

BIM-STATIONS: WHAT IT IS AND HOW IT CAN BE USED TO IMPLEMENT LEAN PRINCIPLES

Aleksander Vesteremo¹, Vegar Murvold², Fredrik Svalestuen³, Jardar Lohne⁴ and Ola Lædre⁵

ABSTRACT

Companies are starting to use BIM and Lean processes simultaneously to create predictable workflows. Contractors are taking BIM from the office and making it an on-site tool in the production phase. This is a relatively new approach to on-site production control, and there seems to be a lack of research regarding BIM-stations on-site. This paper explores 1) what a BIM-station is and 2) how it can be used to implement lean principles. The research is based on an extensive literature review and 10 general in-depth interviews of personnel from different management levels within five contractors.

According to the research carried out, a BIM-station can best be characterized as an on-site information-tool. The BIM-station is set up so the project participants can use it for an easy and constant access to an up-to-date BIM-model and drawings. Using a matrix that links BIM-station functions with lean construction principles, 12 interactions have been identified.

So far, very few projects have used BIM-stations, limiting the number of easily available cases. However, the analysis is presented so that it may be used to create a better understanding for companies wanting to implement BIM-stations and/or lean.

KEYWORDS

Building information modeling, BIM-station, BIM on site, Lean principles, Implementation

¹ M.Sc., Dept. of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, +47 928 41 916, aleksave@stud.ntnu.no

² M.Sc., Dept. of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, +47 918 13 994, vegarmu@stud.ntnu.no

³ Ph.D. Candidate, Dept. of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU)/Veidekke Entreprenør AS, Norway, +47 986 73 172, fredrik.svalestuen@ntnu.no

⁴ Research scientist, dr. art., Department of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

⁵ Associate Professor, Dept. of Civil and Transport Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway, +47 911 89 938, ola.ladre@ntnu.no

INTRODUCTION

To create predictable workflows, companies are starting to use lean processes and Building Information Model (BIM) simultaneously. This can provide better reliability of scheduling and deliver the most value from the client's perspective while consuming the fewest resources (Dodge Data & Analytics 2015).

BIM is a digital representation of a building's physical and functional characteristics. The information in BIM is what differentiates it from being just a 3D model. BIM is a resource for information about a building, and can be basis for decisions during the building's lifecycle. Digitalization of data in this way automates the coordination of changes to the model, and those involved can extract the information they need immediately after a change to the model.

According to Womack and Jones (1996), lean thinking can be summarized in five principles, notably value, value stream, flow, pull and perfection. Of these, they claim that value is the critical starting point. They consider value defined by the customer, and explain it as a good or a service that meets the customer's needs at a specific price at a specific time. The answer to what creates value is complex (Drevland and Lohne 2015). It will be a result of the conversation between the ends, means, and constraints of the client (Ballard 2008). In the opinion of the authors of this paper BIM could possibly be a good tool to increase the value of information between project participants and ensure a better understanding of the client needs throughout the whole building process.

Many firms are starting to use BIM as a lean tool through production planning and control. Bhatla and Leite (2012) established a framework for incorporating BIM functionalities like 4D scheduling and clash detection into the Last planner system™. Another way of improving the production planning is by increasing the detail for planning using BIM. Sacks et al. (2009) did this by developing a tool called "KanBIM". This represents the implementation of a lean pull system using BIM. The system helps to achieve stability in the workflow and to minimize waste of labour time in construction (Sacks et al. 2013). By giving the workers on site access to the BIM-model, they can visualize the final product and the potential of positive impacts is great.

BIM and Lean Construction have both been researched extensively the recent years. Different lean construction researchers claim that the use of BIM technology in construction can reduce inefficiencies and rework (Arayici et al. 2011; Sacks et al. 2010; Sacks et al. 2009). However, there has been little research linking these two (Sacks et al. 2010). One of the key principles of lean construction is continuous process improvement. By linking lean construction with BIM-stations, new work processes can emerge and create an even more efficient construction industry. Consequently, this paper addresses:

- 1) what a BIM-station is and
- 2) how it can be used to implement lean principles.

Firstly, we will present our research methods. Secondly, we review recent research on the use of BIM on site. Then we will list BIM-station characteristics and lean principles. Finally, we will link these together and analyse the interactions.

RESEARCH METHODS

The main body of the research is based on a literature review and general in-depth interviews with key actors from five contractor organizations. The review focused on the use of BIM in the construction phase, and how it is related to the principles of lean. The literature study followed the steps specified by Blumberg et al. (2011) with; 1) the building of an information pool, 2) the application of a filter to reduce pool size, 3) a rough assessment of sources to further reduce pool size, 4) an analysis of the literature in the pool and 5) the refinement of filters or stop search when theoretical saturation is reached.

To gain experience in several areas, key actors from five of the leading contractors in Norway were interviewed. These contractors have to a varying degree adopted BIM-stations in their projects. Ten general in-depth interviews with people considered to be among the most experienced on BIM within these contractor organizations were conducted. These included seven BIM-specialists and three project managers. The interviews were carried out in line with the recommendations of Yin (2014).

In addition, the first two first authors of the paper had part-time jobs on a building project with BIM-stations during the research period. One of the responsibilities was to keep the BIM-stations running. This gave the ability to do observations and have conversations with the workers during the research period.

THEORETICAL FRAMEWORK

THE USE OF BIM ON SITE

Over the last years there has been developed different methods to bring BIM to the workers on site, enabling access to the model wherever they are. The different tools that are being used can be divided into three categories. 1) Computer terminals on site (hereafter called BIM-station), 2) mobile devices and 3) specialized environments (e.g., BIM-caves). With BIM on site, it is possible to find and solve problems early. This is a relatively new approach to on-site production control for contractors. Van Berlo and Natrop (2015) state that paper drawings typically dominate information on the workplace. Furthermore, they claim that BIM on site can realise a great potential in the construction phase and that construction workers get the benefit of visualizing when communicating with BIM on site.

Hewage and Ruwanpura (2006) found through their research that there was a need for a mobile, real-time information source on site. Workers wanted an opportunity to view 3D and 4D (3D with timeline) drawings, technical information, safety information, weather updates, and other information related to the project. Following this research, Ruwanpura et al. (2012) developed an information booth to give the workers on site access to material management, work demonstrations and updated drawings. This led to positive result in productivity, efficiency and worker satisfaction.

Davies and Harty (2013) found that there is limited research on how BIM has been used on site. They studied the implementation process of “SiteBIM” in a case study of a large hospital project in the UK. Mobile tablets were used to access the project’s BIM

model. Tablets on site combined with in-house document management systems resulted in positive effects, like waste reduction and a lower than usual cost growth for service installations. Harstad et al. (2015) has also documented positive effects from their research on tablets at the construction site. In sum, tablets provide easy access to information, are easy to carry around, and can increase the understanding of the project while creating a new line of communication.

The contractor Skanska developed in 2014 a prototype of what they called a “BIM computer kiosk” (Bråthen and Moum 2015). They placed a computer connected to a 50-inch TV-screen on each floor of the building. These computer kiosks allowed workers to access the 3D-model on site. The equipment was placed inside a protective wooden cabinet with internet connection (Bråthen and Moum 2015). BIM kiosks were widely used and resulted in better productivity, especially for MEP workers.

Van Berlo and Natrop (2015) analysed a concept using BIM to generate drawings adapted to the task of workers on site. The idea behind this was to “[...] provide site workers with all the information they need for the task, but nothing more”. They found that this approach created a very good communication tool between the site office management and construction workers. According to Chen and Kamara (2008) the most effective way for workers to acquire information on site is to collect or capture information at the point where they are, when they need it.

BIM can result in a leaner construction process with a greater degree of utilization of prefabrication, improved workflow stability, reduced inventories and enhanced teamwork (Alarcon et al. 2013). When BIM is implemented in the design phase, there could be some challenges to carry it forward to the construction phase. Some of the most common barriers are: software and hardware issues, cultural barriers, contractual and legal aspect, lack of commitment, lack of training and lack of client request (Alarcon et al. 2013). Compared to the positive aspects with implementing BIM in the construction phase, however, the challenges must be said to be of relatively limited nature.

Different approaches to BIM on site have been tried, and it is hard to say if one is better than the other. The i-booth, computer kiosks and tablets are all examples of ways of getting more information to the construction site. These are also ways to introduce lean principles to construction projects. With BIM on-site, the workers have the benefits of better understanding of the planned building. This is due to possibilities for visualization and a greater level of collaboration between the site workers.

LEAN PRINCIPLES

In the following, we present seven lean construction principles that can interact with BIM-station characteristics. The principles are adapted from Sacks et al. (2010). These researchers came up with 56 hypotheses that link BIM and lean construction. According to the article, BIM can reduce variability in both product, process, cycle time and flexibility. The 56 issues identified were intended to guide and stimulate further research. Not all principles from the research of Sacks et al. (2010) are relevant to BIM-stations. The principles that are chosen for this research are listed in bold with a following explanation:

Go and see for yourself is a "going to gemba" principle. This is a principle of Japanese business strategy, which means "go to the real place." The gemba is where the action is and where the facts may be found (Imai 1997). The principle says that to really understand the situation, one must go to gemba (Liker 2003). **Standardization** of work process reduces variability and facilitates continuous improvement (Womack and Jones 2003). **Visual Management** is an orientation towards visual control in production, quality and workplace organization (Greif 1991). The goal is that visualisation should be immediately recognizable by anybody. This is one of the original "just-in-time" ideas (Koskela 1992). **Reducing variability** reduces the volume of non-value adding activities (Koskela 1992). **Reducing cycle time** reduces the time it takes to perform a process through elimination of non-value adding activities and variability reduction (Koskela 1992). **Cultivate an extended network of partners** - An extended network of partners should be built, challenged, and helped to improve (Sacks et al. 2010). This can lead to better collaboration across disciplines in construction projects. **Decide by consensus, consider all options** - By increasing the number of people who influence a decision, one can expand the knowledge base for the decision to be taken. One can get more suggestions and opinions, thereby increasing the likelihood that the best decision is taken. This principle comes from practice at Toyota (Liker 2003).

Based on this review we can see that there is a limited amount of research regarding BIM on site and its effect on implementation of lean principles. Furthermore, there is a need for more research that can guide management when implementing lean principles along with BIM-stations.

FINDINGS AND DISCUSSION

According to the research carried out, a BIM-station can best be characterized as an on-site information tool. It is typically a computer connected to a TV-screen that the workers can use to easily visualize and determine how practical problems at the construction site can be solved. The BIM-station is set up so the project participants can use it for an easy and constant access to an up-to-date BIM-model and drawings. It is a meeting place for collaboration internally and between different disciplines, contributing to problem solving. Contractors also use the BIM-station as an information channel to show delivery schedule, HSE-information, weather forecasts and updated rig plans.

The aim with the BIM-station is to increase the availability of information. Building projects are becoming more complex and harder to build. Workers, particularly in technical disciplines may have difficulty to imagine how the final products should be with only 2D drawings. With the BIM-station, contractors and suppliers could extract the information they need to achieve the intended result. The BIM-station also contributes to a better cooperation between the workers, partly because it can bridge a gap caused by their different native languages. They can use the BIM-model in face-to-face collaboration. By using BIM-stations, workers can easily visualize and determine how practical problems at the construction site can be solved.

A large percentage of workers we talked with experienced saving time with the BIM-stations. They reported higher productivity due to having the necessary information

available at all time. MEP workers use the 3D-model to visualize, plan their tasks and solve any problems that may arise. Carpenters are also found to benefit the BIM-stations, mostly by saving time getting the necessary drawings. The overall impression from the workers is that the MEP workers have the greatest benefit of the BIM-stations. However, some workers find it inconvenient to have access to the BIM-model on only these specific locations. Some of them report that they rather would want to use computer tablets, and that this may be a more practical tool than the BIM-stations. The BIM-specialists interviewed claimed, however, that the tablet software for BIM is not good enough yet. In addition, tablets are fragile in rough environments like a construction site. During the research period there was also carried out a case study. Look at the research of Murvold et al. (2016) for all experiences from the use of BIM-stations on this project.

BIM-STATION CHARACTERISTICS

In the following section, we present and explain the content of table 1, which presents the most important BIM-station characteristics we found through both the literature review and the interviews.

Table 1: BIM-Station Characteristics (not ranked after importance)

BIM-Station Characteristics
Visualization of form. A BIM-station contains BIM program with 3D model for visualization of the final product. It makes the 3D model accessible for the workers on site to visualize the building design.
Visualization of process status. To see clearly the process status, the BIM-station can be used to visualize progress compared with the planned progress. For example, visualization of a three-week plan.
Automatic generation of lists. Workers can enter a room in the BIM and automatically get generated a list of materials needed for this room. This list can then be used to deliver this equipment directly to the room.
Online access to documents. An object in the 3D model can work as a hyperlink to databases. By clicking on the object, a list with links to choose from will appear. There you can get information about floor plans, details, room form, safety sheets and other useful documents. Another alternative is a web page as a background on the BIM-station. On this web page, you will find the same information as on the hyperlink-objects in the 3D model.
Easy maintenance and updating of information. The 3D model updates automatically at the BIM-station. It will be updated whenever it is needed through Dropbox or a script directly linked to the web hosting service.
Easy updating of drawings and documents. When updated technical drawings along with other documents is added to the web hosting service, it will be available for download directly from the BIM-station.
Two-way communication. BIM station can act as a meeting place for workers from one or more disciplines, where everyone can see the 3D model and discuss together as a group.
Online/Electronic Communications. Information like production basis, information about the shipments, weather, safety or other messages from the management can be sent to users through the BIM-station.
Feedback to the management. E-mails can be sent directly from the BIM station to the management. This may be reports, comments on the 3D model or other messages.

INTERACTION BETWEEN LEAN AND BIM-STATIONS

In the following, we propose 12 interactions between the BIM-station characteristics and the lean principles. These propositions are based on the literature review and the interviews. Table 2 contains the interactions we consider to be the most important (not ranked).

Table 2: Interactions between BIM-station Characteristics and Lean Principles

Interactions between BIM-station Characteristics and Lean Principles
(1) A BIM-station makes it possible for the workers to visit the construction site through a virtual reality with the use of BIM.
(2) A BIM-station make it possible for the workers to visualize changes faster as they have access to updated drawings and a 3D model on site.
(3) Using a BIM model on a BIM-station let the workers on-site get a better understanding of how the final product is going to be. The BIM-station can be used for clarification in situations where information in 2D drawings is lacking.
(4) Direct delivery of information to a BIM-station reduce waiting times and improve flow.
(5) By having a BIM-station online, the process of obtaining updated drawings to the construction site can be simplified. This could also prevent a lot of paper waste since the workers do not have to print new drawings to check for updates.
(6) Having online access to information on the BIM-station standardize the way of obtaining information. Workers can retrieve drawings directly from the BIM-model, rather than having them all pre-printed.
(7) Process visualization and online communication make it possible to use BIM-stations for status updates. A carpenter can for example send a status update when he has put up a wall, then the electrician is notified when it is ready for him.
(8) By having updated process status available on the BIM-station, it is possible to use the BIM-station to see where it is ready to start working, or how long one must wait until it is clear. This reduce latency and cycle time for activities.
(9) By automatically generating lists of needed materials from the BIM model, it is possible to save time and achieve more accuracy. A carpenter can for example generate list for a room to see exactly how much materials is needed. This leads to increased productivity and reduced variability.
(10) By utilizing the BIM-station as a meeting place for workers from one or more disciplines, everyone can give their opinions and the knowledge base for taking the decision increases. The likelihood that the best decision is taken therefore increases. By using BIM, you increase the information available to support the decisions. In this situation, the BIM station facilitates a greater level of face-to-face collaboration between site workers.
(11) BIM-stations provides the ability to report directly from the BIM-station to the management. Examples of such need for reporting can be instant feedback on error, conflicts, deviation or other things. Such direct information channels can help to ensure that more time is used for the production and achieve reduced cycle time.
(12) With hyperlinks to drawings and documents, the way of obtaining information is standardized. The variability is reduced when you have direct links to the documents you need.

In sum, it seems clear that the BIM-station contributes to a better workflow by reducing variability while it standardizes the work process. Implementing BIM-stations comes hand in hand with visual management. The BIM-station helps workers manage their own activities with production control and a better understanding of the final result. These interactions can guide management when implementing lean principles using BIM-

stations. It is possible to look at BIM-stations and lean construction as isolated parts. However, to achieve a good outcome one should see them as a whole as they have a synergistic effect to each other.

In table 3, the BIM-station characteristics and the lean principles are linked together. The interactions – numbered from 1 to 12 – show how a client can use BIM-stations to implement lean principles.

Table 3: Interaction Matrix of Lean Principles and BIM-station Characteristics

BIM-station characteristics	Lean principles						
	Go and see for yourself	Standardize	Visual management	Reduce variability	Reduce cycle time	Cultivate an extended network of partners	Decide by consensus, consider all options
Visualization of form	1		3				
Visualization of process status			7				
Automatic generation of lists				9			
Online access to documents		12		12			
Maintenance and updating of information			2	4 5			
Updating of drawings and documents			2	4 5			
Two-way communication							10
Online/electronic communication		6		4	8		
Feedback to the management						11	

CONCLUSIONS

BIM and Lean are being implemented simultaneously on construction projects. The aim of this paper has been twofold: firstly, to explore what a BIM-station is and secondly to explore how it can be used to implement lean principles. According to the research

carried out, a BIM-station is best characterized as an on-site information tool. It brings information out to the construction site. The workers can use it to easily visualize and determine how to solve practical problems at the construction site. It can also serve as a meeting point for internal collaboration between different disciplines, contributing to problem solving.

This study shows that there are many interesting interactions between lean construction and BIM-stations. The interactions show that BIM-stations are helping to reduce the volume of non-value adding activities. The 12 interactions are presented so that they may be used as a guide for companies wanting to implement BIM-stations and/or lean in the production phase of building projects. The use of BIM-stations in the production phase can significantly enhance the lean outcomes.

Further research should try to do more testing to validate the 12 interactions proposed, and explore if there are additional interactions that should be included in table 3. In addition to looking at BIM-stations on site, researchers should study the potential of using tablets and smartphones on site in synergy with lean construction. BIM-stations on site combined with the foremen using tablets could be a good solution for future work.

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