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DEPLOYING BIM IN A HEAVY CIVIL PROJECT

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ABSTRACT

This paper explores the case of a heavy civil project that implemented a comprehensive BIM execution plan. Although BIM was not required in the tender documents, the bid was won partially due to the contractor's proposal to use BIM to develop and manage the complex project. The paper presents a synopsis of the value proposition of BIM on this project and how it supported a number of Lean principles. An outline of project challenges, including design complexity, dispersed design team, and inexperience with BIM, is presented. Finally, through a research method consisting of interviews and site observations, the authors demonstrate that understanding people's work routines and establishing the right level of BIM ambitions for the project allowed the project team to successfully exploit the opportunities BIM has to offer. Using the BIM functionalities list identified by Sacks et al.'s BIM-Lean interactions matrix, the authors identify the Lean principles that the specific functionalities implemented at the project enabled. The aim of this is to support previous research suggesting that there are specific synergies between different BIM functionalities and corresponding Lean principles, as well as document how they were implemented in a heavy civil project.

KEYWORDS

Collaboration, visual management, BIM, heavy civil project

INTRODUCTION

The intent of this research is to explore how the introduction of Building Information Modeling (BIM) functionalities, in conjunction with lean principles, reduce waste and bring a positive cultural shift to an industry segment that traditionally works in two dimensions. Building Information Modeling is the use of an information-enriched 3D-model intended for multi-disciplinary design and coordination. The BIM model is used for several purposes, such as checking design quality, planning, procurement, visualizations and safety evaluation. At a project level, the BIM is a collaboration platform around which processes are built and information is shared. Sacks et al (2010,

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p.968) state that "while [BIM and Lean] are conceptually independent, there appear to be synergies between them." This case study tests that statement as both Lean and BIM methodologies were introduced to a team who was not familiar with either.

The current status quo in heavy civil construction in Norway is to use two-dimensional drawings to guide construction. Heavy civil projects are at a larger scale and generally involve expansive grading defined by GPS coordinates. Design and construction modeling programs, on the other hand, have focused on building components and detailing. However, as heavy civil projects become more complex, and modeling tools expand functionality, the use of BIM to plan these projects becomes both technically possible and necessary for coordination. On the case study presented in this paper, conveyor belts going in all sorts of angles, technically and geometrically complex buildings, and underground tunnels called for a better platform for mutual understanding between project parties.

As heavy civil projects become increasingly complex, they can also greatly benefit from the use of BIM. That said, the authors propose that the lessons learned through the joint implementation of Lean and BIM, in the heavy civil project described, can be utilized by practitioners implementing BIM in other heavy civil projects.

INTERACTIONS BETWEEN LEAN AND BIM

The discussion of the case study presented in this paper uses previous work developed on how Lean and BIM support each other. More specifically, the paper builds on the work developed by Sacks et al. (2010) who studied the potential interactions between BIM and Lean and developed a framework, in the form of a matrix, linking the two. The matrix is useful to understand why companies should care to use BIM in their projects, how the use of BIM can be leveraged by understanding which areas can benefit from its implementation, which areas have traditionally taken advantage of BIM more often, and which Lean principles have the highest number of interactions with BIM functionalities. The BIM-Lean interactions matrix has been used in previous research to analyze and exemplify instances in which BIM helped or could have helped to generate value, promote flow, and reduce waste in projects (e.g., Bhatla and Leite 2012, Harris and Alves 2013). However, examples of the interactions have not been discussed in a heavy civil project, given that these types of projects seem to be lagging in Lean implementation.
Sacks et al.'s (2010) goal was to focus on what BIM as a platform can do for the construction industry rather than focusing on any specific technology that might help achieving these functions. The BIM functionalities they identified were categorized into three main stages of the life cycle of a construction project:

Design: visualization of form, rapid generation of design alternatives, reuse of model data for predictive analyses, maintenance of information and design model integrity, and automated generation of drawings and documents.

Design and fabrication detailing: collaboration in design and construction.

Preconstruction and construction: rapid generation and evaluation of multiple alternatives, and online/electronic object-based communication.

Next, Sacks et al. (2010) identified from the Lean literature at large a number of principles that help define and explain Lean. The main principles were grouped into four categories as indicated below to show how they support areas of the Lean philosophy:

Flow process: reduce variability, reduce cycle times, reduce batch sizes, increase flexibility, select an appropriate production control approach, standardize, institute continuous improvement, use visual management, and design the production system for flow and value.

Value generation process: ensure comprehensive requirement capture, focus on concept selection, ensure requirement flow down, and verify and validate.

Problem solving: go and see for yourself, and decide by consensus, consider all options.

Developing partners: cultivate an extended network of partners.

The lean principles with the highest number of interactions, distributed over the design and construction stages, were: get quality right the first time (reduce product variability), focus on improving upstream flow variability (reduce production variability), and reduce production cycle durations. As for the BIM functionalities, with the highest number of interactions they were: aesthetic and functional evaluation, multiuser viewing of merged or separate multidiscipline models, 4D visualization of construction schedules, and online communication of product and process information. From this analysis it is clear that a number of principles and functionalities were underrepresented in practice and the literature, and there is a lot of room for improvement when it comes to taking advantage of the full potential of BIM to design and improve production systems from design through construction and maintenance.

In order to take the most advantage of BIM, Kunz and Fisher (2012) suggest that key stakeholders be invited to a kick-off meeting in which participants would define: the visualizations of the model that would be most beneficial to them, the levels of detail appropriate for the discussions and the design team, and define breakdown structures that relate cost, schedule, and other relevant information to track the project's performance. Given that powerful computers, visualization tools, and software are more affordable than ever, teams should also use multiple screens to visualize the project in meetings held throughout the life of the project (Kunz and Fisher 2012). The case presented took some of this advice during the implementation stage as discussed later in the paper.

Case Study Description and Method

The case studied was a heavy civil project in Northern Norway, with the scope of expanding an iron ore extraction facility currently increasing its production capacity from 20 to 30 million tons iron ore per year. The project was divided in packages, and the study presented in this paper refers to a specific package, consisting of a screening station, conveyor belts, a spill silo with a technical building, a weight silo, a reloader with a technical building, and a sedimentation pool. The delivery method used was design-build, with the general contractor managing both design and construction. Total project duration was 1.5 year and the cost was approximately 600 million Norwegian kroner (roughly $85M).

The owner prioritized teamwork and Lean culture among all project participants. The alignment of the project team to project goals was fundamental to implementing change on the project. Once the general contractor won the project, a BIM strategy was put in place. There was no specified requirements regarding BIM in the tender documents, but feedback received during the bid phase was that the contractor had shown remarkable understanding of the client needs and project scope through excellent BIM deliveries. This was possible because the contractor has an extensive BIM execution plan consisting of two parts: a document explaining standard requirements and procedures, and a project specific outline of model objectives, procedures, and development schedule. The BIM execution plan was largely adhered to, and the model was successfully used for all defined goals.

When this process started, there was a wide variety of design programs used, file formats, and work flows. The BIM coordinator managed the multi-disciplinary model in Solibri Model Checker, as did design and production teams for viewing the BIM model. The design teams used Autodesk Revit, Elite, Tekla Structures, Solidworks, Microstation 3D Reshaper and Autodesk Inventor to develop their designs. At first, the BIM set up seemed trivial, however, it was a challenge to completely align the team's working methods within an environment with no existing standards. Nevertheless, all design programs could produce files compatible with the model management program. This interoperability allowed the use of one program (Solibri Model Checker) for model checking and viewing, and became the unifying factor between teams.

Furthermore, the design team consisted of people situated in Norway, Germany, Sweden, Denmark, and Finland. This created several challenges in terms of both culture and accessibility. English was spoken at meetings, and the team was only co-located every three months for two full days of well-planned meetings.

The documentation used for this case was obtained by the first author who was part of the project team, and also conducted interviews with members of the team to capture their perceptions about the use of BIM and its synergistic effects with Lean. The discussion starts with the identification of the BIM functionalities that were implemented in the project and how they supported Lean principles (based on Sacks et al. 2010). Then, a discussion of results from interviews with three project team members (owner's representative, project manager, and design manager) is presented showing their perceptions regarding the benefits and challenges associated with BIM implementation.

BIM FUNCTIONALITIES AND LEAN PRINCIPLES

This section addresses the implementation of BIM at the project level and how its functionalities, as defined by Sacks et al. (2010), supported Lean principles. After the initial introduction to BIM through the bid phase, the owner was very supportive of further BIM implementation, and the BIM execution plan quickly established some functionalities that should have positive impact on normal project challenges. Below is a discussion of Lean principles that were supported by the BIM functionalities implemented at the project: reducing waste in the design process, reducing rework through better understanding of existing conditions, using visualization to communicate solutions, increased transparency in the project, and bringing BIM to the worksite (go and see).

1. Removing Waste in the Design Process

Examples in this section address BIM functionalities related to: design – visualization of form, rapid generation of design alternatives, maintenance of information and design model integrity, and automated generation of drawings and documents.

The project team collocated approximately once every three months, and immediate common understanding and collaboration at those meetings was necessary. Spending time interpreting drawings, explaining design concepts, and solving misunderstandings were forms of waste for which this team did not have time.

In this multi-lingual team, using BIM for communication between team members was essential. Where words, lists, and complicated drawings were not sufficient for understanding, the BIM became the central source of truth and understanding. Through clash detection and visual controls, design problems were identified rapidly and made transparent through the model, ensuring a visible information flow.

The team used visual status indicators of BIM objects to show how far into development they had come, enabling the design team members to see if components or systems they were dependent on could move or change dimensions, or if they were locked and should be designed around. This process removed unnecessary rework through locking down design in the correct sequence.

Quantity take-off in all design stages gave the project management better understanding of quantity implications of design changes. This allowed for quick feedback if a design had to be changed entirely instead of creating unnecessary iterations on a design that was not sufficient regardless of how much effort designers could put in trying to fix it.

The Lean principles enabled by these BIM techniques were: reduction in the variability of design output between designers, reduction in the cycle times of design and costing, and visual management of the design process.

2. Reducing Rework through Better Understanding of Existing Conditions

Examples in this section address BIM functionalities related to: design – visualization of form, rapid generation of design alternatives, reuse of model data for predictive analyses, and maintenance of information and design model integrity.

There were a number of tunnels in which old conveyor belts were being replaced, as well as additional conveyor belts being installed. These tunnels were scanned by the contractor's survey department, giving accurate design input to ensure that components would fit when being assembled on-site.

Existing infrastructure was also scanned to be incorporated in the BIM model to ensure coordination between existing and new infrastructure. Several places in the projects were very complex, requiring precision and accuracy. Furthermore, a drone scan was performed to incorporate the current design within the next stage of the project.

The Lean principle enabled by these BIM techniques was to go and see for yourself. Recognizing that 2D as-builts was not sufficient, the team made the investment to document existing conditions to ensure project success.

3. USING VISUALIZATION TO COMMUNICATE SOLUTIONS

Examples in this section address BIM functionalities related to: design – visualization of form, rapid generation of design alternatives, maintenance of information and design model integrity, and automated generation of drawings and documents; Preconstruction and Construction: rapid generation and evaluation of multiple alternatives, and online/electronic object-based communication.

Visualizations have at times been considered potentially "glossy" and not able to extract much value from BIM. However, when used correctly, visualizations can serve the purpose of showing to the client, suppliers, and teams involved during construction how the task is understood and potential solutions for it.

In the project, multiple design versions were maintained until the last responsible moment. This helped the team to clearly communicate the design intent and potential options to the client in a clear, visual way. The client had three different design options to choose from, which provided more value for the client to achieve their business goals. The owner considered the flexibility and attention to the owner's needs in the design workflow to add value to the entire design process.

The Lean principles enabled by these BIM techniques were the use of visual management and focus of concept selection. The team was able to maintain and present multiple options to the owner through the use of BIM.

4. INCREASED TRANSPARENCY IN PROJECT TEAM

Examples in this section address BIM functionalities related to: preconstruction and construction – online/electronic object-based communication.

Between meetings, the model was used for design discussions. Email correspondence often contained screenshots with text and markings, and video meetings had the model on a shared screen view. In the meetings, it was common practice when someone mentioned an issue that the group would stop the discussion until the design manager had navigated to the correct place in the model before the discussion would recommence. Some technical functionalities, such as BIM Collaboration Format (BCF) reports, enabled further improvement in the information flow. A BCF is a digital report where design team members can save viewpoints in a model, add comments, and assign responsibilities.

The Lean principle enabled by these BIM techniques was continuous improvement. The team was able to incorporate and leverage this new means of visualization to significantly improve their communication.

5. BRINGING BIM TO THE WORKSITE (GO AND SEE FOR YOURSELF)

Examples in this section address BIM functionalities related to: design and fabrication detailing: collaboration in design and construction; preconstruction and construction – online/electronic object-based communication.

There was a clear ambition in the project to view BIM as platform for better incorporating design and production. The BIM model was the basis for on-site discussions with production managers about planning and safety, e.g., the rebar crew assembled all the rebar for the screening station straight from the BIM model.

Crews were equipped with tablets and had both BIM and drawings completely updated at all times. Furthermore, BIM stationary units were placed out on site with the BIM model accessible to everyone. The strongest benefit with the stationary unit was that crews could rotate models themselves for better understanding and problem solving, as well as take out quantities and measurements themselves instead of relying on a designer to have put in all the correct measurements on drawings.

The Lean principles enabled by these BIM techniques were verify and validate and go out and see for yourself. This case is an interesting twist on 'go out and see'. Traditionally, this concept is thought of as managers going to the work place to understand issues where they happen. In this case, it illustrates the workers going to the BIM, as a form of visual management, to understand the issues.

INTERVIEWS WITH THE PROJECT TEAM MEMBERS

The first author conducted interviews with some key project participants (design manager, project manager and owner's representative) to document their perceptions about the use of BIM at this project. Initially, the three interviewees were asked about which BIM functionalities affected their daily work at the site, and rated them on a scale of 1 through 5, with 1 indicating that BIM had no effect in the project and 5 indicating that BIM provided exceptional value to the project. These BIM functionalities were selected in an initial meeting between the project management team and the bid team for early processes. During this meeting, the goals related to BIM use were discussed. Throughout the project, these goals were adjusted to include additional goals to be pursued by the team.

Interviewees indicated a number of functionalities had an exceptional effect in their work routine (ratings between 4 and 5), especially those related to having visual representations during meetings, including the use of video clips and using the visualizations for production purposes. The ability to conduct clash detection was also viewed as having an exceptional effect on their work. The use of mobile devices (tablets and kiosks/BIM stations) and the use of BIM for planning obtained ratings between 3 and 4. Additionally, the interviewees were asked a few open questions about implementation challenges and project benefits from the use of BIM. Their responses are summarized in Table 1.

Table 1: Results from the interview about the benefits and challenges of BIM

Question 1: From your perspective, what are the 3 biggest benefits from BIM in your project?		
Owner's Rep.	**Project Manager**	**Design Manager**
1. BIM ensured mutual understanding even though different nationalities and languages were present in	1. Understanding what has been designed. 2. Better compliance towards existing infrastructure.	1. Quick clarifications in meetings of where we are and what we are talking about. 2. Scanning of existing

meetings. **2. We don't speak different languages, we speak BIM.** **3. Visualisations increase ability to demonstrate understanding.**	3. Mutual understanding regardless of spoken language.	infrastructure is very important. 3. Using the model for your own understanding of the project, planning and forward thinking.
Question 2: What have been the 3 biggest challenges while implementing BIM?		
Owner's Rep	**Project Manager**	**Design Manager**
1. Getting all contract parties to understand the importance of BIM and get them to use it correctly. **2. Getting all existing infrastructure into the model.** **3. Knowing the potential with BIM before we have a problem that BIM could easily solve.**	1. Technical issues (not good enough computers for this massive BIM model and ambitious use). 2. Convincing everyone to use; BIM makes everyone's everyday work easier. 3. Creating mutual understanding of the processes of BIM as opposed to 2D-drawings.	1. Model too complex for computer limits, user knowledge. 2. Some designers approached BIM in parallel to drawings, instead of BIM first and drawings just as a result. 3. Constructability not always as easy to check - would expect more from BIM rule sets.
Q3: How has the information flow in design processes been affected by the ambitious BIM plan?		
Owner's Rep	**Project Manager**	**Design Manager**
1. Not too informed, but understand that it has had a notable effect on the design team.	1. Clearly a better information flow, better mutual understanding. Problems solved quickly and more visually creates less confusion.	1. Tremendously improved. A picture says s 1000 words. Still potential to communicate IN the model rather than screen shots.
Q4: How has the information flow from design to production been affected?		
Owner's Rep	**Project Manager**	**Design Manager**
1. Have a feeling that there is much more potential with focus on HOW we use the tools.	1. BIM-kiosks ensure updated, correct design information, correct data is available instantly, easier to understand and communicate.	1. Not too much knowledge, but hearing that the BIM kiosks are very popular.
Q5: What are the three things you will do differently when implementing BIM on your next project?		
Owner's Rep	**Project Manager**	**Design Manager**
1. Using the model more for safety and site planning. **2. Could use design status marking of objects more often.** **3. Explored more opportunities beforehand for further benefits form BIM.**	1. Implement BIM as early as possible. 2. Follow the contractor's BIM manual more precisely to ensure correct element data. 3. More BIM training before project starts to understand tools better and see more opportunities.	1. Specify in the beginning that BIM comes first and drawings second, not parallel worlds. 2. More focus on laser scanning existing infrastructure early. 3. Have resources and time to check that everything was in the model and no are objects missing.

DISCUSSION

Using Sacks et al. (2010) Lean-BIM interaction matrix as a model, it is possible to map the actual BIM-Lean interactions discussed in this case study and further identify interactions identified as most important to the project team in the BIM survey (Table 2).

Table 2: Case Study Specific BIM-Lean Interaction Chart (Numbers correspond to Case Study sections)

	Lean Principle						
	Flow				*Value Generation*		*Problem solving*
BIM Functionality	Reduce Varia	Reduce Cycle Times	Institute Continuous Improveme	Use Visual Management	Focus on Concept	Verify and Validate	Go and See for Yourse

	bility		nt		Selectio n		lf
Visualization of form	1	1		1, 3	3		2
Rapid Generation of Design Alternatives	1	1		1, 3	3		2
Reuse of Model Data for predictive analyses				2		2	
Maintenance of Information and Design Model Integrity	1	1		1, 3	3		2
Automated Generation of Drawings and Documents	1	1		1, 3	3		
Collaboration in Design and Construction						5	5
Rapid generation and evaluation of multiple alternatives				3	3		
Online and Electronic based Communication			4			5	5

By far, the largest perceived benefit of BIM was related to visual management of the project. First, the visual communication helped bridge a project specific language gap. More universal findings included that visual management enabled a better information flow and clarifications were quicker to get, consensus was easier to reach, and the contractor could easily demonstrate compliance with owner intent. The project also demonstrated benefits on the design side, e.g., reduced cycle times and variability; and on the execution side, e.g., verification and validation. Using this study as a model for BIM execution, the most beneficial way to introduce BIM is as a visual management tool.

CONCLUSIONS

This paper aimed at presenting how BIM could be implemented in projects with little or no tradition for using BIM, and which effects can be achieved. The authors indicated which Lean effects were achieved in the project as a result of BIM. The case study provides evidence that an ambitious BIM implementation is possible even with challenging prerequisites such as no contractual BIM demands from the owner, little pre-existing knowledge about BIM in the project team and significant geographical distance between team members. The key finding was that a project culture of willingness and helpfulness overcame challenges and solutions were found. The project management team clearly stated in interviews that they would have liked to start even earlier with BIM planning and training to utilize BIM tools more often and to gain further benefits from

BIM. Regarding Lean effects achieved, the case study strongly supports the previous theoretical foundation of the BIM-lean synergy matrix of Sacks et al. (2010).

FUTURE RESEARCH

Some BIM functionalities were not fully implemented and utilized in this case. Opportunities to achieve added benefits of the joint implementation of BIM and Lean are:

Production planning: The project could have visualized 3 week-lookahead plans, either through simple classifications in the BIM model checker or through a 4D scheduling software, enabling them to build virtually first to find improvement opportunities in sequencing and workflow.

Cost monitoring: The owner's representative was curious how to use BIM to communicate cost over time. This could have been achieved using a 5D software.

Safety training: The BIM model could be used for site safety simulations, such as fire hazard escape routes. Simple visualizations could be a basis for training, to analyse the need for marking, and measure time to exit buildings.

Logistics: BIM could be used to visualize plans for loading equipment and materials into facilities, both for safety and efficiency reasons.

Facilities Management (FM): The owner received a model well-equipped with information. A conversation from project inception regarding the quantity and quality of information for FM would have resulted in a more valuable FM model.

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REFERENCES

Bhatla, A. and Leite, F. (2012) "Integration Framework of BIM with the Last Planner System." *20th Annual Conf. of the Intnl. Group for Lean Construction (IGLC-20).* San Diego State University, San Diego, CA, 111-120

Harris. B. and Alves, T.C.L. (2013). "4D Building Information Modeling and Field Operations: An Exploratory Study." *21st Annual Conf. of the Intnl. Group for Lean Construction (IGLC-21).* Fortaleza, Brazil, Jul.29-Aug.2, 2013, 811-820

Kunz, J. and Fischer, M. (2012). Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions. CIFE Working Paper #097, Version 14, 50pp.

Sacks, R., Koskela, L., Dave, B.A., Owen, R. (2010). "Interaction of Lean and Building Information Modeling in Construction." *Journal of Construction Engineering and Management*, ASCE, Vol.136, No.9, 968-980