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EXPERIENCES FROM THE USE OF BIM-STATIONS

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ABSTRACT

BIM has gone from being a design-tool to being an important part of the production process. BIM-stations make 3D-models available for everyone, including all the workers on-site.

This paper 1) reports on experiences from the use of BIM-stations on site and 2) suggests certain improvements to increase the benefit of the BIM-stations. Following a case study approach, it examines the production phase of a building project in Norway.

Initially, a survey among 50 workers on-site was carried out. Both carpenters, plumbers and electricians conducted the survey. This was followed by semi-structured in-depth interviews with six key actors. Among the interviewees was the project manager, the BIM-coordinator on the project, and managers from the project owner's organization.

The research revealed that workers experience saving time with BIM-stations. They report higher productivity due to having the necessary information available at all time. The highest productivity increase appeared for the MEP workers.

This study was carried out over a relatively short period, with limited access to measurements of cost and savings from the use of BIM-stations. Nonetheless, the findings are still very positive and can guide future implementation of BIM-stations in the production phase.

KEYWORDS:

Building information modelling, BIM on site, BIM-stations, visualization, on-site communication

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INTRODUCTION

The use of 3D-models as a building modelling tool has been in constant development since it was introduced in the late 1970s and early 1980s. Computer Aided Design (CAD) started out as a design tool primarily for mechanics, electronics and aerospace (Eastman et al. 2011). The systems were expensive and overwhelmed the available computing power. As the development went on, new digital tools for all industries were introduced. In the building industry, the Building Information Modelling (BIM) appeared.

BIM is a three-dimensional CAD-technology, widely used in the design phase of all kinds of projects. It is even a requirement from some project owners. BIM has the potential to reduce the number of errors and omissions, as well as improving collaboration in projects, and eventually increasing productivity and reducing costs (Cant 2014).

Even if BIM typically has been seen as a tool for only the design phase, the technology equally represents a great potential in the construction phase. Some of the areas of use in this phase are visualization, calculation, planning and clash detection. Although these are uses for BIM in the production phase, the BIM is usually reserved for managers at the construction office. BIM is significantly less used on the construction site, where paper drawings still dominate. A current trend in construction is that projects are getting more complex and require detailed drawings. Van Berlo and Natrop (2015) question if the information presented by the drawings really constitute the information needed on the construction site. They even claim that most drawings are not specific enough for specialized tasks. With BIM, much more information is available.

To develop the use of BIM in the production further, it consequently seems desirable to move BIM from the office to the construction site, where the physical work is actually carried out. Such an introduction of BIM to the workplace enable information to be available when and wherever it is needed.

In this paper, we examine a case from the Norwegian construction industry. The case project is an ongoing project, notably the building of a new university building in Trondheim, Norway. The project was initiated by the Norwegian Directorate of Public Construction and Property, Statsbygg, as building owner.

In this project the main contractor, Betonmast, has introduced so-called BIM-stations on site. A BIM-station is a computer with a large screen placed on the construction site, where the workers can access the information they need. Here they can find the 3D-model, the web hosting service with all the drawings and other useful information previously reserved for the management.

The main contractor is using BIM-stations for the first time on this project. In addition, only a limited number of contractors and clients have previous experience with use of BIM-stations. Since research on the topic seems limited, but the potential to achieve higher productivity in the production process seems great, we wanted to:

1) report on experiences from the use of BIM-stations on site and

2) suggest improvements to increase the benefit of the BIM-stations

This paper proceeds as follows; first, we review recent research on the use of BIM on construction sites. Second, we present our research method. Next, we present and discuss

our findings on the use of BIM-stations in the case study. Finally, some concluding remarks follow.

RESEARCH METODS

The literature part of the study followed the steps specified by Blumberg et al. (2011), notably 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. This provided the theoretical framework as the basis for the research of this paper.

To gain knowledge about the utilization of the BIM-stations, what effects they might have and to find possible improvements, a case study was carried out. According to Yin (2014), a case study is most relevant if the questions one seek to explain is about "how" or "why" some phenomenon works. The same goes for questions that require an "in-depth" description. This made a case study the preferred choice for the research method.

There are two reasons why the new university building was chosen as case. First, the two first authors of the paper had part-time jobs on this project during the research period of 4 months. One of the responsibilities was to keep the BIM-stations running. This enabled observations and conversations with the workers during the research period. These observations and conversations provided the foundation for the research questions, and not at least for the questions in the interview guide and the survey. The authors have strived, however, to avoid that the impression from the observations and conversations impacted too strongly on both analysis and discussion. Second, this is a complex university building project, consisting of both new buildings and rehabilitation, with an area of approximately 16.000 m^2. Because of a very short construction period, the main contractor concentrated on achieving high productivity. To make this possible, the contractor introduced lean principles as takt-time planning and visual management. BIM-stations can be seen as a way of facilitating lean principles, as described by Vestermo et al. (2016).

The case study is based on document studies, in-depth interviews with 5 key actors with expertise and knowledge on the topic and a survey. The authors carried out the document study in order to acquire knowledge with background information of the project and the BIM-stations. The project managers from both building owner, main contractor and technical subcontractor, as well as the BIM-specialist on the project and head of the contractor's BIM department were interviewed. In general, the interviewees were chosen among those considered as having the best knowledge about the background for using BIM-stations.

The quantitative data in this paper results from a survey among 48 construction workers. Of these, 24 were carpenters, 12 electricians and 12 plumbers. The purpose of the survey was to map the use of the BIM-stations in addition to user's attitude and behaviour. The questions were a combination of multiple choice and free text answers. Multiple choice gave the ability to compare the answers and obtain a statistical representation.

The limited scope of the study does not permit for generalising the results. However, as Flyvbjerg (2006) points out, even a small number of interviewees can constitute a powerful source of information to generate new knowledge.

THEORETICAL FRAMEWORK

THE USE OF BIM AND INFORMATION CHANNELS ON CONSTRUCTION SITES

Studies have shown that the information on construction site seems to be inadequate. Hewage and Ruwanpura (2006) carried out research on this in Canada in 2003, with field observations, interviews and surveys. Findings indicate that the 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 outcomes of the project. Many workers also described a lack of clarity surrounding the instructions and the technical details. Nearly all the interviewed foremen reported difficulties in accessing the real-time information from the head-offices. Foremen spent about 15 % of their working time walking between the site office and the working area. Almost all the workers expressed that they were not aware of how the final product should be.

These results were presented 10 years ago, but it seems like it is only over recent years that something has been done about it. There have been many attempts to obtain more information to the construction site, with devices like tablets and computer-kiosks. Ruwanpura et al. (2012) concluded that there was need for an information kiosk that could show updated information. Accordingly, they developed the so-called i-Booth. This was an on-site communication framework, designed to give the site-workers material management, work demonstrations and updated drawings. The i-Booth had positive results in productivity, efficiency and worker satisfaction.

The use of tablets is another way of getting information to the construction site. Davies and Harty (2013) 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. The model was automatically updated when the tablet was connected to the network at the construction site. Tablets on site combined with an in-house document management showed positive results, like waste reduction and a lower than usual cost growth for service installations.

Atkinson (1998) states that bad communication is one of the main reasons why errors occur during the construction phase. Harstad et al. (2015) researched how tablets can improve communication on the construction site. This research showed that tablets could provide an easy access to up-to-date drawings and BIM on the construction site. It was found that tablets make it less time-consuming to obtain necessary information. The research showed, however, that some workers have little or no motivation to use new tools on the construction site. Furthermore, Harstad et al. (2015) emphasize the importance of adequate supervision, training and change in culture when new tools are introduced at the construction site.

The construction industry has been known to have some resistance in using new technologies (Brodie and Perry 2001). The resistance to IT is especially evident on building sites (Scott et al. 1994). The study of Hewage et al. (2008) showed that the older

and more experienced workers tended to be the most resistant. This also proved to be the case in the research of Harstad et al. (2015).

Several researchers have pointed out the importance of training to utilize BIM in construction. Hardin (2011) maintained, for instance, that; "You wouldn't hand a man a tool without training him how to use it […] the same rule applies to BIM". So when another contractor in Norway, Skanska, developed their prototype of what they called a "BIM computer kiosk" in 2014, they focused on training sessions (Bråthen and Moum 2015). A training program was developed by Skanska's BIM coordinator to give the workers a sufficient basis of knowledge on how to use the BIM-model in their daily work. They carried out the training at the construction site, gathered around the BIM computer kiosk. One session could include approximately five workers and last about one hour. The workers could ask questions and everyone got to navigate in the model during the sessions. The result was a highly used computer kiosk, with documented positive results, especially for the workers on electricity and ventilation (Bråthen and Moum 2015).

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. With BIM on site, the information also includes a valuable opportunity to visualize the building in 3D. The use of BIM on site is new to most, and an implementation may involve cultural change and time for training to get benefits greater than the costs. Although BIM might not be suited for all building projects at present, some building owners demand that certain buildings are designed with BIM.

Based on this review we can see that there is still a limited amount of research on the use of BIM on-site, and that further efforts are needed to bridge this gap in knowledge.

FINDINGS AND DISCUSSION

Set-up of the BIM-stations

A BIM-station can best be characterized as an on-site information tool, typically as a computer connected to a TV-screen. On the examined project, the BIM-coordinator had to design how the BIM-stations should be set up from scratch. A 40-inch TV-screen was placed inside a freight-case on wheels together with a powerful computer and cooling devices. Six of these home-made BIM-stations were placed on site, one on each floor of the building, available for everyone.

The BIM-stations provided the site-workers with constant access to an up-to-date BIM and all the drawings from the web hosting service. Apart from the design, the BIM-stations were a lot like Skanska's "BIM computer kiosks". Both allow site workers to visualize the planned project on a big screen and use the 3D-model to plan their work. Additionally, the workers can go to the BIM-stations to get information about delivery times to the site, HSE-information, weather forecasts and updated rig plans.

The use of BIM-stations was a wish of the building owner. They had positive experiences from previous projects, and believed that this could improve the project. The main contractor, Betonmast, wanted to follow their competitor's technological

development, and decided in collaboration with the project owner to invest in BIM-stations on this project. An implementation of BIM-stations entails a certain amount of costs and effort. The project owner covered the costs, while Betonmast developed the BIM-kiosks and the technical subcontractor was in charge of the internet connection.

EXPERIENCES FROM THE USE OF BIM-STATIONS

Limited Use and Lack of Training

Firstly, the BIM-stations were found to be used less than desired. The qualitative data collected from the survey showed that the use has generally been poor. When asked if they use the BIM-stations, 79% of the MEP workers said that they use them, compared to only 12,5% of the carpenters. Within the MEP workers we find electricians and plumbers, reporting almost the exact same use. The limited use was confirmed through all of the interviews in the case study. Both the survey and the interviews reveal that most believe that the limited use is due to a lack of training. Survey respondents and interviewees alike pointed out training as an important part of the implementation of BIM-station in the production phase. The training was found to be inadequate when approximately 90 % stated that they had not received any training. Most workers also stated that this was their very first project with BIM-stations. Very few had tried anything like this before. A few had gotten some general information about the BIM-stations on the project, but only foremen had gotten proper training.

The managers claimed to be aware of the lack of training, but explained that resources for proper training had not been prioritized. As a consequence of the survey, the workers got a one-to-one training session by the BIM-stations. Although some workers claimed to be in too much of a hurry, most workers were positive to the training, and even stated that they used the BIM-stations more after this. The low priority of BIM-stations was also found through the document studies. Meeting minutes from the last 1.5 years were studied, looking for BIM-station-related cases. The result showed that BIM-station was mentioned in the starting phase, but never mentioned after the first one was mounted. In addition, the mounting was postponed a number of times before it was completed.

Difference in Use between MEP Workers and Carpenters

The second main finding was the large difference in use between MEP workers and carpenters. By talking to some of the carpenters, we got quotes like; “Why should we use the BIM? We get more useful information from the paper drawings.” This is probably true in some cases. An example is the level of details in the walls, where information about different layers and insulation often is excluded from the BIM-model to save time and computer capacity.

As shown in table 1, the use within two weeks varied a lot, and confirms the previous results. Most carpenters did not touch the BIM-station within the last two weeks before the survey, but for the MEP workers, the use seems to be evenly distributed. Almost 50% of the MEP workers state that they had used the BIM-stations four times or more over the last two weeks. As opposed, almost 90% of the carpenters stated that they had not used BIM-stations at all in the same period.

Table 1: The use of BIM-stations within two weeks

	How many times the BIM stations were used within two weeks				
	Never	Once	Two to three times	Four to ten times	Over ten times
MEP workers	21%	21%	13%	21%	25%
Carpenters	88%	8%	4%	0%	0%

Previous research has shown that older and more experienced workers tend to be the most resistant to new technology. This has been the case on this project as well. Some of the younger workers had experience with BIM-technology, and were the most positive to training sessions. To quote one of the older workers; "I have never used and I'm never going to use the BIM-stations. I don't even use a computer at home. I have 12-year old son for those kinds of things".

What the BIM-stations are used for

The interviews and surveys revealed what the BIM-stations on the project are used for. It was apparent that the 3D-model is the most used feature. Users report that they use the 3D-model to help visualize tasks, and to see how the finished building will be. By using the web hosting service at the BIM-station, the workers can get access to all of the drawings for the project. This is the function that is the second most used. All the drawings on the BIM-station is up-to-date, which can be needed by everyone on site. Many workers, especially the MEP workers, state that they save time having access to the drawings on site. Without the BIM-stations, workers have to walk all the way to the construction office to obtain the same information. Saving time this way is one of the main purposes of using BIM-stations on site, but it didn't always work as planned. On this project, we experienced that workers walked to the office to ask someone to show them things in the 3D-model. When this happens, the biggest advantage of a BIM-station, notably the location on-site, is lost. Once again, the lack of training becomes apparent. The workers know that there is information in the BIM-stations on site, but go to the office anyway because they can't find it themselves. The positive thing about this is that many workers now want to use the new tools. When someone see the benefits, the word is spread. Eventually, the positive attitude can spread throughout the construction industry, and tools like BIM-stations can be used even more. Rig plans and weather forecasts are also features that are available at the BIM-stations, but these seem to be less used. The interviewees claim that too much information available on-site may reduce the effect, when users take longer to find what they need.

Improved Communication with BIM-stations

The interviews and survey showed both that workers and managers alike think BIM-stations can improve the communication on the construction site as well. Both communication between different companies regarding interfaces and communication within the companies is reported to have been improved on this project. In addition, 3D-models at the BIM-stations can be a way of bridging the communication gap between

subcontractors caused by their different native languages. Other ways of using BIM-station to communicate exist as well. At this project, the screensavers on the BIM-stations had HSE-messages and –pictures. The interviewees state that it is hard to know if this had any positive effect, but it definitely did not hurt.

Positive Effects of BIM-stations

As for the positive effects of BIM-stations on the project, the opinions were divided. Some of the carpenters considered the BIM-stations an unnecessary cost, with no positive effects what so ever. That was yet not the general opinion. A large percentage of workers experienced saving time with BIM-stations. They reported higher productivity due to having the necessary information available at all time. The overall impression from both survey and interviews is a unanimity that the MEP workers have the greatest benefit of the BIM-stations. This is also reflected in the answers of the last question the workers were asked. We wanted to know if BIM-stations are something the workers would like to have access to at their next projects. 96% of the MEP workers wanted this, while the result from the carpenters was 50-50.

SUGGESTED IMPROVEMENTS TO INCREASE THE BENEFIT

Figure 1 shows what the workers suggested as improvements to increase the benefit of the BIM-stations. It was clear that proper training was something the workers wanted. When asked what had to be done to achieve greater use, most workers called for training sessions. Both workers and managers see this as the most important improvement that has to be done in order to exploit the BIM-stations' potential.

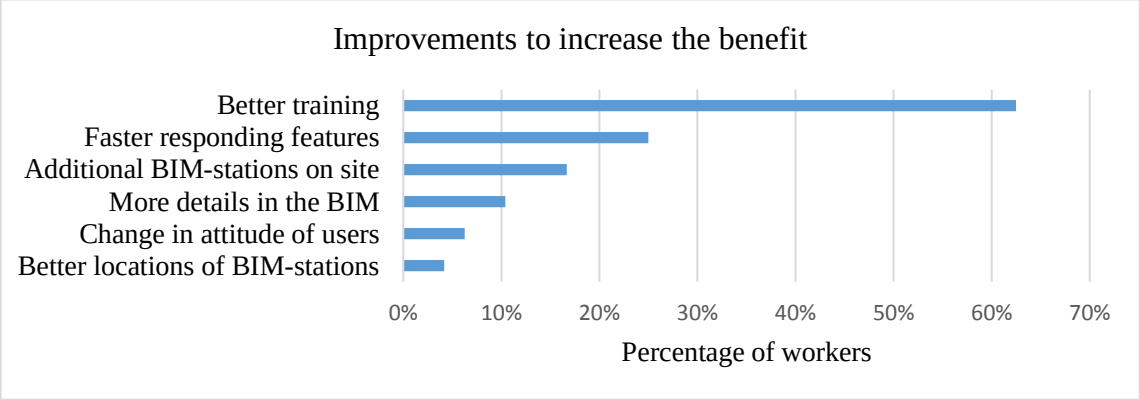

Figure 1: Improvements to increase the benefit, based on survey

Not all the workers were happy about the level of details in the BIM-model. It appears from the survey that the level of details is a limitation for the use of BIM-stations, especially for the carpenters. To increase the benefit of BIM-stations for carpenters, details as layers and insulation in walls should be added. For the MEP workers, the BIM-stations proved much more useful. The 3D-model made it much easier to visualize their tasks. However, all fields point out the ability to visualize the building as a big advantage of the BIM-stations.

The number of BIM-stations at the construction site was another thing some of the workers were unhappy about. The project was large, with about 15.000m^2 of new

buildings. A few workers therefore stated additional BIM-stations as important to exploit the BIM-stations' potential. Better locations could according to the workers also increase the benefit.

A BIM that responds faster than today is another way of increasing the benefit of the BIM-stations. Some of the workers stated that they had stopped using the BIM-stations because downloading drawings took too much time.

The observational studies identified some challenges with the use of BIM-stations. Some of the workers had little or none respect for the BIM-stations on site, and did not seem to care that others might need them. Like a few of the workers admit, it seems like a campaign to improve worker's attitude could improve the benefit of the BIM-stations. The BIM-stations were often found unplugged and stored in a corner, or under a pile of junk and clatter. This led to another problem, the downtime. Moving and reconnecting the BIM-stations was found to take a lot more time than expected. Improving the prototype to a more mobile station would make this easier, result in less downtime and increase the benefit.

CONCLUSION

By presenting experiences from the use of BIM-stations, this paper supplements existing literature on the topic. BIM-stations give the workers access to the project information on site. The 3D-model helps visualize the project, and the web hosting service provides easy access to up-to-date drawings on the construction site. This can eventually lead to higher productivity in the production process. It has been found that MEP workers benefit the most from the BIM-stations. They use the 3D-model to visualize, plan their tasks and solve any problems that may arise. Carpenters also benefit from the BIM-stations, mostly by saving time getting the necessary drawings, but they were not using the BIM-stations as much as desired.

The costs of implementing BIM-stations are usually covered by the building owner. This was also the case in this project, where the building owner covered all costs. The contractors benefitted from the BIM-stations without responsibility for the cost, so they were happy. For future projects, the authors recommend the client to ask the question about what to achieve with the BIM-stations before implementation. That can help when deciding the functionality. In the investigated case, it seemed like the client decided to use BIM-stations without considering what they wanted to achieve.

As for improvements, proper training is found to be crucial. On this project there has been too little training in order to exploit the BIM-stations' potential. Many workers also pointed out that the BIM-model could be improved, with more details and faster responds. Additional BIM-stations on better locations is another thing the workers pointed out as possible improvements. These small changes, in addition to a change in some workers' attitude to new technology, could be great improvements in order to increase the benefit of BIM-stations on site. We consider the need for a cultural change in mind-set to be something that will take some time, but come more or less automatically when the project participants on site get used to continuous access to the BIM through i-booth, computer kiosk or tablets. However, there is still need for research on the use of

BIM-stations in order to exploit the full potential. BIM-stations are a relatively new tool to access information at the construction site. The numbers of cases studied are few, which makes the findings unsuitable as a basis for statistical generalization. More research is needed to be able to conclude what workers on a construction site can use BIM for and what value it can give the construction process. With future research on the effects of BIM-stations on construction sites, BIM-stations can develop further, and become even better.

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