents must be signed by the persons authorized by the university charter to approve or acknowledge receipts.
   (2) *Supporting documents*. Supporting documents contain the details of facts, data, and information for performing each task. Examples of these documents are meeting minutes and reports.
   (3) *Electronic documents*. Electronic documents are prepared in an electronic format and stored in an entity's database system. Typical

formats for these documents include text, spreadsheet, Computer-Aided Design (CAD), and Portable Document Format (PDF).

Table 1. Project stages, stakeholders, and their roles and responsibilities

Stage	Stakeholder	Role and Responsibility
Conception Stage	Master Plan Unit (MPU)	• Concept • Budget estimating • Surveying • Project approval • Design team selection • Data recording
Design Stage	Design Unit (DU)	• Project planning • Spec. preparation • Preliminary design • Design development • Blueprint / copying • Cost estimating • Estimating standard price • Drawing inspection • Data recording • Pre-procurement
Procurement Stage	Procurement Section	• Procurement
Execution Stage	Construction Management Unit (CMU)	• Construction planning • Construction preparation • Group meetings • Construction supervision and coordination • Reporting • Facility testing • Project delivery • Data recording • Defect notification

Figure 2 presents a construction process map of the OPRM. It illustrates work processes and information exchanges along the project timeline. The *horizontal swim lanes*, which are used to illustrate each stakeholder's roles and responsibilities, were categorized into the internal stakeholders and the external stakeholders. The *vertical swim lanes* were divided into four stages, as discussed previously. Part of Figure 2 is enlarged to display the details of work process and information flow of *Act.18 Preliminary Design Preparation*. In *Act.18*, technical officers prepare architectural drawing drafts that will be transmitted from the design team to the *Design Unit (DU)*

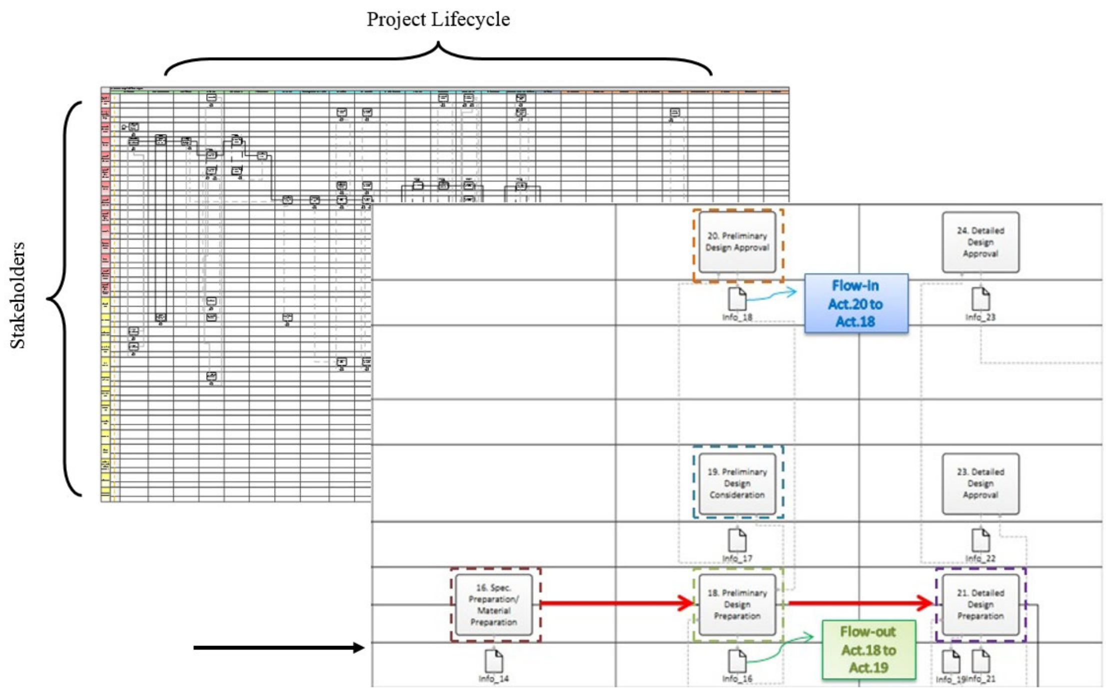

Figure 2. Process map of the OPRM's construction projects.

for consideration (*Act. 19*). The Director of the Architecture and Infrastructure Section is responsible for checking and approving the proposed drafts (*Act. 20*), which will further be transmitted for detailed design (*Act. 21*).

As can be seen, the work flow associated with *Act. 18* begins from *Act.16 Specifications Preparation/Material Preparation* and ends at *Act.21 Detailed Design Preparation*, as shown by the thick arrow line. Information associated with *Act. 18* entails *Info_16* (architectural drawing) that flows out from *Act.18* to *Act.19* and *Info_18* (architectural drawings, consideration documents, and design approval form) that flows in *Act.18* from *Act.20*.

Verify Process Map. To ensure the completeness and correctness of the mapping results, we conducted in-depth interviews with the experts (unit chiefs of the three units) who are familiar with the work flow and information exchange within such construction entity and incorporated their feedback into the final model. This verification process was modified from the BIM guideline prepared by the Computer Integrated Construction Research Program (2013) and consisted of two parts:

1) The work processes were presented to the Director of the Architecture and Infrastructure Section to check the correctness and completeness of the overall processes. All comments and suggestions were integrated for editing and deriving the final version of the process map.
2) The information exchange among stakeholders was verified by conducting in-depth interviews to ascertain its completeness and correctness.

DISCUSSION

The process map for the OPRM contains 70 activities and 72 information exchange notations. Most of the documents used were paper-based and that many activities were redundant. At present, the OPRM does not exploit information efficiently to add value to its business operations. Even though the OPRM has a clear goal to be a BIM-based organization soon, many of the activities did not comply with BIM concepts and technology. In addition, most personnel still have limited knowledge of BIM technology. A redesign of existing work processes is necessary for the OPRM to achieving its BIM goal. In particular, workflow and information flow must be reengineered to comply with BIM concepts. In addition, the use of electronic documents must be promoted to accommodate information exchanges among the stakeholders through BIM (National Institute of Building Sciences 2007). These issues need to be investigated further.

The introduction of advanced techniques needs to be explored to provide additional improvements to construction work process mapping. An example is BPMNs which allow mapping the graphics of notations to execution languages, particularly Business Process Execution Language for Web Services (BPEL4WS), an XML language designed for the execution of business processes (Business Process Management Initiative 2004).

CONCLUSION

The architecture, engineering, and construction (AEC) industry is making a rapid transition from CAD to the BIM era. Project owners are the parties that stand to gain most from the benefits of BIM and should take the initiative to streamline their project delivery processes to comply with BIM concepts. As the very first step, owners should analyze and reengineer their work process and information exchange within their own organization to ensure their compliance with BIM. In this paper, we present the Business Process Modeling Notation (BMPN) that can be used to map the work process and information exchange along the project timeline within a project owner organization. The application of BMPN was illustrated by mapping the work process and information exchange of the Office of Physical Resources Management (OPRM) at Chulalongkorn University, the unit responsible for the construction of all academic building projects on campus. The results of this formal mapping has proven instrumental in helping all parties, especially project owners, comprehend project the building delivery process thoroughly so that the appropriate elements could be modified to support and accommodate the transition to BIM implementation.

ACKNOWLEDGMENT

The authors are very grateful to the National Research University Project of CHE (CC496A) Chulalongkorn University, the Stimulus Package 2 (SP2) of Ministry of Education under the theme of Green Engineering for Green Society, and the Graduate school of Chulalongkorn University under "CU GRADUATE SCHOOL THESIS GRANT" scholarship for funding this research project.

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