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A CASE STUDY ON IMPROVING STANDARDIZATION IN THE CONCEPTION PHASE BY DEVELOPING TOOLS AND PROTOCOLS

Michaud, Martin[1,2], Forgues, Daniel[1] and Ouellet-Plamondon, Claudiane[1]
[1] École de Technologie Supérieure, Canada
[2] martin.michaud.2@ens.etsmtl.ca

Abstract: In the Architecture, Engineering and Construction (AEC) industry, the variability nature of construction projects leads to the presence of waste. The standardization of activities and processes can help reduce variability and thus reduce the amount of waste. This paper presents an action research approach to develop and implement a framework to help creating an improved visual mapping of the information flows between the departments of an architectural firm. The aim is to use the principles of Value Stream Mapping (VSM) from Lean Production and Building Information Modelling (BIM) processes to improve standardization in the information flow. The focus is on the information flow between the various departments of an architectural firm. This study contributes to the field through the development of a framework used to improve standardization in the information flow. Moreover, the findings presented offer practical implications by helping with the improved interoperability of interdisciplinary professionals work with standardized processes and activities.

1 INTRODUCTION

The current problems in the Architecture, Engineering and Construction (AEC) industry are caused partly to difficulties in communication and information transmission, coordination and teamwork issues (Weippert and Kajewski 2004). A recurring problem is the low productivity due to the fragmented nature of construction projects. This fragmentation leads to the presence of complications, risks and uncertainty making the transmission of information difficult. According to Vernikos, Goodier, and Gibb (2013), inefficient collaboration, coordination and communication represent obstacles in the improvement of productivity. Building Information Modelling (BIM) was introduced in the AEC industry to tackle this problem by improving interoperability and collaboration among parties involved in construction projects (Eadie et al. 2014). BIM approach reduces information loss and centralize it, aiming to decrease fragmentation and inefficiency. The notion of flow is crucial when using BIM. Indeed, BIM contributes to translate the client's value proposition into a successful project by implementing a continuous information flow (Al Hattab and Hamzeh 2013). The notion of flow is also inherent to the lean thinking approach with several tools developed to improve the materials and work flows. The Value Stream Mapping (VSM) is an essential tool used in the implementation of lean production (Shararah, El-Kilany, and El-sayed 2009) to improve materials and work flows. The goal of VSM is to create a map of any productive process by focusing on its entire value stream to identify and eliminate wastes from the production (Braglia, Carmignani, and Zammori 2011). Today, there is a gap in the research concerning the benefits of BIM in the design stage of construction projects. Indeed, a lot of work shows tools and techniques to help with the implementation of BIM during the construction phase of construction projects, whereas BIM in the design stage remains a subject not enough documented. The VSM from lean production appears as an attractive tool to help with this issue.

This paper presents a case study highlighting the potential for standardization in the information flow during the design phase of construction projects. With this research, the main objective is to demonstrate the need to improve the information flows and despite the fragmented nature of the AEC industry, provide the standardization as a way to improve the information in the design phase. The case study focuses on the information flows of an architectural firm composed of several departments and many various construction projects. The focus is on the input and output of information regarding the creation of plans during the design phase from concept to definitive models. The architectural firm has implemented this project to help them in their transition to the BIM with the implementation of good methods right from the start. Using Value Stream Mapping (VSM), a mapping of the information flows of the various departments is done to identify common activities and/or information across the departments to implement standardized tools and protocols in their information flows. By improving standardization, the aim is to decrease the amount of waste in the internal processes of the firm, thus time and money.

2 REVIEW

Implementing BIM in a construction project also means moving from a document-centric approach to an information-centric approach. BIM has been introduced in the construction industry to improve interoperability and collaboration among parties involved in construction projects (Eadie et al. 2014). However, several issues can be observed with BIM collaboration due to the quality and quantity of information exchanged between parties involved, the resistance to change, the lack of understanding of the entire information flows process and the lack of common shared vision (Forgues et al. 2016). The traditional way in construction is based on producing and exchanging information through documents. From a Lean perspective, it is also called “push planning.” This kind of approach is usually done in silos with little communication with the other actors of a same process. According to Crotty (2013), a model-based design (information-centric approach) in the design phase will give tremendous advantages over a document-centric approach. Indeed, there is a better and earlier coordination between all the actors in the design phase, an improvement in the basic design processes giving the ability to test and analyze the design and the most important aspect is a great improvement in the quality of design information produced. The transfer between these two approaches requires major changes of existing processes. Winch (2010) theory and (Koskela 2000) theory of production bring both useful inputs to better understand the impact of implementing these changes.

Several tools and techniques developed in the production industry were transferred to the AEC industry. One of the best known and used method is lean construction adapted from lean production. Both approaches embrace Lean Thinking which core concept is to eliminate waste from processes and improve productivity (Gerber, Becerik-Gerber, and Kunz 2010). Lean production and lean construction are based on similar principles. However, the implementation of the two is different due to major differences between them. The physical features of the end product differ and, compared to manufacturing, construction can be defined as on-site production, one-of-a-kind and complex project (Salem et al. 2006). Lean construction brings advantages the AEC industry; however, its focus is made on the construction phase. Consequently, various tools developed to adapt lean thinking to the construction, such as the Last Planner System (LPS) (Ballard 2000), are focused on improving productivity in the construction phase by improving the workflow. The same can be said about (Koskela 2000) theory of production (TFV Transformation-Flow-Value generation) that provides a link between value generation and the concept of flow to determine the sources of construction problems and the waste generated. Indeed, the theory focuses on the problem occurring during the construction phase.

The Value Stream Mapping (VSM) is an essential tool used in the implementation of lean production (Shararah, El-Kilany, and El-sayed 2009). VSM had a major impact in manufacturing over the years. Apart from helping to identify and eliminate sources of waste (Rother and Shook 1999), VSM also improves productivity (Seth and Gupta 2007) and identifies opportunities for improvement (Singh, Garg, and Sharma 2011). The mapping of processes is not only about material flows but also about information flows (Braglia, Carmignani, and Zammori 2011). In the literature, a large amount of research can be found on BIM, Lean Construction and VSM. However, only a few researches studied the use of VSM with BIM or Lean Construction. Moghadam, Alwisy, and Al-Hussein (2012), have been able to integrate BIM and Lean

Construction on a modular construction manufacturing process. The authors clearly state that a Value Stream Map of the production in a factory was created for the research. The authors show that VSM and BIM are compatible and the combination allowed identifying waste on several activities of the factory. The results from this study are encouraging; however, once again the focus was not on the design phase and was only focusing on the workflow of the process.

This literature review makes it possible to determine that there is clearly a knowledge gap. First, there are a lot of tools or approaches from other industries available to improve processes in the construction industry. These tools and approaches can be used to improve the information flows but the focus is usually made on the materials and workflows due to the persistence of keeping the traditional way of a document-centric approach. Second, there are currently several approaches developed to improve the various flows, however, the focus is mostly on the construction phase. These tools and techniques provide a framework or steps to follow to improve aspects of the construction project in a specific phase. Because of a lack of tools developed for the design phase, there is currently no framework available to improve the design process. Third, for the moment, during the design phase, the various actors of a same process still tend to work in silo and push their information toward the next actor in line. The traditional nature of construction projects is to provide information via documents (plans, budget, estimate, etc.) through a document-centric approach creating barriers to communication and coordination between the different actors of the project (Isikdag and Underwood 2010). Because BIM requires an information-centric approach with the centralization of information, the traditional push document-centric approach makes it hard to implement BIM in the design phase.

3 METHODOLOGY

This study uses an investigation method based upon an action research approach. The aim of this ongoing research is to identify activities or information within the design process of an architectural firm possible to standardize between projects to reduce the presence of waste within the information flows. The research protocol was designed to help the participants model the information flows between their department, the other departments of the firm and other parties involved in the process throughout the design phase of construction projects realized by the firm. To represent accurate and consistent results from the different departments of the firm, the mapping is based on the standard graphic of the Business Process Model and Notation (BPMN).

This research is organized and separated into three main steps (see figure 1). Within each step of the research, a cell composed of members of the architectural firm is implicated in the process. The role of each cell is to help provide data and information during each step of the process.

1. **Thinking**: this step helps mapping the information flow as it is, providing a clear description of the current state of the process of a generic construction project in this firm. Furthermore, it helps identifying possible sources for standardization in the current state.
2. **Operationalization**: this step corresponds to the development of the Future State Map of an improved version of the existing process, including the principles of VSM and the notions of BIM processes to reduce waste in the information flows.
3. **Diffusion**: this last step is necessary to implement the new tools and information developed to inform and allow the employees to use them.

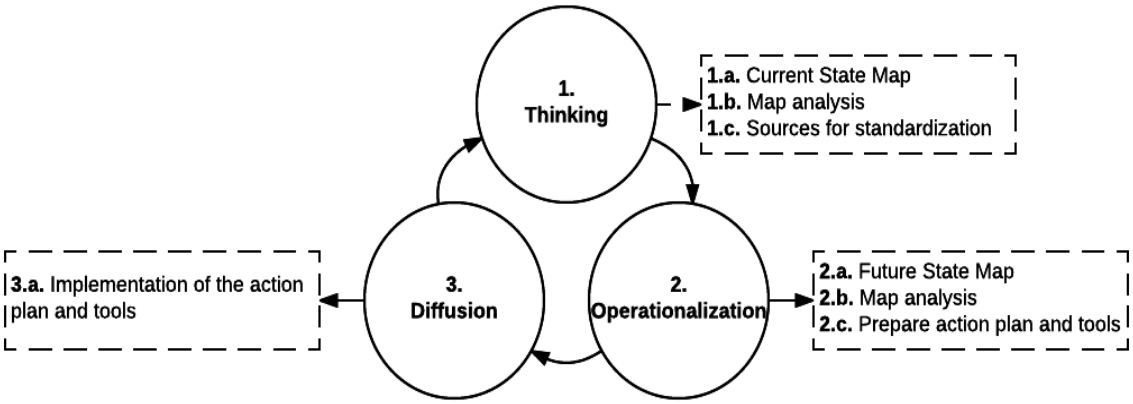

Figure 1: Approach based on VSM used during the research

The data was collected from an architectural firm focusing on building projects, such as residential buildings or shops. The first phase occurred from September 2016 to November 2016 through one 1.5 h interview with each of the six department. The six departments are organized most of the time in silos due to the large variety of projects. For example, commercial projects, such as creation of shops, are only realized within the commercial department of the firm. Each interview was conducted with several members of a department present on a voluntary basis. For the second phase (from November 2016 to January 2017), the data collected from the previous phase was used to help prepare an action plan with templates and tools. The third and last phase (from January 2017 to March 2017) of the study uses data from the two previous phases to distribute the new protocols or documents developed to inform all the departments of the new standardized protocols.

4 PRELIMINARY RESULTS

4.1 Thinking

The first objective of the Thinking step was to create a current state map of the internal information flows of the various departments of an architectural firm during the design stage of a construction project. The cell responsible to run this step was composed of ten members of the firm and one member was responsible for writing down the minutes of every meeting to resume and communicate the information to all the members of the cell. At least one member of each department of the firm was represented in the cell to obtain accurate information from the entire firm. The use of VSM helped the cell mapping the information flows with a set of rules and then helped identify potential sources of information that could be standardized. The figure 2 shows a section of the current state with a highlight of the architectural department realized with the help of the architects. This figure aims to show a typical information flow between the client and the architectural department during the design process at the firm. At this moment, the firm is still using AutoCAD and 2D drawings, as they are currently working on the implementation of BIM. The aim of this mapping exercise was to highlight the input of information needed from the client to produce the drawings, plans or models and then highlight the output of information given by the plans to meet the client's needs. After being refined, the figure 2 shows a process map identifying the input and output of information around the plans created during the design phase. Indeed, several projects were mapped to obtain the most common information exchanges in the firm's projects. The output of information created by the architectural department may correspond to the input of information needed by the other departments, such as engineering to complete their activities.

The information and documents show information present in each project studied (lists of materials, timetables, budgets or plans). The same analysis was done for the other departments of the firm to determine two points. First, the kind of information or documents that can be standardized from one project to another within each department. Second, from these information and documents identified, which ones can be standardized globally and used by each department in the firm. This paper focuses on the second

point and presents several sources of information that can be standardized for all the departments of the firm such as the level of detail between the phases or estimation reports. Furthermore, the Thinking cell, responsible for the first step of the research established the criteria and parameters for each source identified. These criteria were then transferred to the second cell responsible for the operationalization step.

For each source identified, the following protocol was used to keep a certain level of repeatability and standardization. The protocol was composed of four steps:

1. Each department presented their own information flow in the model design process. The focus was made on the necessary input and output of information to create the model or plan.
2. Each speaker pointed only to the advantages of the practices presented.
3. Each department presented an identification of important elements and needs for each source of information identified.
4. A ruling was made on the strategy and tools that were going to be adopted.

The first analysis phase has resulted in the identification of eight potential sources of information that can be standardized. The criteria and parameters needed for each source are described below:

1. **Level of Detail (LOD):** Templates must be created to determine the LOD of the model for each step of the design phase (concept, preliminary design and definitive design).
2. **Template:** Several points were discussed regarding the templates of all the documents that are created during the research. First, the goal is to obtain a unique template, however, because of the construction market in Quebec, two templates were created with one using the metric system and the other the imperial system. Second, the template was created on Revit 2016 after a comparison was made with Revit 2015. Third and finally, the language used for the development of the templates was determined to be the French.
3. **Dividers and doors tables:** Graphical representation for three-level wall types are accepted by all departments. A quality control template in the architecture department needs to be incorporated into the metric template. A table of hardware needs to be inserted in a standard format with the template. A table of doors need to be inserted in the template including all possible elements composing a door.
4. **Materials:** symbols, tables and other information must be defined for each department to keep it constant from one project to another or when the model is used by several departments in the firm.
5. **Zoning plans:** In the Revit template, a table must be created to compare the surfaces indicated in the Design brief from the client and the surfaces modelled. Moreover, the operationalization cell must find a way to the design brief data sheets to the concordant parts in the model.
6. **Estimate:** During the design phase, there is a need for three different estimates. First, during the concept, the estimate must be made in square feet, the unit prices come from Means' database and the costs are calculated according the applications of the project and its usages. Second, during the preliminary design, the estimate must be done with the system Uniformat and generic walls are used for the estimate. Third, during the definitive design, the estimate is made with the system Uniformat with a high level of accuracy and all the walls types are defined.
7. **Coordination per phases:** The conclusion on this topic is that there is a need to develop views or a system to coordinate plans between the various stakeholders internally and/or externally from the Revit model.
8. **BIM management plan:** The BIM management plan is being developed by the diffusion cell in accordance with the results and documents obtained from the other sources.

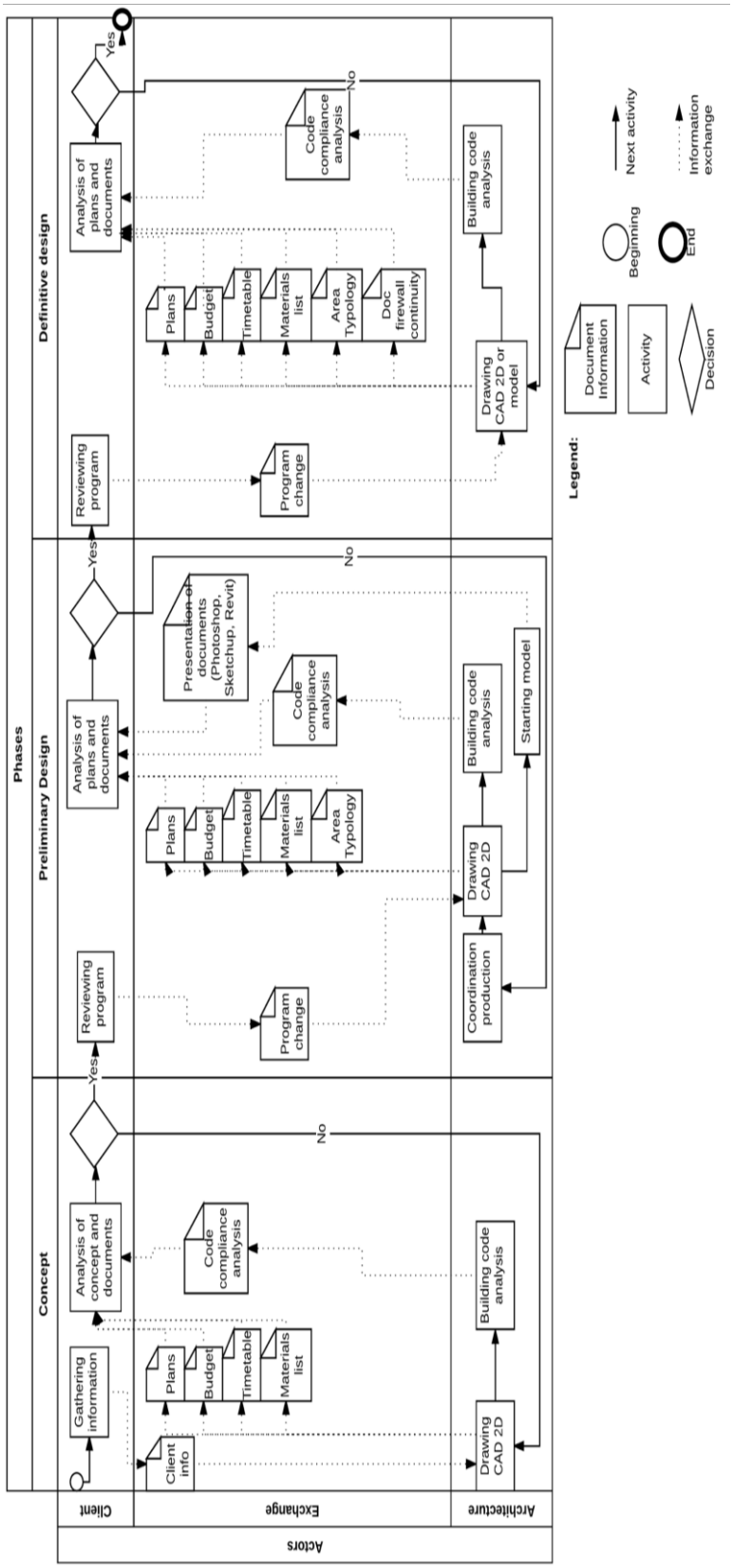

Figure 2: Current State Map of the architectural information flows in the design phase.

4.2 Operationalization

The role of the operationalization cell was to format the template from the criteria and parameters identified by the thinking cell. The cell was composed of ten members of the firm and had the same configuration as the Thinking cell. Furthermore, the cell was responsible to fill the LOD matrix for the whole firm while waiting for the criteria from the reflection cell. The LOD matrix was the first task completed during the operationalization with a study of various references and a formation received by an external firm. The LOD matrix adopted during the research was used regarding every source standardized. Indeed, the design phase in the construction projects of this firm is usually divided into three parts – concept, preliminary design and definitive design – and the LOD of the Revit model is different in each of these parts. A LOD standardization will help normalize the input and output of information, thus, limiting the presence of waste regarding overproduction of information or loss of information because each actor will know the kind of information they need to produce in the model for each phase.

Regarding the dividers and doors' tables and materials, a standardized data bank was created and must regularly updated to allow actors to understand information coming from another department and increase their productivity by gaining time creating models from one project to another. Meetings were necessary between the engineering and the architect departments to coordinate on the families' creation for plumbing and lighting in Revit to standardize their input in the models. Indeed, a nomenclature of Revit families was proposed and adopted based on the needs of each department.

Every change implemented during this step still must be tested in practice. Indeed, this protocol was implemented to facilitate the implementation of BIM in the near future. The standardization of activities and information will help give a better understanding of BIM processes and Revit to the users and finally help the firm limit the presence of waste in the information flows.

4.3 Diffusion

The first step of the diffusion cell was to identify the existing templates for each department. The cell was composed of seven members of the firm and had the same configuration as the other cells. Moreover, there was a need to identify all the training tools available for Revit software, as most of the projects are currently still done with AutoCAD. During the meetings organized with the diffusion cell, there was a consensus regarding the creation of a training manual serving both to train all the employees on the BIM processes, but also on the Revit software and on the processes by departments. The thinking therefore revolved around the design of a single manual, which establishes BIM procedures. Sections of the manual present specificities per department and a section is devoted to the training of the Revit software. This manual is going to be available on the Intranet of the firm. To share knowledge and keep a continuous improvement, the use of a platform such as Trello or Asana (to be evaluated) is necessary.

Work is still in progress within this cell to create an internal BIM management plan and standard documents that are going to be used by each department for the future BIM projects. This research has given the opportunity for the architectural firm to develop standard tools that will benefit them. Moreover, the results of this research are going to be published to provide a framework on how to increase standardization in the design phase to reduce the presence of waste at the source of a construction project with the use of VSM principles. Furthermore, the approach used during the research will be repeated in the future to identify more potential sources of information that could be standardized in future projects. Indeed, this protocol can be used as a form of continuous improvement.

5 CONCLUSION

This investigative action research uses VSM from lean production to improve standardization in the information flows of the design phase in construction projects. This research aims to facilitate the transfer from a traditional practice to a BIM approach. Because of the tendency that stakeholders have, to keep using a document-centric approach by pushing information they created to the next actor, the BIM implementation usually presents some contradictions and issues with the information processing. This case study provides a clear view that, despite the fragmented nature of construction projects and the lack of

repetition in the production process, VSM can be implemented to improve standardization in the design process to limit the creation of waste in the information flows such as overproduction of information. This case study demonstrated the need to improve the information flows in the design phase by increasing standardization. Furthermore, despite the fragmented nature of the construction industry, it is possible to implement standardization on some level in the design phase to improve coordination and reduce waste within the information flow of the design process.

This project is part of a larger research aiming to identify and reduce the sources of waste within the information, materials and workflows by implementing VSM combined with BIM processes and considering the high interdependencies between these processes. The future work regarding this research is to complete several iterations of the framework to identify more potential sources for standardization. Moreover, the future discussion will not only focus on the architectural information flow but will integrate several departments of the firm to demonstrate that standardization of the information flow is possible between various actors of a same process. The project will provide a complete and accurate future state map of the information flows in the design phase of construction projects.

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