Bridging the gap: bringing BIM to construction workers

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Abstract

Purpose – The majority of research on the implementation and use of Building Information Models (BIM) have focused on building design and pre-construction planning. There is only limited research on the usage of BIM in the construction phase, especially by site workers. The purpose of this paper is to analyze the use of BIM by site workers through so-called "BIM-kiosks". The kiosks allow workers to access BIM models on-site. The aim of this paper is to take a closer look on the introduction of BIM-kiosks and scrutinize how and for what purpose site workers use the kiosks.

Design/methodology/approach – This is a single case study of an ongoing real-world construction project. The case study is based on qualitative data which stems from observational studies, interviews as well as document studies.

Findings – Site workers find opportunities for 3D visualization useful and the BIM models are appraised for efficiently handling complex elements. The findings also indicate that the use of BIM-kiosks lead to a greater level of face-to-face collaboration between workers on-site. This may happen because workers meet, both planned and randomly, to discuss in front of the kiosks while using it for visualization.

Research limitations/implications – The research is limited to a single case. However, some of the recommendations may be relevant to other projects. In addition, the findings demonstrate some of the potential of using BIM on-site in upcoming construction projects.

Originality/value – Only a few studies have addressed the use of BIM among site workers. Thus, the findings provide practitioners and researchers insight into how current practices may be improved, as well as areas where more research is needed.

Keywords BIM, Implementation, Collaboration, Visualization, BIM-kiosk, Construction activities

Paper type Research paper

1. Introduction

The architectural-engineering-construction (AEC) industry creates complex and unique products, based on a highly specialized process. Construction work is organized as projects; temporary coalitions between two or more organizations. Due to its characteristics, the industry forms a complex communication environment (Jones and Lichtenstein, 2008; Hartmann *et al.*, 2009). A central task is to get accurate information at the right time and place. Hereby it is challenging to overcome the organizational fragmentation as well as the site-based location of much of the work (Davies and Harty, 2013). This paper reports on experiences made in a real-life building project in Norway, where so-called "BIM-kiosks" (Building Information Models (BIM)-kiosks) have been introduced to the site workers. The purpose of the BIM-kiosks is to allow site workers to view BIM and thereby get on-site access to up-to-date design information of the planned building. The visualization of complex spatial situations was one primary reason for taking BIM to the construction site in this pilot project. This paper takes a closer look at the introduction of BIM-kiosks and asks the following research question:

RQ1. How were the BIM-kiosks introduced and for what purpose did the site workers use the kiosks?

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The purpose is to gain knowledge about the implementation and use of BIM on the construction site. The paper addresses both an important industry challenge as well as an area where the research is still limited.

There are a number of definitions of BIM (Jensen and Jóhannesson, 2013). We use a definition that describes BIM as adjective phrase to: "[…] [D]escribe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation" (Eastman *et al.*, 2008). The most widespread use of BIM today is in the design phase. Construction work is still dominated by paper in the form of drawings (Sacks *et al.*, 2010; Merschbrock and Nordahl-Rolfsen, 2016). There are at least three shortcomings of using traditional drawings to explore building information in current construction practice: poor portability and inadequate handling of the drawings, poor display of problems, as well as problems related to browsing and readability (Yeh *et al.*, 2012; van Berlo and Natrop, 2015). Sacks *et al.* (2010) state the following on the potentials of using BIM on-site compared to traditional drawings:

> BIM tools enable three and four-dimensional visualization of the building product. Effectively communicating design intent is one of its key functionalities and benefits. The weakest link in this communication is the "last mile"; delivery of the product information to the workers during production, because it still relies on formal drawing views of the information that can be printed on paper. Electronic media offer the opportunity to deliver information in dynamic views that can be manipulated and queried by the consumers, including animations and database access.

There are several reasons for the predominant role of drawings at sites all around the world. Until recently, there seems to be no appropriate tools to make use of BIM in rough environments in our part of the world. In addition, there have been challenges associated with training site workers. This implies that the potential benefits of using BIM to visualize and communicate 3D design solutions to site workers have not been enhanced. In order to overcome some of these challenges, the building commissioner Statsbygg and the general contractor Skanska have joined forces and developed and tested out a pilot solution in one of their ongoing building projects. Five stationary BIM-kiosks were built and placed on the building site, giving site workers continuously access to the models.

The paper is structured as follows: in the next section we present a brief review of current research on the use of BIM at the construction site. Subsequently, a framework that highlights rationales for using information systems on-site is presented. Then we elaborate on aspects related to the research methods used in the study. Next, the empirical material will be presented. First, we give an account of the introduction and use of the BIM-kiosks. Second, we present and discuss the findings of the study in light of the previously presented framework. We construct three ideal types of the use of BIM-kiosks that will be discussed. We wrap up the paper with some concluding remarks and recommendations for further research.

1.1 Prior research on the use of BIM on construction sites

Most of the research on the implementation and use of BIM concentrates on building design and pre-construction planning. It is primarily during the last few years that we have seen research on BIM-use in other stages of a building project (Merschbrock and Nordahl-Rolfsen, 2016; Wang and Chong, 2015; Sacks *et al.*, 2010). However, the aspiration of bringing digital design information to the construction site is not new (Kimoto *et al.*, 2005). Hewage and Ruwanpura (2009) report on using an "information booth" with a large

screen and a printer, thus providing workers access to updated drawings on-site. Various digital devices such as personal digital assistants, electric pocketbooks, wearable computers, laptops as well as other forms of mobile computing for a variety of tasks and roles have been tested out at construction sites during the last couple of decades (Kimoto *et al.*, 2005; Sacks *et al.*, 2010; Yeh *et al.*, 2012; Kim *et al.*, 2013). In addition, there is an increasing amount of literature on the use of augmented reality in the industry (Chi *et al.*, 2013; Rankohi and Waugh, 2013; Wang *et al.*, 2014). Nevertheless, there are only few studies on the actual usage of BIM by site workers in real-life projects. Sacks *et al.* (2010) examine the use of large touch-screens on-site. They found that large screens give opportunity for online feedback and are suitable for displaying information to several people at once. Davies and Harty (2013) use the term "site BIM" and conduct an empirical case study of implementation of a BIM system that allows site workers to use tablet computers to various information. They reported that the "site BIM" "[…] was delivered through an exploratory and emergent development process of informal prototyping. Technical IT skills were adopted into the construction project through personal relationships and informal arrangements rather than formal processes." van Berlo and Natrop (2015) analyze a concept where BIM is used to generate drawings addressing a specific task or purpose for the site workers. The idea behind this concept is to give workers the information they actually need, and nothing more. The researchers found that this concept contributes to good communication between the site office manager and construction workers. Merschbrock and Nordahl-Rolfsen (2016) analyzed a case of the use of BIM for facilitating on-site placement of reinforcing bars. In the case, site workers were given access to an advanced virtual model by the use of iPads. Their findings show that the workers experienced great advantages of using models compared to traditional drawings. The authors argue that building process productivity improvements are possible when BIM is introduced on-site.

As this brief review illustrates, there is still only limited research on the usage of BIM in the construction phase, especially by site workers. This indicates that there is certainly a need for more knowledge on how construction workers can benefit from using BIM in their daily work on-site.

1.2 Rationales of using BIM for on-site construction activities

As pointed out in the introduction section, there are a number of potential advantages for letting construction workers use BIM on-site. Advocates of increased use of digital technologies on-site refer to effectively communication of design information for reducing the risk of costly errors and delays as the primary advantages (cf. Kimoto *et al.*, 2005). In an article about the combination of BIM and augmented reality, Wang and Love (2012) identifies the following seven practical rationales for using such an information system for construction site activities:

(1) interdependency;

(2) link digital (paper) to physical;

(3) synchronization of mental models for communication;

(4) project control, monitoring and feedback: as built vs as planned;

(5) procurement: material flow tracking and management;

(6) from design to production: a visualization gap; and

(7) site plan and storage.

For a thorough examination of the rationales, see Wang and Love (2012) and Wang *et al.* (2014). Not all of the rationales are suitable for a case where BIM-kiosks are used by construction workers compared to cases were augmented reality are employed by both managers and workers. Nevertheless, both BIM-kiosks and augmented reality are essentially tools which are meant to be the extended hand of BIM on construction sites. In this case study the framework may be a useful analytical lens for examining and digging into our empirical material. With regard to the BIM-kiosks the rationales which deal with identifying interdependence and complexity (1), providing a common view for on-site communication (3) as well closing the "visualization gap" between the design and construction phase (6) seems particularly relevant rationales for this case.

2. Research strategy and methods

Our research follows a real-world and ongoing construction project that allows construction workers on-site access to BIM. We use a single case study strategy in order to draw lessons from the specific project studied. According to Yin (2003), a case study consists of an in-depth inquiry into a specific and complex phenomenon, set within its real-world context. Case studies allow researchers to retain holistic and meaningful characteristics of real-life events. Such a research design is seen as appropriate to answer "how" and "why" questions and opens for the investigation of many variables, consequently generating in-depth knowledge (Yin, 2003; Eisenhardt, 1989; Flyvbjerg, 2006). This case study is based on qualitative data, which stems from observational studies, interviews and document studies. We collected the data during the first seven months of the construction phase, which is still ongoing (April 2016). In the following sections we discuss the applied data sources.

2.1 Data and analysis

First, we have done observational studies (Yin, 2003). Four times, for about four hours, we walked near the different BIM-kiosks to observe what was going on in front of and on these computers. We both observed training sessions (which will be described later) as well as the actual use of the BIM-kiosks in the workers' daily work situations. Observational studies involve making field notes based on observation of behavior, talk, interaction, practices, etc. A distinct advantage with observational studies is the direct access to situations we were curious about; we could see with our own eyes "what was going on" in front of the BIM-kiosks and in other places within the building (Barley and Kunda, 2001; Yin, 2003).

Second, we have conducted seven semi-structured interviews and 12 focused interviews (Merton and Kendall, 1946). The semi-structured interviews were carried out with key actors in the project, such as the project manager, site manager and the BIM coordinator from the general contractor Skanska, and the project management and BIM specialists from the building commissioner Statsbygg. The purpose of these interviews was to get the informants' own assessments of issues concerning the BIM-kiosks. Semi-structured interviews is the "standard model" of qualitative interviews within the social sciences. A semi-structured interview guide consists of some main themes and a list of questions that should be asked during the interviews (Kvale and Brinkmann, 2009; Yin, 2003). In all, 12 focused interviews were carried out with site workers (carpenters, plumbers, electricians, etc.). As the purpose was to get specific and uncontroversial information about the BIM-kiosks, it was not necessary to conduct this long-lasting in-depth interviews. Instead, we went straight to the point without extensive "warm up

questions"[…] Such focused interviews gave quickly access the informant's experiences with the BIM-kiosks. They took place at the construction site, immediately after the workers had used the BIM-kiosks. Sometimes we also encountered them randomly on the site […] .The majority of the interviews were done in Norwegian. Consequently, most of the quotes used in this paper are translated from Norwegian to English by the authors. Since the EU enlargement in 2004, a number of Eastern European workers, especially Poles, are employed in the Norwegian construction industry (Friberg, 2012). This has led to several new nationalities and languages on Norwegian sites. Thus, a small number of our conversations with workers took place in English. Considering the work practice, we did not observe any particular differences in the use of the BIM kiosk between the Norwegian and foreign workers.

Third, we have studied documents as a supplement to the data generated through interviews and observation. The documents included in the analysis are created for other use than research. Examples are: contract documents and the Statsbygg BIM manual.

The central findings presented in this paper are thus based on data from multiple sources. The data has been analyzed in two stages; the data were coded on the basis of a close reading and the codes were divided thematically in order to make patterns more visible. The use of multiple data sources, is central to overcome problems of bias and validity in qualitative research (Yin, 2003; Tjora, 2012). According to Yin (2003), so-called data triangulation occurs when facts of the study has been supported by more than a single source of data. When triangulated, findings of the case study are strengthened because they are likely to be more accurate when using multiple sources that have different strengths and weaknesses. The following example illustrates this: in interviews, on-site workers told about how they used the BIM-kiosks together for activities such as problem solving or planning. When doing observational studies we could see this interaction by ourselves. This combination of sources of evidence provided multiple measures of the same phenomenon, namely BIM based on-site collaboration. Similar situations have encountered in other parts of our analytical work. The interplay between triangulated data from documents, interviews and observations corroborated facts emerging in our analysis. Although these findings will not provide a basis for statistical generalization, they allow for other ways to bring forth knowledge. A way of generalizing based on qualitative case studies is so-called conceptual generalization. This implies the construction of ideal types, concepts, models, etc. (Tjora, 2012). As well as being a form of conceptual generalization, the construction of ideal types is a data analysis strategy. In this paper three ideal types are constructed. Following Halkier (2011), these ideal types were created through a process of condensing the coded data (stage 2) into a limited number of types, which underline particular characteristics at the expense of others. Ideal types can be seen as a kind of generalization that attempts to enable a more general perspective on specific patterns. A challenge to construct typologies is that it requires a reduction of complexity in the data. Thus, overlaps, gray zones, and multiplicities are toned down. The purpose is not to summarize all our empirical material, but rather take some parts that seem particularly interesting, empirically as well as theoretically.

The vast majority of the on-site workers welcomed the BIM-kiosks in a very positive way. The reason for this might be the fact that they were not forced to use the kiosks and that they still, in addition, could use traditional drawings. This freedom of choice may have affected the overall positive nature of our findings. We do not, however, consider this as a challenge of the rigor of the study, as our ambition is to discuss findings from a case concerning a field were the knowledge is still scarce, rather than to draw lessons from a representative sample of BIM-kiosks users.

3. The case: BIM-kiosks on the construction site

3.1 Case study background and context

Statsbygg and Skanska are both part of an ongoing Norwegian innovation project called SamBIM (Collaboration with BIM as a catalyst), funded by the Norwegian Research Council. The overall aim is to develop BIM-driven processes and collaborative models that boost value creation in the SamBIM companies, in the building projects and in the AEC-industry. The real-life project studied in this paper is the refurbishment of a 115 years old university building named Urbygningen at the Norwegian University of Life Sciences. The project delivery method is based on a design-bid-build contract. The preliminary design was completed in 2009, and in 2013 Statsbygg initiated the detailed design phase. The construction phase started in august 2014 and final completion of the construction work is scheduled to be in 2016. Because of the connection to the SamBIM research project, the BIM ambitions were raised compared to a more "normal" Statsbygg project, according to our informants. As a result of the elevated BIM ambitions, Statsbygg wanted to test out BIM for site workers in the construction phase.

3.2 The origin of BIM-kiosks

According to one of our informants from Statsbygg, on-site workers often experience that drawings do not give enough and sufficient detailed information. In the Urbygningen project, Statsbygg wanted to test out how making BIM accessible on the construction site would affect this situation.

Thus, it was decided that Statsbygg would require the use of BIM-kiosks. In Statsbygg's contract documents the following can be read about what is expected from the general contractor related to the BIM-kiosks:

> "[The general contractor should] establish and operate 5 stationary BIM stations with 50" monitors connected to a PC with Solibri Viewer (free version) software and a wired network access. The equipment should be encapsulated so that the screen and PC can operate in a dusty and rough environment (Statsbygg, 2014).

As we see, the decision about using BIM-kiosks in the construction phase was made by Statsbygg. Despite this, the contracts had fairly vague specifications of how the kiosks should look like and actually be used. Consequently, it largely became the general contractor Skanska's responsibility to determine the details. Each BIM-kiosk was established with a large screen, a Windows-based PC inside the wood cabinet, as well as a keyboard and a mouse. The kiosks were thus relatively cheap to produce. The kiosks also had a wired broadband internet access. This made it easy to update the model, which is done once a week. When the construction phase started, the kiosks were placed on the landing in each floor of the building.

3.3 Training sessions on-site

Virtually none of the site workers had any experience with BIM from other projects. A short training program was set up in order to give the workers sufficient skills for using the model in their daily work. This training program was developed by Skanska's BIM coordinator in the project, together with a Statsbygg employee with a similar role. The training took place in front of the BIM-kiosks at the construction site. Each training session was scheduled to last for about one hour with an instructor and a group of approximately five workers. The first part of the training session contained a demonstration of the model. In this demonstration, the workers were

shown how to navigate in the model and how to obtain various design information. The sessions were held several times so that everyone working on the site should get the opportunity to participate.

One of the main goals with training sessions was to give an introduction to how the workers themselves could use the BIM-kiosk and how the kiosk could be useful in their daily work. The instructors emphasized that everyone should get to try the BIM-kiosk within a safe setting; "[E]veryone should have tried spinning around in the model during the sessions to see how this could be done." In our interviews it appeared that it was more or less unproblematic to get the workers to show up for training sessions. Most of them perceived the BIM-kiosk as an interesting and exciting innovation. In the training sessions we noticed that most site workers were interested and had a positive attitude toward the use of BIM. In our interviews the informants described that they think the learning outcomes of the training sessions were good and gave a useful overview of the BIM-kiosk's possibilities. Albeit, a few workers stated that they thought the use of BIM seemed complicated and that they probably would not use the BIM-kiosks to any great extent. It should nevertheless be underlined that this was a minority of the responses we observed.

4. Findings

In this section, we present our findings First; we will take a look at the introduction of BIM-kiosks. Then we will discuss how and for what purpose the site workers used the kiosks in this project.

4.1 The training sessions had an important participative purpose

The on-site training sessions could be characterized as a type of practical on-the-job training. The sessions were clearly necessary because none of the workers were familiar with the use of BIM or BIM-kiosks. Arranging short training sessions is in accordance with research literature. Hardin and McCool (2015) point out that that field personal training should be relevant focused and to the point; on-site personal typically do not need to become BIM experts. The training sessions in this study became an arena where the workers got the opportunity to influence and give feedback on how the functionality of the kiosks might be improved. Additionally, our data suggests that the training sessions had a further important but more unintended function. This is coupled to the actual implementation of BIM at the construction site, more specifically to the communication of the purpose and usefulness of the BIM-kiosks to all actors involved. Innovations and developments such as BIM-kiosks that are perceived as important and necessary by top management are not always viewed in the same way by the troops on the ground. Although the main purpose may be clear, it is important that those who are involved and affected by the change have a meaningful understanding of the initiative. In addition, it is crucial to involve the workers affected and to listen to their opinions and allow them to have an impact on the process. In the training sessions it was not communicated that the workers had to use BIM for a certain purpose or in a specific manner. On the contrary, the site workers were free to use the kiosk in the way they found it advantageous. The data indicate that the workers got an ownership and commitment to the BIM-kiosk initiative. They were involved in the developing process to make it useful, rather than forced to use in a specific way.

It was also important for the instructors to demonstrate the user-friendliness and the usefulness of the BIM-kiosks to the site workers – that digital devices can be helpful rather

than a hassle and an annoyance in their daily work. For workers without much computer experience, the training sessions were essential to demystify the purpose of using computers in construction work. Our data implies that the training sessions stimulated learning and commitment, independent of the age and BIM-competence of the site workers.

4.2 A better understanding of the design material

By introducing the BIM-kiosks, Statsbygg and Skanska sought to gain experience with how the use of this kind of computers influenced the work at the construction site. Our data indicates that the workers who use the kiosks experienced great advantages in a number of areas compared to a situation where only drawings were used. This applies for all disciplines present such as plumbers, bricklayers, ventilation workers, carpenters and electricians. It also applies to workers employed by the general contractor as well as those employed by the different subcontractors.

Concerning their rationale about interdependence, Wang *et al.* (2014) claim that "[…] different roles involved in the current construction practice mainly focus on their individual tasks, with less concern about the interdependencies between different tasks." Several workers told us about such situations and claimed that using traditional drawings make it difficult to apprehend dependencies between own task and other disciplines. More or less all interviewed emphasized the model's ability to visualize complex situations and display the totality of the building as particularly helpful. Many also pointed out that they found it much easier and quicker to "get the overall picture" and that the model gives insight into a greater level of details and complex dependencies between own tasks and other disciplines compared to drawings. The following quote illustrates some of what is discussed here:

> I am working on ventilation and our drawings are often intricate with lots of details. There are other disciplines we must deal with as well. The model illustrates things much clearer and I can see how this will look when everything is completed.

Other informants highlighted that navigating in the model and finding the right view was much easier compared to searching for details in a huge stack of paper drawings. Most workers explained that they often approached the BIM-kiosks to get information about some specific detail or problem. This could, e.g., be details that were difficult to identify, or even completely missing, in the drawings. The informants thus indicated that paper drawings are not providing sufficient and specific enough information. The use of BIM-kiosks is furthermore time saving because workers do not have to consult the site office to find the correct plan which is updated or ask for clarifications. These kinds of situations are somewhat similar to the rationale about closing the visualization gap between design and production. In the discussion of this rationale it is argued that BIM on-site can give workers a better understanding of details and that a high level of constructability could be achieved. It is also claimed that the "[…] 3D reinforcement detailing reduces the periods of time usually required for alteration to drawings, saving time for all parties involved" (Wang and Love, 2012). Our informants were also concerned about several of these benefits. The 3D model's richness of details was actually highlighted as one of the BIM-kiosks major advantages by the workers interviewed. The following quotes illustrate some of the advantages they emphasized in our interviews:

> I can see by the drawing that there should be some pipes here. This is what I'm working on right now. But by this drawing I cannot see if the pipes should lie under the floor or over the ceiling. By using the model I can immediately see that the pipes must be over the ceiling.

> I have never used it [BIM] before, but think it's awesome! I can check things out more accurately than with drawings. Often we have so many drawings. Look at this big stack, it's almost impossible to find the right one.

It should be added that it was made an effort to make the models as intuitive and easily read as possible. In such refurbishment projects it may furthermore be difficult to see which building elements to keep or demolish or by using traditional drawings. Consequently, they used different colors in the model to highlight such differences. This measure also helped the site workers to recognize the spatial relationships between the various technical installations. The BIM-kiosks were often used by only one worker at the time, to check details, planning issues, etc. Nevertheless, this was not always the case. In the next section we will take a look at situations where two or more workers used the kiosks together.

4.3 BIM-kiosks as meeting places: a common view for problem solving and planning

Already in the very beginning of our data collection and throughout the observation of the training sessions, we observed some particularly interesting situations. While the workers tried the model by navigating for the first time, we observed that those who were gathered in front of the BIM-kiosks sometimes started a dialogue about the details displayed on the screen. Comments such as "look over here" and "what have the architects and engineers planned here?" reflected that the model opened for a professional conversation among the people standing in front the BIM-kiosks. During observations of the post-training use on-site, we encountered similar situations where workers gathered around the kiosks and discussed issues displayed on the screen. Such meetings were sometimes planned, i.e. two or more workers went together to the BIM-kiosks. The meetings could also be spontaneous, occurring when one or several workers stood by the BIM-kiosk and additional persons came along and participated in the discussion. When these situations occurred, we used the opportunity to ask the workers about it. The following quotes illustrate some of the answers we got:

> If I see another person standing at the BIM-kiosk when I pass along, sometimes I join in for a short talk about what he is doing, or potentially difficulties etc. It's space for more than just one in front of the computer. I think this is a good thing.

> Again and again it has been useful standing in front of the computer together so that we can discuss what we see. Sometime we discuss what to do in a specific part of the building, other times it is more about making planes or clarify what we are going to do throughout the day.

In the quotes above, the informants describe benefits of using BIM-kiosks together with other workers. The informants explain that in these kinds of situations the kiosk was typically used to discuss specific challenges, or to plan or look more closely into work that had to been done. This finding can be seen in conjunction with a rationale Wang and Love (2012) and Wang *et al.* (2014) label as "synchronization of mental models for communication." These are situations where on-site communication and coordination can occur between workers using the BIM on-site. In other words, the BIM-kiosks may provide a common view and perspective on the design information. In situations where two or more informants used a BIM-kiosk together in a planned meeting, our data show that these usually were workers from the same discipline, e.g. carpenters. Consequently, these workers were most often employed by the same company. They found it most useful to discuss discipline-specific details with colleagues from the same discipline. When we observed workers using the BIM-kiosk together in spontaneous and unplanned meetings, they were more often from various disciplines. However, not only professional discussions

were taking place when several workers gathered in front of the BIM-kiosks. A number of times we observed situations which gave the impression of being some kind of teaching situations rather than planning or discussions. In the following quote, we are dealing with such a situation. A site worker stated the following about how he and his colleague just recently had used the BIM-kiosk:

> We did not discuss anything special. I have used the model more than him; I'm pretty good at this. He was with me so I can show and teach him about how to use it [the BIM-kiosk]. This is the future, right?

As the informant points out, one worker had followed the other to learn more about using the BIM-kiosk. Thus, the workers did not discuss anything particular in front of the kiosk.

As a whole, this discussion of findings shows that the BIM-kiosks were used in different ways; sometimes by one worker alone, at other times by a group. Our findings also show that kiosks were utilized for a variety of activities. First and foremost, our data indicates that the BIM-kiosks are useful for getting a fast overview and to visualize complex spatial relationships which are difficult to perceive on traditional 2D drawings. Further, the BIM-kiosks are beneficial for discovering interdependencies between own tasks and other disciplines as well as investigating details. In addition our findings indicate that when the BIM-kiosks are used by several workers together, the kiosks are useful to get a common view for collaboration including discussion, decision making and planning. In the next section we will draw some more general conclusions on how the BIM-kiosks are utilized and what future projects can learn from this case study.

4.4 How are the BIM-kiosks used, and what are the potentials?

In order to generalize our findings, we have identified the following three ideal-typical situations for how the BIM-kiosks are used and how this affects the work at the construction site:

(1) Individual use: this first ideal type involves a situation where a single worker uses the BIM-kiosk alone in order to perform various tasks. This could be getting a quick overview, visualizing complex spatial relationships, discovering dependencies etc. as discussed in the previous section.

(2) Learning or teaching: in this ideal type, the situation is similar to the first one. The difference is that there is more than one person standing in front of the BIM-kiosk. However, it is mainly one worker who is in command, i.e. who is actively using the computer. The other workers are not involved in any kind of professional discussion or dialog with the person in command, but they pay attention to what is happening on the screen. This ideal situation thus distinguish itself from pure individual use as it includes "instruction or teaching coworkers BIM", as a couple of informants called it. These situations are in other words characterized by individual use as well as one-way communication or teaching from the person in command to colleagues nearby.

(3) Discussion, collective problem solving and planning: the third ideal type differs significantly from the two others. In this type, there are taking place discussions and exchanges of views and ideas involving two or more people in front of the BIM-kiosks. The kiosks provide thus a meeting place for professional discussions, facilitating face-to-face collaboration between site workers. This is given by the kiosks' possibility to show the model on a big screen where everyone nearby can see challenges, problems, errors, ambiguities and more.

The reality will obviously be more complex than illustrated by the ideal types. Still, it is essential to one-sidedly underline particular characteristics to illustrate some key points in our material. The ideal types are useful as they specify some complex and yet rather unexplored situations and thus make them more tangible (Halkier, 2011). All ideal types constructed have a focus on the "one-way" information flow from the design phase to site workers. This is a result of Statsbygg and Skanska's idea behind testing BIM-kiosks in this project. Their main objective was testing out an approach for communicating design information directly to site workers by the use of BIM-kiosks. Their assumption was that this approach could contribute to better and more seamless flow of design information and thus be a step toward integrating the design and construction activities. The integration of design and construction through using BIM on-site is a topic that has received increased attention from practitioners as well as in academia (Wang and Chong, 2015; Davies and Harty, 2013). Statsbygg and Skanska's BIM-kiosks trial succeeded quite well in communicating design information through BIM-kiosks to site workers and in this way narrowing the much-discussed gap between the design and construction activities (cf. Gray and Hughes, 2001). Thus, the three ideal types clearly demonstrate some of the potential of using BIM-kiosks in future construction projects.

However, the ideal types do not capture the full potential of using BIM-kiosks. There are several other conceivable areas of application of BIM-kiosks. One possibility could be to allow workers to jot down remarks or leave comments or questions directly via the BIM-kiosks. In this way, workers would be given the opportunity to communicate with actors such as those in the project and construction management, design team or others. The workers could quickly enroll errors or omissions to the proper person. Such a function could contribute to capture "as-built information" and thus ensure an updated model. This is a topic that has received much attention from researchers in recent years (cf. Chen *et al.*, 2015). When the "as-designed" BIM is not updated in line with construction changes etc., it will often contain inaccurate information and would not be trustworthy. By contrast, a reliable "as-built" model can support information exchange and decision making throughout the project life-cycle. However, it is certainly not our proposal that on-site workers should manually update and correct the 3D model with the use of the kiosks. This would surely require too much modeling knowledge as well be very time consuming and prone to errors (Chen *et al.*, 2015). The BIM-kiosks may be a somewhat easy way to let workers notify about deviations between "as designed" BIM and the build reality on-site. In such case, the BIM-kiosks area of utilization would be extended from the current "one-way" to a "two-way" information flow system. This implies that information could potentially flow from design personnel to site workers and vice versa through the use of BIM-kiosks.

To which degree are these findings colored by the BIM-kiosks' charm of novelty? Are the BIM-kiosks still in use after the first seven months of the construction phase? In a follow-up after the first round of data collection, we have contacted some of our respondents in order to explore the consistency of our data. They could confirm that the BIM-kiosks are used to the same extent as when the data collection was undertaken. The BIM-kiosks have caught a lot of attention in the Norwegian AEC-industry. Several news articles have been written about the project (e.g. Iversen, 2015). The key points of these articles are consistent with our data.

5. Concluding remarks

As the literature review demonstrated, the on-site use of BIM is still not very widespread. Upcoming projects on using BIM-kiosks or tools should consider

several factors: First, this case study shows that the training sessions played an important role in the successful implementation. The workers experienced immediate benefits from the sessions, which introduced them to the user-friendliness and basic functions of the BIM-kiosk. Second, the courses became furthermore a demystifying arena stimulating the involvement and commitment of the site workers. Thus, rather than a single success factor, a combination of factors may explain the successful introduction of BIM-kiosks in this case. In sum, facilitating the involvement of the workers through training and dialog created a necessary ownership for the BIM-kiosks.

This case study, as well as other studies, demonstrates that there are obvious advantages of using BIM at the construction site (Sacks *et al.*, 2010; Davies and Harty, 2013; Merschbrock and Nordahl-Rolfsen, 2016). In the Urbygningen project, the workers obtain a better understanding of the planned building through the excellent possibilities for visualization. The workers get the ability to investigate particularly complex issues, as well as details that hardly can be grasped by looking at a regular drawing. The relationship and dependencies between task and disciplines are also easier discovered by using BIM. All these advantages can be found in one or more rationales in Wang and Love's (2012) framework. In addition, a further advantage of using BIM or other on-site information system is the ability to provide workers access to continuously updated information. As a whole, the findings of this case thus indicate that the use of BIM-kiosks resulted in a better flow of information from design to the constriction workers on-site. This may lead to a reduced amount of errors and delays which is of significance for the overall time spent and cost for the project as a whole. Consequently, all the three ideal types identified in the case study represent interesting situations when it comes to the introduction of BIM to the construction site. Still, the third ideal type (discussion, collective problem solving and planning) is of particular interest. In this ideal-type situation the BIM-kiosks stimulate a new form of collaboration among site workers. Our findings indicate that in certain situations, the data kiosks facilitate a greater level of face-to-face collaboration between site workers. This occurs because workers meet, both planned and randomly, to discuss, make decisions and planes, etc., in front of the computer kiosk while using the model together for visualizing. The BIM-kiosk or similar robust and stationary digital installations might thus pave the way for new collaboration forms on-site. Our data implies that such situations of interaction would most likely not have happened if the site workers used the current individual and mobile computers such as tablets and smart phones.

At first glance, the BIM-kiosks may not seem very innovative and future-oriented. Nevertheless, the low-threshold setup of a PC combined with a big screen worked well in this pilot project. The introduction of the BIM-kiosks actually won the price for "best idea" at a central conference for the Norwegian construction industry in the autumn of 2015 (Statsbygg, 2015). This may seem paradoxical given that the design is fairly basic and kind of old-fashioned. More modern and advanced tools already exist. Nevertheless, the way the kiosks have brought BIM out to the construction site has been pioneering. This indicates that it can be profitable to go for "low-hanging fruits" in the effort of bringing BIM to site workers in other projects as well. Still, there is a need to explore and test out the potential given by more modern solutions and devices with more functions. As the literature review revealed, BIM and mobile computing in general may be used for various operations on-site; a lot more than visualization which was the main purpose in the Urbygningen project. An obvious advantage of technology such as augmented reality, computer tablets and smart phones, is that they allow site workers to bring the BIM with them to the specific working situation. A next step in

research and development would be to initiate and study construction projects where several tools, e.g. BIM-kiosks and mobile devices, are used in combination. This might open up for new and interesting ways of working for site workers. The possibilities are many; exciting times are ahead at construction sites throughout the world.

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