

Lean Construction & BIM in the Value Chain of a Construction Company: A case study

Cristian-Camilo OSORIO-GOMEZ¹, Maria-Jose MORENO-FALLA²,
Angelica OSPINA-ALVARADO³ and Jose-Luis PONZ-TIENDA⁴

¹ Research Assistant of the Engineering and Construction Management Research Group, MSc Student, Department of Civil and Environmental Engineering, Universidad de los Andes, Carrera 1 N° 18A 12, Bogota, Colombia; PH (57) 300-319-2643; email: cc.osorio10@uniandes.edu.co

² Civil Engineer, Department of Civil and Environmental Engineering, Universidad de los Andes, Carrera 1 N° 18A 12, Bogota, Colombia; PH (57) 320-903-3061; email: mj.moreno11@uniandes.edu.co

³ Lecture Professor, Department of Civil and Environmental Engineering, Ph.D., Universidad de los Andes, Carrera 1 N° 18A 12, Bogota, Colombia; PH (57-1) 3324312; email: am.ospina@uniandes.edu.co

⁴ Assistant Professor, Leader of Engineering and Construction Management Research Group, Ph.D., Department of Civil and Environmental Engineering, Universidad de los Andes, Carrera 1 N° 18A 12, Bogota, Colombia; PH (57-1) 3324312; email: jl.ponz@uniandes.edu.co

ABSTRACT

The use of methodologies, such as Lean Construction and Building Information Modeling (BIM), has transformed how construction companies deliver their projects. Throughout the analyzed literature, several studies have proven that the implementation of these methodologies can have significant impacts on the project's productivity level and on the mitigation of time and cost overruns as well. This paper presents a case study of a leading construction company in Colombia and the process that was followed to implement the Lean and BIM principles, and proves how this implementation affects the company's value chain. First, the method followed in the evaluation of the processes map, and the definition of the organizational structure of the company through the application of the Value Stream Mapping (VSM) is presented. Second, the methodology developed to analyze improvements in the processes map of the company and how they are aligned with the principles of Lean/BIM is stated. Finally, the strategy for tracking the improvements for all the departments of the company, showing a more efficient organizational structure and an increase in the productivity of the company is outlined.

KEYWORDS

Lean construction, BIM, value chain, construction company, competitive advantage.

INTRODUCTION

Lean Construction and Building Information Modelling (BIM) are considered currently two of the most relevant emerging methodologies in the construction industry (Sacks et al. 2010; Hamdi & Leite, 2012; Dlouhy et al. 2017; Bolpagni et al. 2017; Saieg et al. 2018; Gómez-Sánchez et al. 2019). It is relevant to understand each methodology individually in order to later explain how these two concepts can be complemented and how they can be used together.

Lean Construction is the adaptation of the TPS (Toyota Production System) principles to the construction field, in order to optimize value and reduce waste, aiming to minimize costs and durations. However, Koskela (1992, 2000) argues that, while many of the principles and tools of the Toyota production system are applicable in construction, there are also principles and tools in Lean Construction that are different.

On the other hand, BIM is an acronym that corresponds to Building Information Modelling. It consists of a methodology that, based on technology and collaborative work, allows the integration of project stakeholders, the information flow, and the virtual construction of the project. The main objective is to involve the stakeholders in a project, during all stages from predesign to operation and maintenance. Smith et al. (2009) found that the main attribute that differentiates BIM from previous 3D modeling is how information is managed, organized, defined, and exchanged. Currently, many construction companies are using technology and following the BIM methodology. Bryde et al. (2013) argue that BIM has the potential to be the catalyst to re-engineer the processes to integrate the stakeholders.

Moreover, it has been proven that the implementation of both methodologies combined has a significant impact on construction companies and their projects. As an example, the study performed by Bolpagni (2017) at the Massachusetts Port Authority, concludes that Lean and BIM are essential tools for innovating the delivery of projects and maintain assets. This implementation is transforming the operation of construction companies. However, to be effective, it must be correctly implemented, and the company must be analyzed as a complex system.

Different departments of the company must be integrated from several points of view in order to optimize the implementation. By doing this, the processes in which there is a waste are identified. In order to identify these processes, it is necessary to study the operation of the company through the value chain (Prescott, 2001). The latter is considered a linear sequence composed of activities carried out by the company in order to visualize the process of creation of value. There are different paths for representing and understanding this chain. One path that is widely used in the academic field is Michael Porter's value chain. In his book, *Competitive Advantage* of 1985, he explains this tool in which separate value-generating activities are visualized in supporting and primary activities.

Historically, the analysis of the value chain has focused on reducing waste, but according to Prescott (2001) sales, customer service quality, and delivery times can be improved as well. This statement coincides partially with the five principles of Womack & Jones (2003). Therefore, a convergence point between the Value chain and Lean principles can be found.

Lean Construction has a tool called Value Stream Mapping (VSM), which represents not only the activities but also the connection they have between them in terms of the flow of information and materials. It is advantageous to find waste in the activities of the company.

METHODOLOGY FOR LEAN/BIM IMPLEMENTATION

The research methodology was divided into three main phases; the diagnosis phase, evaluation and improvement of processes and, monitoring and control.

1. Diagnosis phase.

In the initial stage of implementation, it is necessary to understand how the company is structured and how they deliver the projects in order to outline an implementation plan. First, meetings must be held with the main stakeholders of the company, in order to agree on their expectations. Additionally, the Capability Maturity Level (CMM) of the organization must be established in order to reorient the actions to improve processes (Succar, 2010; Succar & Kassem, 2015). According to Hamdi & Leite (2012), CMM-based improvement tools are used

to identify the strengths and weaknesses of an organization's processes in order to make changes and convert deficiencies into strengths.

Subsequently, it is crucial to start with the first approximation of the company's value chain. This value chain is created through an initial scan of all core operations in the company; and also, of the supporting activities that allow this value flow. After identifying all the activities that generate value to the company, a process map of the company is developed, to identify the company's strategic plan, as well as to identify competitive advantages, roles, resources, information flow.

Next, a Value Stream Map must be developed to help find the inefficiencies of the processes whether the process is transportation, communication, suppliers, contractors, procedures, or tools. Rosenbaum (2012) argued that VSM could distinguish between events that add and do not add value, while traditional tools do not allow it.

After developing the VSM and analysis', it is essential to conduct interviews that gather information from all the areas involved in the generation of value of the company. Depending on the scale of the company, the number of actors to interview may vary, but it is crucial to obtain information from both senior managers and operative workers, which allows a more holistic view of the company and helps identify those key actors in the operation of the company. According to Dlouhy et al. (2017), the interviewees must have a senior management position in the construction department or be directly involved with the Lean implementation process. Therefore, similar answers could be categorized, and later, the hybrid questions could be evaluated in the same way as the closed questions. It is imperative to include possible answers such as, for example, not responding.

The focus of the implementation can be represented in two sections that can be seen in Figure 1. In an inner focus called PIC cycle (Processes, Information, and Culture) and an outer focus, that is compound of clients and context. The main reason to focus on the PIC cycle is that the processes are the vehicles in the company for exceeding customer expectations and achieving organizational goals (Anjard, 1998). The information is a crucial point in processes and BIM, Porter (1985) argues that the value activities always use and create information. For this reason, in the information segment, there is also the differentiation with the rest of companies. Transforming the culture is key to the implementation (Gómez-Sánchez et al. 2019). Because the collaborators are the main actors that will make the difference and maintain an attitude of continuous improvement into the company. These sections will be described down below:

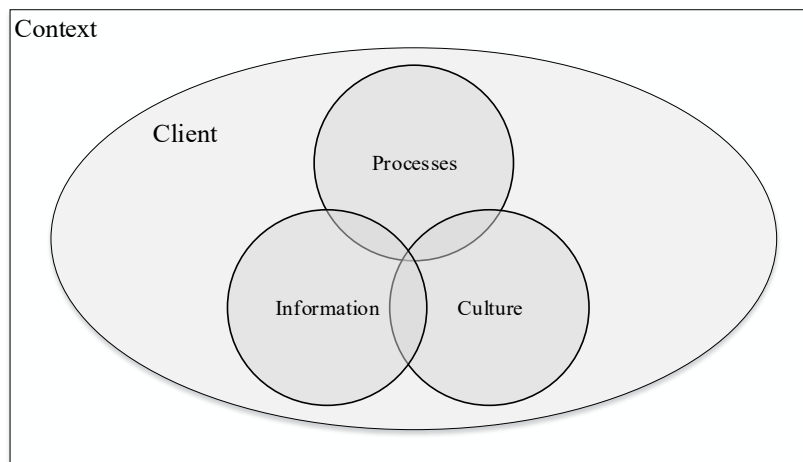


Figure 1. PIC Cycle, Client, and Context

Internal analysis

This analysis is divided into three main categories; processes, information, and culture. These three aspects are those in which the company has a significant influence and can improve. Under the value chain approach, the internal client considerations are implicit in the PIC cycle, and the most significant opportunities for improvement are in the primary activities.

Processes: This category helps to understand activities that are performed inside each department, as well as understanding the part of the process in which the different stakeholders are involved and how the different departments interact. Anjard (1998) stated that a process is a series of activities that takes an input, adds value to it, and produces an output, make allowances from the perspective of the client. It also contains a proactive part, which is necessary to understand how these stakeholders from their point of view, could improve the processes. These perspectives generate a fundamental role to understand the problems and lack of linkages in the value chain (Prescott, 2001).

Information: The information category provides a general understanding of the communications inside the company, identifying the communication channels most frequently used, if the information exchange is timely or if the flow of information is inefficient. BIM contributes to enhancing the collaboration with the stakeholders and sharing the information. Therefore, it reduces the non-value-adding waste (Olatunji, 2011).

Furthermore, this category allows to determine how the company handles lessons learned and quality control. This aspect is a fundamental element, to avoid making the same mistakes that were made and to pass the company's knowledge to new employees.

Culture: When culture is analyzed, a panoramic view of how decisions are made in the company is obtained, demonstrating the level of the hierarchy and how this causes bottlenecks in the processes. It also serves to clarify if decisions are made in a timely manner and to identify situations that generate delays in the continuity and cycles of the processes. It allows to analyze if the employer's thoughts and perceptions are aligned with the company's objectives; according to Hackler et al. (2017) educating people about lean principles and leadership perhaps is the most effective way to incorporate Lean thinking into the company's culture. It also encourages collaborators to help to identify possible uses of Lean/BIM by the current state of the company.

External Analysis

This exploration is divided into two main categories; client and, context. In these fields, the company has a limited influence; however, knowing its restrictions and expectations can make the company have a more significant competitive advantage over its competitors. The client represented in Figure 1. Represents the external client and the considerations that the company must have to meet their expected value.

Client: this category aligns expectations of the clients with the value offered by the company, identifying the significant flaws and gaps with the market. It is necessary to state the strategy of the company, which must be consistent with the mission, vision, and actions, but which is also satisfactory for the clients' perspective. Kumar & Rajeev (2016) stated that a competitive strategy differentiates a firm from its competitors when the prime responsibility is to give superior value to customers.

Context: The context proposes an environment within which the implementation should be executed. It considers aspects such as policies, economy, culture, social, environment, contracts, and legal issues. Thus, the implementation and improvement of processes can be adopted these characteristics create barriers or opportunities during the improvement process of the value chain at the local, national, and international context (Kumar & Rajeev, 2016).

After conducting the interviews and the client-context knowledge, a feedback of the process map is performed; it allows the identification of interactions and linkages that in the

first approach was not defined, arriving at a process map closer to the reality of the company, which takes into account external factors and the client points view.

2. Evaluation and improvement of processes

Based on the process map, a procedure was established to analyze the processes and what kind of optimization could be carried out. The improvements must be based on the principles of Lean Construction and their interaction with BIM (Sacks et al. 2010). To analyze the processes, the flow presented in Figure 2 was followed. Having formal processes applied to manage changes that occur within a company fulfils several objectives, including continuous improvement and reduction of variability (Succar, 2010; Sacks et al. 2010). For a correct analysis of processes, it is necessary to establish if it is possible to have improvements or reduce the variability. If the answer is affirmative, the next step is to ask the stakeholders if the objectives with the improvement are evident. It is fundamental to ask whether an increase in value has been seen, according to the client's perspective. Dlouhy et al. (2017) defined a fundamental principle of Lean Construction as defining the value from the client's point of view. This aspect is fundamental because it is where the company is going to have an established roadmap for improvement.

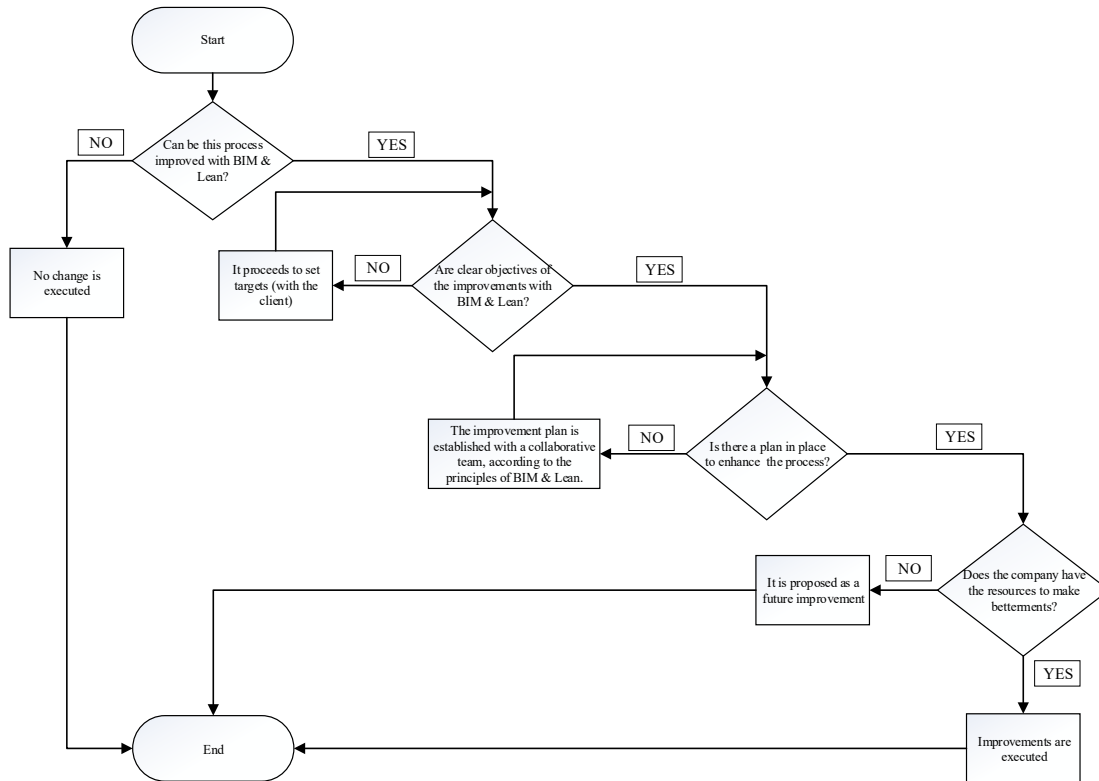


Figure 2. Flow diagram for process improvement according to Lean & BIM

After the assessment or diagnosis is performed, it is necessary to establish a plan to improve each process, to design this plan as appropriate and close to the reality of the company as possible, it is necessary to have collaborative workshops that involve the different stakeholders. Thus, it is possible to obtain the different perspectives, ensuring that the Lean / BIM improvements add value to the value chain of the company and are going to be adapted and accepted. The plan must be concrete and have measurable goals that guarantee the

continuous improvement of the process. Finally, the company should have in place the necessary resources to execute the improvement.

Following the flow diagram, the feedback cycles within the company are guaranteed. From the value chain approach, the company is the one that has the experience and expertise to execute the processes.

3. Monitoring and control

After the implementation of the improvements is in place, it is necessary to track and monitor the objectives established. Individual monitoring must be done since each improved aspect has traceability within the life cycle of the projects and in the organizational structure. Possibly, some of the changes introduced in the value chain have their maximum impact in the long term. For this reason, it is essential to establish periodic checkpoints that serve to measure whether the established changes are affecting productivity. Besides, the continuous improvement procedure has to be established to make the improvements found on the run.

CASE STUDY

This methodology was applied to a leading Colombian construction company in the country. The sales in 2017 for this company reached 350 million dollars. This company has projects throughout the country, but currently has a subsidiary in five major cities.

1. Diagnosis phase.

The CMM was very helpful for analyzing the initial state of the company, not only its internal processes but also its interaction with the different stakeholders. It also allowed studying the expectations of the Lean / BIM implementation and establishing an Employer's Information Requirements (EIR) more appropriately to the company's situation. Besides, the preliminary information allowed the first analysis of the company's value chain, which was reflected in the process map and its stages in Figure 3. It was also the starting point to the VSM in order to see the inefficiencies of the processes, information failures, and wastes. Likewise, the analysis helped to determine the people within the organizational structure that needed to be interviewed, due to their role in the generation of value in the company.



Figure 3. Process Map Stages before Lean / BIM Implementation

Subsequently, 50 interviews were conducted in the different departments of the firm, to understand the operation of the company and the inefficiencies in the value chain. The interviews allowed to generate an environment of questions and proposals, which helped generate opportunities for improvement for the organizational structure, which would improve the existing processes. At the end of the interviews, seventy-eight improvement proposals were obtained, covering both the PIC cycle and the client.

These improvement opportunities were categorized in process, information, culture, and, client; as can be seen in Figure 4; nonetheless, in the seventy-eight proposals for improvement that were discovered, many of them had similarities and synergies. For this reason, an evaluation of the improvement proposals and a grouping was made. Thereafter, there were seventeen improvement opportunities that were proposed to the company to have an impact on the value chain. The final part of this diagnosis was to define the guidelines for the next phase.

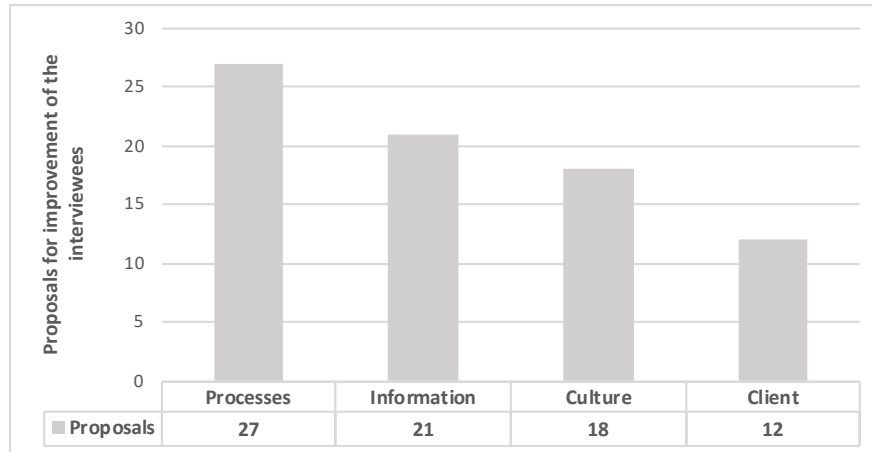


Figure 4. Proposals for improvement of the interviewees

2. Evaluation and improvement of processes.

First, the seventeen improvement opportunities have different objectives, scopes, and resources. In this way, there should be an essential criterion to determine which were the most relevant and timely opportunities for improvement. According to its strategic planning, the company decided that all improvement opportunities were necessary. Nevertheless, it defined an order of importance to carry out the implementation. The order began with the most relevant improvement opportunities according to its strategy until the last of seventeen.

- **Processes:**

2. Definition of new phases in the projects.
3. Definition of the clients / responsible for the processes.
1. Integration of processes with Lean / BIM.
15. An approach based on the life cycle of the projects.
7. Standardization of the processes in Construction.
14. Scheduling the tasks in diverse departments with LPS.

- **Information:**

13. Management and dissemination of knowledge.
12. Information for the client with the help of BIM.
6. Unified classification system.
5. Management of lessons learned.
11. Centralized communication system.
16. Interaction with contractors through BIM.

- **Culture:**

10. New decision making.
9. Continuous training plan.
4. Integration of stakeholders.
8. New roles and responsibilities of project managers.
17. Improvement in personnel selection and retention processes.

Collaborative workshops were held with the departments involved in generating value in each of the processes. In these workshops, training was conducted about Lean / BIM and how it could improve the workflow. During the workshop, opportunities for improvement arose according to the situation of the company and its context.

One of the most relevant improvements opportunities were the stages of the process map. Since the initial process map had a brief design period, it also did not have a pre-constructive stage. With this structure multiple reprocesses were generated between departments, lack of information, late deliveries and decreasing construction quality.

For these reasons, the new stages of the process map were established as can be seen in Figure 5, allowing a longer and integrated design phase with checkpoints and concurrent engineering. Additionally, a pre-constructive stage that would align the contractors with the construction team would allow for planning the supply chain and the logistics of the construction. In addition, the information flow, clash detection and scheduling were done through BIM and Last Planner System (LPS). Finally, an operation and maintenance stage was added, so that the company's assets can be efficient managed during the rest of the project life cycle through BIM.

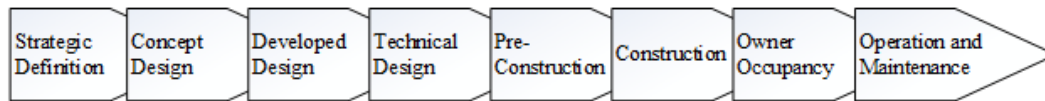


Figure 5. Process Map Stages after Lean / BIM implementation

In this way, the improvements of the rest of the processes was carried out following the principles and tools of Lean / BIM. It is essential that the changes generated are compiled in the management system, and thus transform the organizational structure. Also, culture is a complex transformation process, for this reason, it is necessary to keep people motivated with a training and incentive plan. So that the improvements also generate positive changes in the way of working.

3. Monitoring and control

Finally, the improvement opportunities for the different departments were executed; in this way, transversality was generated in the implementation of Lean/ BIM, improving the processes, the flow of information, and the culture. Checkpoints and indicators were established in each improved process, such as cost variation, changes in construction quality, number of reprocesses, variation in delivery times, and perception of internal and external customers. To identify if the changes had the expected effect, periodic evaluations were made; if the result was not according to the company expectations, the process was reassessed according to the flow diagram.

CONCLUSIONS

The implementation of Lean / BIM has extensive benefits for companies (Sacks et al. 2010; Hamdi & Leite, 2012; Bolpagni et al. 2017; Dlouhy et al. 2017; Saieg et al. 2018; Gómez-Sánchez et al. 2019). This research finds a direct synergy between the implementation of Lean/BIM and positive improvements in the company's value chain. Thus, the implementation, seen from a strategic vision of the company, affects all departments and the construction processes, including process improvement and the optimization of the organizational structure of the company. Value Stream Mapping (VSM) and the Capability Maturity Level (CMM) were used to identify shortcomings in processes and how to convert them into strengths of the company. Having an optimized value chain, according to Lean and BIM, will be a fundamental element of differentiation that will generate a competitive advantage among competitors and improve customer perception. It is essential that the construction industry be understood as a union of synergistic processes and better interaction of stakeholders generates value, even when departments are not part of the primary activities of the value chain. This research is useful for

companies that want to carry out a Lean / BIM implementation at a company level, and that want to have a competitive advantage in their market.

Throughout this study, there were many lessons learned. First, excellent top-down leadership is necessary by the upper directives, which impulses the lower range of personnel. Furthermore, during the implementation process, people must be clear about the goals and group objectives, thus keeping interests aligned, maintaining the strategic objectives of the company above personal interests. Besides, an organizational structure is necessary to be as flexible as possible for the implementation to be carried out most effectively.

For future research, the issue of how to directly involve contractors and suppliers in the implementation is essential, since this external sphere has a high impact on the company and how they could be part of the proposed improvements.

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