SITE MANAGERS' USES OF BUILDING INFORMATION MODELING ON CONSTRUCTION SITES

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During the past decade the development of building information modeling (BIM) has seen as a possible catalyst for fostering the development of construction industry and as a solution for some of the challenges in the industry. (Eastman et al. 2011; Li et al, 2009). Uses of BIM have lately expanded from design activities to construction site management activities. Still BIM is a new tool for site personnel and there are still few studies of real-life uses of BIM on sites (Davies et al 2013). In this paper, we present an analysis of BIM use on two different renovation sites in Finland. The method of our study is shadowing. Based on our data we have reconstructed the working days of the site managers minute-by-minute. In our analysis, we zoom into their work and into how they use BIM as part of their work. We focus on the following questions 1) what are the daily tasks of a site manager or a site engineer 2) how, for what tasks or purposes, or with whom they use BIM. We also study the communication practices of the site personnel.

Keywords: activity theory, construction site, site management, building information modeling (BIM), shadowing.

INTRODUCTION

Proponents of the new modeling technology promise that the adoption of BIM increases performance, accuracy and quality in a design and construction process (Eastman et al. 2011; Hardin 2009). It is also expected to increase collaboration and communication between the project stakeholders. BIM technologies enable construction project partners to 3D visualize the designs, to integrate the designs of different design disciplines and automate some functions, such as clash detection, simulations or quantity calculations (Li et al 2009, p. 365).

However, implementing BIM as a new tool to the construction projects is challenging and happens step-by-step. Due to the traditional work and collaboration practices, using BIM may remain within the professional communities (Neff et al 2010). It may also result to only reactive communication between different professionals. Dossick et al (2011) have argued that BIM does not replace verbal communication in the cases when tacit knowledge is needed to solve a problem.

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BIM software and technologies, primarily developed as tools for designers, have only lately been extended to other processes of construction projects, such as construction management, bidding or client services. As BIM tools tend to be well-known and widely used among design disciplines, they are still quite new for site managers. There are still only a few studies focusing on BIM uses on real-life sites (Davies et al 2013).

In this paper, we study the daily work and the uses of BIM on construction sites. We focus on the actual uses and the communication practices of site managers. To conclude our paper, we discuss our analysis in light of Styhre’s (Styhre et al 2006) organizational learning concepts of ‘writing’ and ‘non-writing communities of practice’ and Dossick’s description of messy talk (Dossick et al 2011).

The implications of the paper are intended to contribute to the knowledge of site management, the uses of BIM and the BIM-related communication practices between site managers, designers, and other project partners.

THE WORK OF A CONSTRUCTION SITE MANAGER

According to Styhre’s (2006; 2011a; 2011b; 2012) analysis, construction site managers are omnipresent paternal 1ures having full control of both the foreseen and the unforeseen situation. Unexpected situations are accepted as part of a normal project work, and the managers do not think they could be avoided by anticipating. They see work as skillful, improvisational problem-solving (‘muddling through’) where the unforeseen events require immediate attention and quick decision-making. While the work practices may vary, the site managers share a common goal to keep the production going, no matter what the circumstances are. They are committed to their work and spend long hours on site, and occasionally do more overwork at home.

Site managers consider documentation, designs and plans to be important yet an imperfect source of information for solving problems and carrying out the work. Instead, personal work experience is highly valued. Long work experience helps them act proactively. When they need help, they rely on their contacts, i.e. experienced colleagues, even colleagues in a different company, for advice.

Site managers have a position between the top management and the workers, but they feel having only a little support from their organizations. Sometimes their work is considered highly stressful, especially because the schedules of projects, quality standards and cost pressures get more and more demanding. They are generally satisfied with their jobs and feel professional pride, when they “see something grow out there, a physical effect” and they feel like being in the center of the activity. They are in charge and no day is like another. (Styhre et al 2006; 2011a; 2011b; 2012)

Styhre and his colleagues (2006) divide the communities of practice into writing and non-writing communities, from which the designers represent the former and the builders the latter. According to them “the designers on the design phase are a community of practice relying on writing, whereas the community of practice of the construction phase is dependent on talking”. In the non-writing communities communication and learning are based on speech, telling war stories and sharing experiences. It is not documented and kept visible for outsiders like communication in the writing communities. Problem-solving and decision-making in the project is interpersonal and verbal. Transferring of learning from a project to another relies on the individuals' memory, experience and story telling. (Styhre 2006)
In their article on communication and collaboration with the help of BIM, Dossick et al. (2011, p. 87) emphasize the importance of ‘messy talk’ in their article about communication and collaboration with the help of BIM. According to them, “BIM excels at helping people to find problems, but does not support the dialogue needed to solve many problems encountered in complex design and construction.”

According to our study, the construction site management and the collaboration between the managers and the designers include a lot of verbal face-to-face communication. There are also other forms of communication, in which verbal and written communication merge. The site managers spend a lot of time on the phone, which can be considered as verbal, while not face-to-face, communication. If the other person cannot be reached by a telephone, the site manager sends him an email message. So, the previous verbal message is forwarded in a written form.

Communication and collaboration between the site manager and designers emerge particularly when BIM-related errors are encountered. Solving the errors or creating new design solutions typically requires face-to-face meetings on site. BIM-related communication emerges also when a site manager and workers use the BIM-models to look for information from them. The retrieved information, written or symbolic, is found in the model and shown on the computer screen. While looking at the symbolic information, the site manager and workers discuss the model and the future execution of work. The information is not only received from the models, but it is also adapted and further developed in the face-to-face discussion.

CASES OF THE STUDY: TWO RENOVATION SCHOOL PROJECTS IN CENTRAL FINLAND

The cases of our study are two Finnish school renovation projects in which all the design disciplines utilized modeling. The main users of the models were managers on site both of whom had some years of experience as site managers and good IT skills. The models and the software in use were architectural models (by ArchiCAD) and combined models (by Solibri). Site manager 2 used only the combined model even though he also had ArchiCAD software on his computer.

The site managers were the only users of the models on the sites. Site manager 1 who also worked as chief manager disseminated knowledge on the model to other site managers and workers. Site manager 2 instead used the models purely for his own work. The models were utilized solely in the site offices. When needed, information was transferred to the site with the help of printouts of blueprints or other documents printed out of the models. No mobile devices, such as iPads or laptops, were in use in these projects.

METHODOLOGY OF THE STUDY

According to cultural historical activity theory (CHAT) the relationship between a subject and an object is mediated by cultural means (tools and signs), division of labor, and rules in an activity (Engeström 2001, Miettinen 2009). The adoption of building information modeling (BIM) to construction management involves implementation on the elements of the construction management activity.

The construction management activity can be analyzed as interconnected to other activities such as the activity of designers. The site management can be seen as a “down stream activity” for the design activities. The design activities produce design documents, models and other tools for site management activity.
DATA AND METHODS OF THE STUDY

The ethnographic method of our study is shadowing. Shadowing is a research technique which involves a researcher closely following a member of an organization over an extended period of time. When a person being shadowed goes to a construction site, the researcher follows him. When the site manager has a project meeting or meets with a partner, the researcher sits in. If he has coffee with his colleagues, the researcher goes along, too (McDonald 2005; Reder 1993, Czarniaswska, 2007). I, as the first author, followed both site managers step-by-step for three days and audio- and video-recorded what they were doing during their working days. I also made field notes on an observation template and took some photographs. If the purpose or meaning of their task or an act was unclear to me, I asked some additional questions, such as “with whom or concerning what were you talking on the phone?”

One three-day shadowing period generated 14-16 hours of audio- and video-recorded material, dozens of photographs and the field notes (204 rows of entries) depicting the everyday activities on the sites. The length of data collection period was agreed with the site personnel. It was their wish for the researcher not to extent the data collection period over three days.

Based on the shadowing data of site managers’ or site engineers’ work, I have reconstructed the working days of the site managers minute-by-minute. In our analysis, I zoom into their work and how they use BIM as part of their work. Shadowing the site personnel in natural work situations is needed to discover the actual uses and collaboration in every day working life. This follows the insight of the tradition of ethnography of design engineering; interviews and surveys are insufficient to uncover problems or challenges or the emerging innovative uses of tools (Buchiarelli 1988, Henderson 1999, Miettinen et al 2012).

ANALYSIS OF THE DATA

After each data collection day I entered my hand-written field notes into an Excel-document. Later, after each field period, I watched and listened to all the recorded data and complemented the Excel-document by the data, mostly concerning the site manager's task description; the starting and finishing times of the tasks; discussions carried on in relation to the tasks; relevant activities, circumstances, participants of events, utilised tools and the location of the work.

I first categorized the site managers’ tasks into six main types of tasks. I coded the different types of tasks, locations and the BIM tools used in the Excel-document using
different colors. Then I selected the events where the BIM software were used for further analysis. I analyze those events from the point of view of participation of different project partners and from the point of view of communication, whether it was verbal, written or other type of communication.

THE DAILY WORK OF SITE MANAGERS

The daily tasks of the site managers are presented in Table 1. Site manager 1 spent most of his working time, in work planning and briefing (42 %). This task included both the planning of the forthcoming construction work and briefing or re-planning the on-going work on site. Every morning and every afternoon Site manager 1 had so-called ‘site rounds’, during which he visited every work group and task in-progress on site and discussed the on-going work with workers and foremen. When needed, he commented on possible needs for making changes and planned together with the subcontractors’ workers and the other managers how or where to continue the work. In addition to the site rounds, he visited the site several times a day to solve different problems or to plan for forthcoming tasks. Most of ‘work planning and briefing’ took place in face-to-face discussions. At times the drawings at the walls on site were used to facilitate the discussion. For example, while planning the partition wall installation, the site manager and the carpenter had printed layout drawings, where the locations of the walls were visible. They discussed and measured the locations of the walls in the existing building, and marked down the corrected locations on the drawing. Work planning and briefing also took place in the construction site office by the computer. In such cases the discussion referred to the model, construction schedule or other documents visible on the computer screen.

Site manager 2, instead, spent most of his preparing calls for bids and procurement (88 %). This included e.g. defining the initial data, like quantities of the work, writing calls for bids and sending them to the subcontractors. Preparing for bids and procurement was mostly conducted by himself alone and the needed information was gathered from the models, other project documentation or from the company’s documentation system. However, after sending the calls for bids via email to the subcontractors, he called each of them by phone. He ensured that the subcontractor had received the email message and they discussed the details of the work, such as content and timetable. He negotiated on the phone with all the subcontractors to find out if the subcontractors were going to give their bids and to ensure that they were aware of the strict work timetable.
Another type of tasks emerged, when the site managers solved problems for the others or answered questions put forward by the other foremen. As a chief foreman Site manager 1 was higher in the site hierarchy than the other foremen. Given his position, he had the most accurate perception of the overall situation on the site on the whole so he was consulted in decision-making or problem-solving situations. The site manager's IT skills also invited people to ask him for more detailed information on the models when needed. Site manager 2 had only a few occasions in which he was needed to answer the questions of the other workers. ‘Solving problems for others’ usually started with a face-to-face discussion. Typically somebody walked up to the door of the construction site office (or gave a target person a call) and asked for a solution to a problem. The site managers answered the question orally and possibly searched for additional information from the model, in which case the discussion was continued alongside the model. If a problem needed to be solved by a person outside the construction site, the site manager made a call and the discussion continued via telephone. If the person could not be contacted even by phone, the discussion was conducted via e-mail and also the response was typically obtained via e-mail. When needed the site manager sent an attachment from the model or some other document and received as response an email message, an updated picture or a document. This was how verbal and written communication merged.

Both site managers did also some ‘paper work’, which they did on their own, working on a computer, in the office. Paper work included taking care of the project’s invoicing and making entries to the site diary and keeping other documents updated. Then the principal type of communication was writing. Typically, the site managers worked alone on their computers, but occasionally they discussed face-to-face an issue related to the task with their colleagues.

Site manager 1 spent some time looking for the information missing in the model and distributing the information to the other parties involved. This type of task was not the situation of someone asking him for information or presenting a problem. Instead, anticipating certain situations or promoting collaboration between the different parties, he looked for and distributed information from one person to another. In such a situation, he could say: “the designer actually has this model himself, but things get ahead quicker if I send him this image myself”, ‘Looking for initial data and design details’ combined verbal and written communication similarly to problem-solving.

When additional information was required from designers, the e-mail messages and the attachments were sent to support the discussion.

Both site managers also spent some time in attending or preparing the pre-scheduled meetings. The data include two scheduling meetings with contractors and one meeting related to briefing the safety issues on site. The meetings were based on verbal communication to a great extent. The meetings could possibly have an agenda, but the agenda did not function as mediator of information from a person to another, but as a memory back-up for the addressed topics. In the briefing meeting for example, the site manager reviewed orally all the topics written down on the paper document, but did not hand out the paper to the workers.
Table 1: Different types of daily tasks of the site managers

<table>
<thead>
<tr>
<th>Type of task</th>
<th>Example</th>
<th>With whom</th>
<th>Site manager 1</th>
<th>Site manager 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work planning and briefing</td>
<td>Planning a door installation at site</td>
<td>Subcontractors, other site managers, workers</td>
<td>42 %</td>
<td>_</td>
</tr>
<tr>
<td>Preparing for bids and procurement</td>
<td>Writing a call for bids of window blind installing</td>
<td>By himself, other site managers, subcontractors</td>
<td>_</td>
<td>88 %</td>
</tr>
<tr>
<td>Solving problems for others</td>
<td>Answering ad-hoc questions</td>
<td>Site managers</td>
<td>19 %</td>
<td>9 %</td>
</tr>
<tr>
<td>Paper work</td>
<td>Invoicing, making notes to a site diary</td>
<td>By himself</td>
<td>18 %</td>
<td>6 %</td>
</tr>
<tr>
<td>Looking for initial data for design</td>
<td>Calling a curtain supplier to find out the suspension requirements</td>
<td>Designers, material suppliers</td>
<td>11 %</td>
<td>_</td>
</tr>
<tr>
<td>Scheduled meetings</td>
<td>Briefing safety meeting, contractor’s meetings</td>
<td>Workers, contractors</td>
<td>10 %</td>
<td>9 %</td>
</tr>
</tbody>
</table>

USES OF BIM ON SITE

In this part of analysis, I, as the first author, focus on in what situations, and with whom the site managers used the BIM software and what kind of communication emerged during using the models and encountering errors in them. In these construction projects, each design discipline produced their native models. In addition, a so-called combined model was drawn up to combine the separate native models. The models could be viewed on a computer screen using a suitable software program, in this project ArchiCAD and Solibri respectively. Documents, images or other plans of the building were printed out from the models on paper. In our analysis, I focus on how the site managers used the digital BIM models (Solibri or ArchiCAD models). For the closer analysis I have selected all the events in which the modeling software were in use.

Table 2 depicts the BIM software use events, and with whom and how long time the site managers used the BIM software during a three-day shadowing. When the site managers used BIM software, they were either ‘looking for existing information for his own work’, ‘looking for or sending existing information to the designers or other site managers’, ‘encountering an error or a missing information in a model and asking for a new design solution’, or ‘work planning and briefing and updating a model’.

In addition to the uses mentioned above, Site manager 2 had a habit of "wandering in the model" while he was, for example, speaking on the phone. However, the issue discussed on the phone and the contents of the model were not connected.
**Table 2: BIM uses of the site managers**

<table>
<thead>
<tr>
<th>BIM uses</th>
<th>With whom</th>
<th>Time used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking for information for his own work (e.g. calls for bids)</td>
<td>By himself</td>
<td>42 min</td>
</tr>
<tr>
<td>Looking for/sending information to designers, other site managers</td>
<td>A structural designer, curtain supplier, other managers, carpenter, door carpenter</td>
<td>39 min</td>
</tr>
<tr>
<td>Encountering an error in a model, asking for a new design solution</td>
<td>An architect, a structural designer, HVAC-designer, maintenance manager, plumber</td>
<td>34 min</td>
</tr>
<tr>
<td>Briefing construction work</td>
<td>Other managers, workers</td>
<td>24 min</td>
</tr>
<tr>
<td>Updating a model</td>
<td>By himself</td>
<td>5 min</td>
</tr>
<tr>
<td>Browsing a model while e.g. making a phone call</td>
<td>-</td>
<td>24 min</td>
</tr>
</tbody>
</table>

The uses of ‘looking for information for his own work’ and ‘updating the model’ did not include verbal communication. In these cases the site manager worked alone on his computer. The needed information either was available and no communication with the others was needed.

As shown in Table 2, Site manager 2 used models solely to get the information for his own work. He worked by himself, but sometimes he asked the chief manager a question. The chief manager was not that eager to use the model, so he might take a glance at the computer screen and say “okey, you look at the model, but…” and then he walked to the meeting room to look at the traditional drawings on the wall. So, the site manager followed the chief manager, and they continued their discussion by the paper drawings on the wall. The chief manager did not seem to find the model a convenient or sufficient source of information for himself.

‘Looking for and sending information from BIM to the others’-type of uses indicated the importance of the site manager 2’s role as a BIM user on site. He was the only person who knew how to use models on site, hence it was his responsibility to distribute the needed information to the others. Usually these situations started with a verbal face-to-face discussion, for instance someone came to the site manager’s office or called to ask for information in the model. The site manager retrieved the needed information from the model and they continued the discussion alongside the model or on the phone. Here the symbolic documents, models, were used to support verbal communication. Sometimes Site manager 1 solely relied on written or symbolic communication, and, for instance, he sent an excerpt from the model as attachment for a designer.

Missing information and discrepancies in the models generated extra work, so-called ‘encountering an error in a model, asking for a new design solution’ on site. The missing information cases were mostly solved by calling the designers. In some cases, if the designer could not be reached by phone, the site manager sent him an email message, and also got the answer by email. In some cases, the site manager simply notified that “hey, there is something missing or something wrong with the model!” but he did not do anything to solve out the problem.
BIM models were rather scarcely utilized in ‘planning and briefing construction work’. This was partly due to the BIM models being only available in the site office. While Site manager 2 did most of the work planning and briefing on site, the BIM models were not available for this task. When the planning and briefing took place in the construction site office by the models, it commenced as face-to-face discussion and continued as a discussion alongside the model.

**Errors and discrepancies as triggers for collaboration**

During both shadowing periods, there were several cases of errors, discrepancies, or some problematic design solutions in the models. The errors, the discrepancies and a problematic design solution were encountered when the site managers were looking at the models as part of their daily work. Those were the occasions when the most vivid communication between the site managers, designers and other stakeholders emerged.

The errors, discrepancies and problematic design solutions were mostly solved in face-to-face discussions or in face-to-face meetings on site, not by the models. The most intensive problem-solving cases took three days to be solved, and involved several managers, designers, workers, maintenance staff and other experts to solve the design problem.

**DISCUSSIONS AND CONCLUDING OBSERVATIONS**

Shadowing enabled me as a researcher to zoom in to the every-day activities on site and collect rich research data. It made visible the uses of new technologies on site. It also showed the diversity between the different users. To get an access to the field to shadow the daily work practices on site required months of negotiation with the stakeholders in the company, the construction projects and the construction sites. At the same time, I collected other data from the site meetings and visited the construction site on several occasions. The data collection and negotiation process was lengthy, but I believe it helped with how the site staff related to myself and how relaxed they were in having me shadowing their everyday work life on the sites.

BIM was actively used on the sites. During the three days of shadowing, Site manager 1 did not use traditional drawings in the site office once. He got all the design information from the models. The use of models still faces many challenges related to information content and accuracy of designs, lack of mobile computers or lack of people who know how to use the models. To achieve the desired accuracy level of the models, there is a great demand for better collaboration between construction site personnel and designers to ensure the quality of the models. On the other hand, the collaboration between the designers and Site manager 1 was very active, even though reactive, including several e-mail messages, phone calls or face-to-face meetings every day. The collaboration emerged when a BIM-related problem was encountered. The other site personnel represented more reserved attitude towards the collaboration with the designers and the occasions of collaboration were fewer. On that site, BIM was used, as Dossick et al (2011) argue, within only the site manager’s own work, not in a collaboration with designers.

Our research supports Styhre’s arguments (2006) of site managers’ work as skillful, improvisational problem-solving (‘muddling through’) where the unforeseen events require immediate attention and quick decision-making. Also the argument of a site management activities relying heavily on face-to-face communication seems accurate. However, Styhre’s dichotomy between non-writing and writing seems overly simplified. Based on our research it seems that the forms of communication are more
complex and interwined: face-to-face communication proceeds as telephone-mediated and further to e-mail mediated communication. Symbolic or written documents are used to support verbal communication, but the communication is rarely based solemnly on the written documents. So, the written or symbolic documents mediate the face-to-face communication.

Dossick & Neff (2010) describe the communication relationships on construction site hierarchical, such that the main contractor communicates predominantly with the owner, who forwards the information to the designers. This is also the official hierarchy in Finnish construction projects. Our study shows, however, that in some cases, the collaboration and communication between the project manager and the designers can be very active and direct, especially communication related to information in the models.

Based on this study, it can be concluded that BIM models are utilized on site and the models advance the site management. Although, the use of BIM is challenged by the lack of mobile tools and skillful BIM users, insufficient and inaccurate information content of the models and the coexistence of the new and the old tools and related practices. Of these challenges, the most problematic are those regarding the content and accuracy of the models. In light of the current study we see two possible trends. Either the content and the accuracy of the models is developed in the design phase in collaboration with the designers and other stakeholders, such as builders, and the design data is transferred from the design phase to the construction phase as technology- or BIM mediated. Or some of the design details are acknowledged as such, that they are solved in the construction phase, still in collaboration with the designers and other stakeholders, such as builders, but in a premeditated manner, not reactively as is the case at the moment. In both cases the messy talk or face-to-face discussion considering design solutions between the stakeholders is needed.

Because BIM is still relatively new technology on construction sites, the research focusing on how the models are used and what kind of communication or collaboration has emerged are relatively sparse. Further research on BIM deployment, using BIM as a new tool and the changes in collaboration within the project partners is needed.

REFERENCES


