Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

Site managers' daily work and the uses of building information modelling in construction site management

Tarja Mäki & Hannele Kerosuo

Construction Management and Economics, 2015
Vol. 33, No. 3, 163–175, http://dx.doi.org/10.1080/01446193.2015.1028953

Routledge
Taylor & Francis Group

Site managers' daily work and the uses of building information modelling in construction site management

TARJA MÄKI* and HANNELE KEROSUO

Center for Research on Activity, Development and Learning, University of Helsinki, Finland

Received 28 January 2014; accepted 9 March 2015

The use of building information modelling (BIM) and related software tools is increasingly expanding in the work of site managers in construction projects. The early uses of BIM in the actual tasks of site managers are explored by examining the utilization of BIM in their work and the challenges in the deployment of the new digital tools for traditional project collaboration. The ethnographic method of the study consists of shadowing the site managers' work. The site managers actively used BIM and found it beneficial for their daily work. However, the use of BIM in construction sites is still limited because only a few managers have the competence to use BIM software tools, mobile tools are lacking, and the information content of the models needed for construction work is insufficient.

Keywords: Activity theory, building information modelling, construction management, ethnography, site manager.

Introduction

The construction industry is Europe's largest industrial employer, accounting for about 7% of total employment. In OECD countries, the construction industry accounts for an average of 6.47% of the gross domestic product (bit.ly/18LVwiG). The industry has a reputation for being conservative, reluctant to change and slow to produce innovations (Styhre, 2010, 2012). The challenges facing the construction industry and construction projects are artificial tools and methods, the impossibility of testing an end product before building, discontinuity in the processes, and ineffective information and knowledge management (Li *et al.*, 2009).

During the last decade, the development of building information modelling (BIM) has been seen as a possible catalyst for the development of the construction industry (Eastman *et al.*, 2011). Building information models in the form of digital 3D designs present parametric information about the construction project. BIM technologies enable project partners to visualize the designs in 3D, integrate designs from different design disciplines and carry out clash detection, simulations or quantity calculations more efficiently (Li *et al.*, 2009, p. 365). Proponents of the new modelling technology promise that the adoption of BIM will increase performance, accuracy and quality in the design and construction process (Hardin, 2009; Eastman *et al.*, 2011). From the viewpoint of construction site management and production, the benefits would include more constructible and precise designs as well as more manageable schedules and better budgets for projects.

BIM software and technologies have thus far mainly been used as tools for designers. They have only lately been extended to other processes of construction projects, such as construction management. Davies and Harty (2013) studied the implementation process of SiteBIM in a longitudinal case study of a large hospital project in the UK. They emphasize the importance of active construction project personnel in the adaption of innovations, in their case the adaption of SiteBIM and tablet computers in construction.

According to Rogers (1995, pp. 263–5), early adapters comprise a small group who adopt innovations quickly, but who are more integrated into the social system of practitioners than innovators. Early adapters are

*Author for correspondence. E-mail: tarja.maki@helsinki.fi

often opinion leaders and advice givers to potential adopters in their social context. They are also more respected in their community than innovators. Compared to early adapters, the early majority of users are relatively slow to adopt innovations. They would rather wait and see the results from the early adapters before making an effort to implement innovations themselves. In our renovation project cases, the construction site managers can be considered the early adapters of BIM software. Building information models are available only in construction site offices and are only available for the managers to use. The managers' role is to act as advisors and information distributors to others in the sites.

Owing to the novelty of BIM use, only a few studies focus on actual BIM uses in construction sites in real life. These studies mainly focus on BIM implementation processes (Davies and Harty, 2013) and communication, collaboration practices and conflicting obligations in BIM-based projects (Dossick and Neff, 2010). The theoretical BIM framework, BIM maturity stages (Succar, 2008) and the benefits of BIM (Barlish, 2012; Bryde *et al.*, 2013) have also recently been studied in academic research. The literature giving guidance on the use of BIM tools, methods and workflows (Hardin, 2009; Eastman *et al.*, 2011) largely concentrates on possible uses, not actual ones. Even though the authors give several examples of how BIM has been utilized in previous projects, the examples only examine potential uses of BIM rather than analyse its use on the task and practice levels by individual actors such as site managers within building projects.

Few recent studies have investigated the actual contents of a site manager's daily tasks. The daily tasks of site managers are mainly taken for granted or researched in interview studies (e.g. Styhre, 2011), in which the interviewees evaluate their work and tasks as well as the related challenges. However, detailed studies on what is actually done are missing. To fill the gap between descriptions of the possible and actual uses of BIM, this study aims at extending the scope of the existing research by focusing on the daily work of site managers and the actual uses of BIM in construction sites. Moreover, it also presents the challenges that may prevent the diffusion of BIM use in construction sites.

As a practice-based approach, cultural-historical activity theory (CHAT) addresses what people actually 'do' when they are managing. In this view, what people do every day to complete their work itself constitutes explanations of social life (Miettinen *et al.*, 2009). CHAT emphasizes the role of mediation in object-oriented human activity (Engeström, 2001). Tools and signs mediate human activity. An object of activity refers not only to its materiality but also to the sense and meaning that actors place on it. Human activity is systemic in that a change in one element of an activity affects the other elements of that activity. The adoption of new elements from outside (for example, a new technology) aggravates the contradictions within an activity and between different activities, which emerge as disturbances, errors and flaws and also as attempts to innovate. The identification of these manifestations of contradictions as sources of change is important in order to accelerate change. The activity-theoretical approach is applied to study the actual uses of BIM in the daily work of site managers. The research questions of this study are:

(1) What are the daily tasks of the site managers?
(2) How do the site managers use BIM in the early phase of deployment?
(3) What are the flaws and errors in the models and the consequences caused by them in the site managers' work?

The data analysed for this article are a part of a larger corpus of ethnographic data collected by interviewing site managers, shadowing construction site managers during their working days in several construction sites, and by observing the site meetings of two construction projects for two years. Shadowing is an ethnographic method of closely following what research subjects do in practice (McDonald, 2005; Czarniawska, 2007). The article contributes to the knowledge of site managers' daily work, the deployment of BIM on site and the collaboration between the site manager and designers in the construction phase.

The first section of the article presents the previous research on construction site managers' work, in which site managers are seen as omnipresent problem-solving figures under pressure from the demands of loosely coupled partners, designers and workers. Their work is affected by insufficient design data and production needs alongside high-pressure deadlines and unexpected situations. After this, the ethnographic methodology, the methods and the empirical data of the study are presented. In the following sections, the findings of the analysis are presented. First, the range of the daily tasks of site managers is described in order to contextualize BIM use in the Finnish construction industry. Second, the results show how and with whom the site managers actually used BIM and what challenges arose when using BIM on site. Third, as an example of a challenge, the flaws and errors in the models and the consequences caused by them are examined more closely. Finally, the main findings are discussed in the context of the research literature, and the conclusions of the study are summarized.

The work of a construction site manager in previous research

Construction projects are complex and lengthy processes involving a great number of different occupational groups, such as clients, users, designers, contractors, construction workers, material suppliers and authorities. Information is traditionally transmitted from one phase to another through written and printed documents such as designs and plans, and nowadays also through building information models. The different design disciplines, contractors and managers in a construction project are organizationally loosely coupled.

Dossick and Neff (2010) describe the relationships between design and construction teams, based on over 12 months of ethnographic observations for two commercial construction projects and interviews with industry leaders across the United States. The two teams worked separately, and workers for the subcontractors collaborated directly only with the managers representing their own organization or with the chief manager of the main contractor. The site managers communicated with designers through a client or a developer. Even though designers, construction site managers and subcontractors are organizationally loosely connected, their activities are tightly coupled in the work procedures during the construction phase. The activities follow each other in a strict schedule, which places considerable pressure on the site manager, who is trying to orchestrate the construction process as a whole (Dossick and Neff, 2010; Styhre, 2012).

Site managers have a central position in the construction organization between the design and the production of the building. If the design documents of the buildings are insufficient or include errors, which happens often, it is the site manager who either asks for more accurate designs or interprets or completes them in the production work. Depending on the project, the accurate information requested is gained through the hierarchical steps described above or by asking the designers directly. In the case of interpreting or completing the designs, the managers rely on their personal work experience, or they call upon their contacts, experienced colleagues and even colleagues in different companies for advice. This communication demonstrates a characteristic feature of a community of construction site managers: 'The community of practice of the construction phase is dependent on talking' (Styhre *et al.*, 2006, p. 91). The exchange or creation of information and learning in the projects is highly based on the verbal sharing of experiences, informal conversations and on 'messy talk', as Dossick and Neff (2011) call it. This happens even when an advanced technology such as BIM is used in the project. In addition, the transfer of learning from one project to another relies on individuals' memory, experience and skill at story-telling (Styhre *et al.*, 2006).

Styhre has published several research articles concerning the work and role of project managers based on three construction research programmes in Sweden in the years 2001–09. From the interview data and the experiences of the interviewees, he examines, for instance, site managers' role as middle managers and the amount of administrative work in the work of site managers (Styhre and Josephson, 2006). In the studies mentioned above, construction site managers are seen as omnipresent paternal figures in full control of all situations on sites, in both foreseen and unforeseen situations. Unexpected situations are accepted as a part of a normal project, and the managers do not think that these situations could be avoided through preplanning. They see work as skilful, improvisational problem-solving ('muddling through'), where unforeseen events require immediate attention and quick decisions. While work practices may vary, site managers share the common goal of continuing the production, no matter what the circumstances are. They are very committed to their work and spend long hours on site, occasionally also working overtime from home. They like being at the centre of activity. They are in charge, and no day is like another (Styhre, 2012).

According to Styhre (2006), the site managers involved in the interviews evaluated their workdays as consisting of up to 80–90% of office work. The remainder of the time was spent on the construction site talking to the workers and engaging in problem-solving. This is contrary to the findings of an earlier study (Fryer, 1979) reported by Fraser (2000, p. 30), '[the site managers] spent a considerable amount of their time outdoors talking to people, mainly supervisors, about technical matters'. The increase in administrative work is one example of the changes in the work of site managers. Another change is the expanding use of BIM in both design and construction management work. The introduction of BIM changes both the work of site managers and the collaboration between designers and site managers. Along with the use of BIM, standards in design work are expected to rise (Eastman *et al.*, 2011). Models should be compatible with each other so that clashes between the models can be identified and solved in the design phase. The models are expected to be used in more extensive ways than traditional drawings. The increased accuracy of the models improves the reliability of calculations and simulations. Further, it enhances the productivity and quality of construction activities. Creating as-built models requires that the building be constructed precisely according to the design models and that changed design solutions are updated in the model. Consequently, deeper collaboration is required between site managers, designers, material suppliers, maintenance people and other partners in a project.

Methodology of the study

The ethnographic methodology of the study draws on applied ethnography (Chambers, 2000) and the ethnographic methodologies of development and change in CHAT (Engeström, 2000; Kerosuo, 2006). Instead of providing a full description of the people under study, the ethnography of change and development examines the processes that are undergoing change. Applied ethnography is a practically oriented approach that is often connected to efforts to effect change in the service of a public good and/or in decision-making. For this purpose, it addresses how people actively create new meanings in their continually changing relationships and circumstances.

The focus of the study is on following the evolving use of BIM in the daily work of construction site managers. The tool- and sign-mediated relationship between a subject and a material object is followed, including the new interpretations and meanings the managers give to the use of the new BIM tools. The activity of construction can be analysed as interconnected with other activities, such as the activity of designers. Site management can be seen as an activity taking place downstream from design activities. Design activities produce design documents and building information models for site management activity. However, in real life the interconnections between these activities are complex. While the designers are producing the design for a building, the constructors, the material suppliers and the maintenance managers comment on the design solutions and suggest changes in them. This happens in both the design and construction phases.

While many of these characteristics are commonly described in current ethnographies of construction projects and their management (e.g. Pink *et al.*, 2013), the focus on the historical change of adapting a new BIM tool in construction site management brings a developmental flavour to these ethnographies. During technological change, old and new technologies often operate concurrently, and the social order of work is associated with each technology and developed alongside its use (Barley, 1990). According to activity theory (Engeström, 2001), the use of old and new technologies concurrently may cause contradictions to emerge. These can be observed in our case, for example, as flaws and errors in BIM use. These phenomena are focused on as indications of the evolving use of BIM in the context of the 'normal flow' of daily tasks in construction site management.

Project work is described as temporally fragmented and involving multiple spaces. Not being able to be everywhere at once requires the ethnographer to make choices about which action to follow and where (Marshall and Bresnen, 2013). The choices made have consequences on the conceptualization of the research site in ethnographies of project work 'to one that is rather mobile and transient' (Marshall and Bresnen, 2013, p. 113). One of the research strategies to follow in such cases is a *stepwise* research strategy and technique, which is applied in this study. In stepwise ethnography, a long-term field presence is replaced by brief ethnographic visits to solve particular research problems posed by an ongoing research project (Chambers, 2000, p. 863).

A notable challenge of rapid ethnographic methods such as stepwise ethnography is the immersion of an ethnographer into the culture (or activity) that s/he is studying. Stepwise ethnographies are often applied in contexts familiar to the researcher. *At-home ethnography* refers to a study 'in which a researcher describes a cultural setting to which s/he has a "natural access" and in which s/he is an active participant, more or less in equal terms as other participants' (Alvesson, 2009, p. 157). An ethnographer doing at-home ethnography is already immersed in the culture/activity s/he is studying and needs to gain an etic or objective relation to it. Therefore, careful documentation and interpretation of the observation are needed, and the analysis does not require the inclusion of the personal meaning or strongly subjective aspects of the research experience (Alvesson, 2009, p. 160). A researcher can also use *structured observation* if the focus is on certain types of behaviour (Czarniaswska, 2007, p. 25). In structured observation the researcher is focusing on certain types of structured data, although the categories used in the observation are created during the fieldwork (Mintzberg, 1970, p. 90 cited in Czarniawska, 2007, pp. 25–26).

In our case, the first author of the paper has a long history of work experience in construction sites, and she was already familiar with the worldview and language of construction work and site management. This previous knowledge enabled the research focus and research techniques in the study to be further specified. At the same time, she was also involved in extended fieldwork focusing on the use of BIM in construction projects. As a consequence, the connection between the real-time work of site managers could be considered through a broader perspective that includes the entire project, from the design phase to the maintenance phase (see also Nicolini, 2009). The second author of the paper did not participate in the activities of the construction site, but she did, however, conduct fieldwork in the design phase of the same projects that the first author observed in the construction sites. As she was an outsider in the field of construction, the collaboration between the first and the second author enabled the study to have both 'emic' and 'etic' perspectives.

The methods and the data of the study

The ethnographic method of the study involved shadowing the research subjects from an activity-theoretical perspective. Shadowing is a research technique that involves a researcher closely following a member of an organization over an extended period of time. When the person being shadowed goes to a construction site, the researcher follows. 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 observes that, too (Reder, 1993; McDonald, 2005; Czarniaswska, 2007). In addition, the fieldwork includes informal discussions, negotiations and short interviews with the research subjects.

Shadowing the site personnel in natural work situations enables uncovering the actual uses of BIM and collaboration practices in everyday working life. This follows an insight from the ethnography of design engineering: interviews and surveys are insufficient for uncovering problems or challenges or the emerging innovative uses of tools (Bucciarelli, 1988; Henderson, 1999; Miettinen *et al.*, 2012). Similarly, in the culture of construction work, 'doing' and 'not explaining' are current ways of being (Nicolini, 2009). The activity-theoretical orientation of following the site managers' uses of BIM directed how the study was conducted.

The cases of the study were two school renovation projects in Central Finland. The renovation projects were part of the same life-cycle project, which included four schools and a day care centre. The projects were independent, but scheduled so that the second project started after the completion of the first. The first set of data was collected in January 2012 and the second in January 2013. Some of the personnel were the same in both projects. However, the shadowed site managers were different people.

Both projects were in the fit-out phase at the time the shadowing data were collected. The first author negotiated the most suitable time for the shadowing period with the site managers. As some phases of a construction project are more critical than others, the collaboration activities between the designers and subcontractors also guided the selection of phases for observation. The fit-out phase was selected for the observation of the site managers' work because this phase involved several collaborations with the subcontractors on site. For example, the heating, ventilation and air conditioning (HVAC) installation work would then be in progress, and the building information models could potentially be actively used in the coordination of different building tasks. The same phase was selected in the second project to make comparisons between the two parts of the data more plausible.

Because the shadowed site managers were the only members from site management who used the building information models in the sites, they were selected to be the research subjects in the study. The site managers had access to the models in the project repository, from which they could be downloaded on to their personal computers. The roles of the two people being shadowed in their site organizations were different. Site manager 1 had the combined role of a chief manager and a site engineer while the actual chief manager was on sick leave. During the second project, site manager 2 was working as a site engineer. The data collected in the two projects are presented here to reveal alternative uses of BIM in two different situations of site management.

The models were utilized solely in the site offices, and information was transferred to the site with the help of printouts of the models. In neither project were there tablets that could have been used to present the models in the site. Traditional paper drawings were also in use in the construction projects, as Finnish legislation requires. The blueprints were also hanging on the walls of the meeting rooms and in the corridors of the site offices. During project meetings in the meeting room or informal discussions in the corridor, the project personnel often referred to the paper blueprints on the walls. This was done mainly by personnel who did not use BIM in the project, but also sometimes by the site managers, who were very active BIM users. In a similar way to how Harty and Whyte (2010) describe the hybrid practices of designers, the site managers managed the project using hybrid media, including digital building information models on a computer screen, revisions of paper drawings on a wall or paper printouts of a model printed from the computer.

The main contractor organization had no exact guidelines or protocols on the use of BIM on site by the site managers. The site managers were free to create their own practices. During the first projects of the life-cycle project, the designers, the project manager and the other project partners were surprised how actively BIM was used by the site managers. The active use of models on site created new requirements for the content of the models and the need to follow the design schedule in upcoming projects.

During the shadowing periods, the researcher followed every step of the site managers for three days and audio and video recorded what he was doing during his working days. She also made field notes on an observation template and took photographs. The observation template consisted of the topics in which she was especially interested, such as the time, the task, the discussions between the site manager and his collaborators, the participants involved in the task, and the tools used in construction site management. If the purpose of a task or an action was unclear, questions such as 'With whom or concerning what were you speaking on the phone?' were asked. Otherwise the researcher tried not to interfere with the work of the site managers. The shadowing periods generated about 30 hours of audio and video recorded data, dozens of photographs, and field notes (some 400 rows of entries in the templates) depicting the everyday activities in the sites.

After each fieldwork period, all the video recordings were watched, and the content of the data template was updated with the help of the video recordings. The first author reconstructed the working days of the site managers minute by minute: the site manager's tasks; the duration of the tasks; discussions related to the tasks; the actions, operations, circumstances and participants of events; the tools utilized; and the location of the tasks. The activity-theoretical analysis focused on how the tools were used and how BIM served the activities on the construction site. The disturbances in the activity and the flaws and errors in the models were also analysed. In addition, the collaboration practices and the changes in the traditional rules of the construction activity were analysed.

According to Czarniaswska (2007, pp. 55–7), the method of shadowing allows the researcher to take the attitude of an outsider in relation to her research subject. However, the shadowing method brought many challenges. These included the balancing of feelings of physical discomfort between the research subject and the researcher, the constant negotiation of access into the activities of the site managers because of ethical reasons, the difficulty of note-taking while constantly on the move, and the effects of shadowing on the person shadowed, which were uncovered in informal discussions and interviews afterwards. Because of the intimate presence of the research subjects in the research data, the choices of equipment, the fieldwork methods and the reporting of the research findings were an especially integral element of the project, as has been advised by Pink (2004).

In the following sections, we will present the findings of the analysis. First, the everyday tasks of the site managers are presented. Second, the findings on how, with whom and for what purposes the site managers used BIM as well as the challenges of using BIM are described. Third, as an example of one type of challenge, the flaws and errors encountered in the models and how these were solved in the sites are discussed.

What are the daily tasks of the site managers?

In the first part of the analysis, we focus on the site managers' daily tasks (see 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 the briefing or replanning of the ongoing work in the site. Every morning and every afternoon he carried out 'site rounds', during which he visited every work group and task in progress in the site and discussed the ongoing work with the workers and the foremen. When needed, he commented on possible needs for making changes or 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 ad hoc problems or to plan for forthcoming tasks.

Site manager 2, instead, spent most of his time *preparing calls for bids and procurement* (77%). This included, for example, defining the initial data for the bids, such as the quantity calculations, writing calls for bids, sending them to the subcontractors, and calling them to ensure they had received the documents and will submit their bids. Site manager 2 mostly worked in the site office, but also visited the construction site when subcontractors or material suppliers came to see the work posts.

Both site managers *solved problems for others or answered questions* put forward by the other managers. Because of his role as chief manager, site manager 1 had the most accurate perception of the overall situation at the site as a whole, and he was often consulted in decision-making or problem-solving situations. In addition, the site manager's IT skills drew people to ask him for information from the models. Site manager 2 worked more independently and was asked to answer questions from workers or other managers on only a few occasions.

Both site managers had some *paperwork*, including doing the project's invoicing, making entries in the site diary and keeping other documents updated.

Site manager 1 also spent some time looking for information missing in the model and distributing the information to the other parties involved outside the site, such as designers and material suppliers. In doing so, he proactively anticipated problematic situations and promoted collaboration between the different parties. He explained it in this way: 'The designer actually

Table 1 Different types of daily tasks of the site managers

Type of task	Example	With whom	Percentage of time	
			Site manager 1 (%)	Site manager 2 (%)
Work planning and briefing	Planning a door installation on site	Subcontractors, other site managers, workers	42	_
Preparing for bids and procurement	Writing a call for bids for window blind installation	By himself, other site managers, subcontractors	_	77
Solving problems for others	Answering ad hoc questions	Site managers	19	9
Paperwork	Invoicing, making notes in a site diary	By himself	18	6
Looking for initial data for a design	Calling a curtain supplier to find out the suspension requirements	Designers, material suppliers	11	_
Scheduled meetings	Induction meeting, contractors' meetings	Contractors, workers	10	9

has this model, but things proceed more quickly if I send this image to him myself.'

Both site managers spent some time attending or preparing for prescheduled meetings. The data include two scheduling meetings with contractors and one induction meeting.

How do the site managers use BIM in the early phase of deployment?

Each design discipline had produced its own native model, and a combined model was drawn up to integrate the separate native models. The site managers used the architect model and the combined model with Solibri Model Viewer[1] or ArchiCAD[2] software actively during their working days. We selected all the events in which the above-mentioned modelling software was in actual use for closer analysis. Images from the models could be printed out on paper, but our analysis focuses only on the digital uses of models.

Table 2 depicts the types of BIM software uses and with whom and how long the site managers used the BIM software during the three-day shadowing periods. Our categorization describes whether the site manager looked for existing information for his own work, looked for or sent existing information in the building information models to the designers or other site managers, encountered an error or missing information in the models and asked for a new design solution, briefed the construction workers with the help of models or updated an actual building information model.

In addition to the BIM uses mentioned above, site manager 2 had a habit of 'browsing the model' while he was, for example, speaking on the phone. However, the issue discussed on the phone and the models seen on the screen were not connected.

Both site managers used building information models actively in their daily tasks. Site manager 1 did not use traditional drawings at all in his site office, where the models were available on computer. He occasionally took a paper printout of a model when he went to the site to do a task such as measure doorways so that he could write the measurements down on paper.

Site manager 1 used BIM widely in his own work and his communications with others. He distributed the modelled information to others in the site and the designers outside the site. He also very actively collaborated or communicated with the designers both with BIM and without BIM on issues related to designs.

Site manager 2 mostly used BIM to find needed design information. Yet he still sometimes used the paper drawings in the site office when the most detailed information was not available in the combined model. The task range of site manager 2 was much narrower than that of site manager 1. He mainly worked on calls for bids and procurement and mostly worked by himself. He used BIM only for his own purposes, mainly for the calls for bids and procurement, not to distribute information to others. Neither did he communicate actively with the designers, even when he encountered design-related problems in his work.

The differences between the BIM uses of these two site managers are explained, at least partly, by their different roles in the site organizations. Site manager 1 worked as a chief manager and was responsible for everything in the site. Because of his role, he had a wider range of responsibilities, which created more opportunities to use BIM, and was in a position to be able to promote the use of BIM on site. In contrast, site manager 2 worked as a site engineer, and he worked mostly by himself or in collaboration with the

Table 2 BIM uses of the site managers

Types of BIM uses	With whom	Time used	
		Site manager 1	Site manager 2
Looking for information for his own work	By himself	42 min	1 h 32 min
Looking for/sending information to designers or other site managers	A structural designer, curtain supplier, other managers, carpenter, door carpenter	39 min	_
Encountering an error in a model, asking for a new design solution	An architect, a structural designer, HVAC designer, maintenance manager, plumber	34 min	_
Briefing the construction work	Other managers, workers	24 min	_
Updating a model	By himself	5 min	_
Browsing a model while, e.g., making a phone call	–	24 min	_

subcontractors and material suppliers. He did use BIM for his own work but not in conjunction with other site personnel, who were clearly not interested in using BIM.

Having BIM only on the computers in the site office limited the use of BIM to certain tasks. This was the case in both projects. For example, most of the work planning and briefing happened on site, and it was not possible to use BIM in these cases because the site managers had no mobile computers.

Another hindrance in the use of BIM was inaccurate and missing information in the models. The models included an extensive amount of information, but sometimes the specific information needed for construction was lacking, not accurate enough or even wrong. We will elaborate on the flaws and errors encountered in the models in more detail in the next section.

What are the flaws and errors in the models and the consequences caused by them in the site managers' work?

In this section, we first introduce and categorize the flaws and errors in the models encountered during the shadowing periods. Then we select one example from each project to show how the problems were solved at the site.

During the first shadowing period, information was missing in the models in six instances (see Table 3). In addition, two discrepancies arose between the model and the existing building and one discrepancy between the model and a demolition contract. Correspondingly, in site 2 information was missing in the models in six instances, one design solution was problematic, and two discrepancies arose between the model and the existing building or other documents (see Table 3).

Calling or e-mailing the designers mostly solved the instances of missing information. In some cases, site manager 1 simply stated, 'Hey, there is something missing in the model', but he did not notify the designers about the missing information. This was most probably because the missing information was not crucial for his work at the moment, and the site manager expected the model to be updated and the missing information to be added later during the project.

The discrepancies or problematic design solutions required redesign. In site 1, a discrepancy arose between the model and the demolition contract. At the beginning of the project, an old chimney had been designed to remain in the building. Later, the plans changed, and the design showed that the chimney was to be demolished. Unfortunately, this change was never added to the demolition contract, and the demolition contractor was issued 2D drawings based on the earlier model. Thus, after all the demolition work was finished, the chimney was still present in the building. It took three working days and several working hours from the designers, managers and the supervisor to make a new decision about the chimney.

The chain of actions related to the discrepancy between the model and the demolition contract was the following:

On the first day:

(1) The site managers discovered a discrepancy between the new model revision and the demolition contract.
(2) Site manager 1 discussed the problem with the other site managers and took photos of the structure in the site.
(3) Site manager 1 sent photographs and a model view to the structural designer and the supervisor of the project, and made several phone calls.

Table 3 Missing information, problematic design solutions and discrepancies in the models

	Site 1	Site 2
Missing information	Surface finishing missing	Facade board
	Floor structure missing	Floor materials
	Window insulation missing	Division and type of curtain attachments
	Some doors missing	Cables
	Ceramic tiles missing	Finishing of the rain water drain
	Ceiling materials missing	Trellis and doorframe
Problematic design for maintenance		Blinds
Discrepancy between BIM and the existing building	No room for routing some air conditioning ducts	Clashes between the HVAC structures
	Not enough room for HVAC equipment in the kitchen	
Discrepancy between the work plans/contracts and BIM	Chimney structure: to demolish or to keep	HVAC duct: to demolish or to keep

(4) The supervisor visited the site to see the problem.
(5) The site managers considered alternative solutions.

On the second day:

(6) The manager responsible for maintenance visited the site to see the problem. A meeting was held with site manager 1 and the main contractor representatives to solve the problem.

On the third day:

(7) Site manager 1 announced the decision: the structure will remain, and it will be filled with concrete.

In site 2, there were issues with the design of the motorized blinds on the windows in a gymnasium. One of the windows was just behind HVAC pipelines, which caused two problems. First, the blind should have been installed first, before the pipeline installation. And secondly, maintenance of the blind would be impossible because there was no access to the blind through the pipelines. Redesigning the darkening of the window involved the site managers, the maintenance manager and several material suppliers and contractors. The final result of the process was that the window was darkened from the outside with a film. Other parties made the decision collaboratively, and no designers were involved.

The chain of actions related to the problem with the design of the motorized blinds was the following:

On the first day:

(1) Site manager 2 noted the problem at the site: 'We need to go and see in the model how those blinds in the gym have been designed.' He discussed how the blind should be installed and maintained with another manager, and he investigated the documents of the previous project to find out what kind of blinds had been installed there.
(2) Site manager 2 called a blind supplier about delivery times. He pointed out that the schedule was a pressing matter.
(3) Site manager 2 asked for the opinion of the chief manager.
(4) The blind installer visited the site. Site manager 2 and the blind installer discussed the situation both alongside the drawings up on the wall and by the models on the computer. They came to the conclusion that installing the blind would not be the right solution because it would be impossible to service and maintain. The blind installer promised to send a bid regarding the film installation by e-mail.

On the second day:

(5) The issue of installing the blind or using film was discussed in a contractors' meeting.
(6) Site manager 2 called a contractor about the film delivery.

On the third day:

(7) Site manager 2 made several phone calls to find out how soon the film could be installed on the inside of the window.
(8) Site manager 2 talked with the chief manager.
(9) He called the maintenance manager.
(10) He called a glazing company to ask someone to visit the site. He discussed the loss of the warranty if the window was covered with film with the chief manager.

(11) The person from the glazing company arrived with some sample films. They came to the conclusion that the window should be covered with a film from the outside as the glass could not hold up a film on the inside.
(12) Site manager 2 called the maintenance manager to make sure that he agreed with the decision.
(13) Site manager 2 and the glazing expert checked the window sizes on the paper drawings in the site office. Site manager 2 told the chief manager the decision and pointed out: 'One could have guessed [the end result], but it is always a good thing that an expert [a representative of the glazing company] comes to the site [and rechecks the solution].'

As the examples show, discrepancies and problematic design solutions in the models cause extra work and costs for project partners when they are discovered in the construction phase. Unfortunately, situations such as these are quite common in construction projects in general, not only in BIM-based construction projects. This is what Styhre (2012) is referring to when he states that the site managers' work is improvisational problem-solving ('muddling through'), where unforeseen events require immediate attention and quick decisions. Whether this should be business as usual or whether the problems should be solved earlier in the design phase will be addressed in the discussion section below.

Discussion

The activity-theoretically oriented ethnographic methodology and method enabled the daily practices related to BIM uses, the informal knowledge sharing and the communication relationships in the projects to become visible. This kind of tacit knowledge is easily overlooked in construction research (Pink *et al.*, 2010).

Our findings support Styhre's (2012) arguments that the work of site managers is skilful and involves improvisational problem-solving and quick decision-making. Working days tend to be long and require multitasking to complete even a part of the tasks. Site management activities rely heavily on face-to-face communication, 'messy talk' (Dossick and Neff, 2011), and informal, active and flexible conversations.

In Finland, the use of BIM in sites is still mainly in the hands of early adapters such as the ones shadowed in our data. At that stage of adaption, managers have no exact guidelines for how to use BIM and are free to create their own ways of utilizing the models. The range of BIM uses seemed to depend on the tasks, the role and the responsibilities of the individual managers. Their position, role, and tasks partly defined whether BIM was used for their own work or in collaboration with others. The site engineer's opportunities to use BIM collaboratively were much more limited than those of the chief manager.

Despite the deployment of building information models, traditional paper drawings were still concurrently used in the sites. In our data, the shadowed chief manager did not use traditional drawings in his site office at all, but obtained all the needed design information from the models available on computer. The site engineer used paper drawings occasionally, but he also mostly relied on BIM. However, the paper drawings on the walls of the meeting rooms and the corridors of the site offices supported the informal conversations of the site personnel. This demonstrates the hybrid use of paper design documents and building information models in the projects (compare Harty and Whyte, 2010).

The use of BIM was limited by the lack of mobile tools and personnel who knew how to use BIM. As computers were only available in the site offices, BIM cannot then be used on site, even though many of the central tasks, such as work planning and briefing, partly happen on site. Further, software development is required to expand the uses of BIM in sites. The site managers in our cases used design software tools (ArchiCAD and Solibri) to find the needed design information. The modelled information was otherwise separate from the project management software tools in use. As our cases represent the early stage of adaption of BIM, only one person in each site knew how to use BIM. This prevented collaborative uses of BIM.

The information content and accuracy of the models were not sufficient for the needs of all the site activities. Although there have always been imperfections in design, the use of digital 3D models reveals flaws and errors more clearly. To achieve the desired quality of the models, deeper collaboration is needed between constructors, designers, maintenance people and material suppliers. The flaws and errors found in the data can partly be seen as a lack of collaborative design or collaboration between designers and site personnel, not as errors within the software. This highlights the need to develop design processes and increase collaboration between different project parties so that designers can gain a better understanding of the information that models should include and the level of detail at which the information should be presented. The collaboration should also include negotiations and agreements conducted during the project about the tasks the models will be used for, the information included in the models, and the way that the models should be created to ensure that the information is usable for construction and maintenance tasks. As the site manager stated,

> There should be clear instructions for the designers of what the models must include and how that information should be modelled. If the modelling work is done in the way that is easiest for the designers, the information in the models is not detailed enough or we don't get accurate information from the model, for example, the amounts of the materials. (Site manager 2)

Chambers (2000) reports that the principle of informed consent, the confidentiality of the research subjects and the openness of the research findings have proven difficult to ensure in applied ethnography. In this study, the first author asked permission to interview project personnel and to gain access to observe project meetings with the representatives of the main contractor company before the actual shadowing period. These negotiations included several encounters with the project management, the site managers and other personnel of the construction site. The negotiations also enabled the building of trust between the researcher and the site managers as well as a process of becoming acquainted with each other. The site managers involved had a positive attitude about being included in the study, but the project manager wanted to ensure that the study would not cause any harm to or extra work for the project personnel. During the shadowing period, the researcher repeatedly negotiated with those involved whether she was allowed to video record the informal meetings or encounters in the sites. The researchers have left out any descriptive details that might enable the recognition of the research subjects, the projects or the companies during the writing of the research findings. Any descriptions that might have been considered 'company secrets' have been eliminated. The research findings and the article manuscript have been presented to the representatives of the companies and the research subjects for comments and revisions. One of the site managers resigned from the company before the analysis was completed, and it was not possible to present the research findings to him.

Conclusions

The daily tasks of site managers have recently been examined in interview studies. Research concerning BIM as a new technology and a tool in site management is still sparse and mainly focused on the possible uses of BIM. This study is arguably one of the pioneering studies examining how BIM is actually used on sites as a part of the site management work.

The ethnographic approach of our study revealed the first steps of the deployment of BIM in construction sites. According to our findings, the use of BIM is active at this stage, but hindered by the insufficient information content of the models and the lack of mobile devices and employees who know how to use BIM. These challenges restrict the effective use of BIM to only a few limited tasks, places and situations.

Expanding the use of a new tool, such as BIM, requires changes in activities and collaboration between the designers and the site managers. The changes needed on the level of daily work were specified by one of the project managers. First, designers have to learn to provide constructible designs and models. Secondly, constructors need to learn to build according to the designs instead of improvising. These changes are a big challenge for the industry, in which design and production have traditionally been quite separate from each other. The designs have traditionally been considered an important but imperfect source of information for carrying out the construction work (Styhre, 2006). The imperfection of designs has compelled site personnel to interpret the designs and sometimes even to accomplish the construction work without following the design documents.

From the activity-theoretical perspective, the adoption of BIM in site management activities changes not only the tools of site managers, but also the object of the work. The work of site managers will probably include more and more participation in the design management processes. This will require a wider perspective on the whole construction process, a better knowledge of design work, and the ability to collaborate with different design disciplines, material suppliers and other project partners. For BIM to be a possible catalyst in the development of the construction industry (Eastman *et al.*, 2011), it cannot merely replace traditional drawings. The rules (timetables and contracts), the community (the partners needed to produce the new type of design), and the division of labour between the partners will all need to be reconsidered. These changes will then have consequences in the network of other activities of construction.

Research is needed on further steps of BIM deployment, such as mobile devices and the development of new ways of collaboration between different designers, site managers and other project parties. Moreover, future research should examine the critical elements of context-related BIM use, such as the changes in the rules, the division of labour and the attitudes of the members of the construction site community towards BIM use.

Acknowledgements

We owe our sincere thanks to the project personnel who allowed us to collect our data in the construction sites. We also gratefully thank our colleagues at CRADLE for their positive and insightful comments and their help with the English language. The study is part of PRE research programme 'Built Environment Process Re-engineering' organized by RYM Oy. The funding from the Finnish Funding Agency for Technology and Innovation and the Strategic Centre for Science, Technology, The Academy of Finland and Finnish construction companies is gratefully acknowledged.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Solibri Model Viewer is free software built for viewing Open Standard IFC files and Solibri Model Checker files (bit.ly/1hefmZt).
2. ArchiCAD is 3D building design software developed for architectural design. It is object based, and its development is based on the idea of BIM. ArchiCAD supports open IFC-data transfer (bit.ly/1kP7RrC).

References

Alvesson, M. (2009) At-home ethnography: struggling with closeness and closure, in Ybema, S., Yanow, D., Wels, H. and Kamsteeg, F. (eds.) *Organizational Ethnography. Studying the Complexities of Everyday Life*, Sage Publications Ltd, London, Thousand Oaks, CA, New Delhi, Singapore, pp. 156–74.

Barley, S. (1990) Images, or imaging: notes on doing longitudinal field work. *Organization Science*, **1**(3), 220–47.

Barlish, K. (2012) How to measure the benefits of BIM — A case study approach. *Automation in Construction*, **24**, 149–59.

Bryde, D., Broquetas, M. and Volm, J.M. (2013) The project benefits of Building Information Modelling (BIM). *International Journal of Project Management*, **31**, 971–80.

Bucciarelli, L.L. (1988) An ethnographic perspective on design engineering. *Design Studies*, **9**(3), 159–68.

Chambers, E. (2000) Applied ethnography, in Denzin, N.K. and Lincoln, Y.S. (eds.) *Handbook of Qualitative Research*, 2nd edn, Sage Publications, London, pp. 851–69.

Czarniawska, B. (2007) *Shadowing and Other Techniques for Doing Fieldwork in Modern Societies*, Liber/CBS Press, Malmö/Copenhagen.

Davies, R. and Harty, C. (2013) Implementing 'Site BIM': A case study of ICT innovation on a large hospital project. *Automation in Construction*, **30**, 15–24.

Dossick, C.S. and Neff, G. (2010) Organizational divisions in BIM-enabled commercial construction. *Journal of Construction Engineering and Management, ASCE*, **136**(4), 459–67.

Dossick, C.S. and Neff, G. (2011) Messy talk and clean technology: communication, problem-solving and collaboration using Building Information Modelling. *Journal of Engineering Project Organization*, **1**(2), 83–93.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011) *BIM Handbook. A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*, (eds.) John Wiley and Sons, Inc, New Jersey.

Engeström, Y. (2000) From individual action to collective activity and back: developmental work research as an interventionist methodology, in Luff, P., Hindmarsh, J. and Heath, C. (eds.) *Workplace Studies*, Cambridge University Press, Cambridge, UK, pp. 150–66.

Engeström, Y. (2001) Expansive learning at work: toward an activity theoretical reconceptualization. *Journal of Education and Work*, **14**(1), 133–56.

Fraser, C. (2000) The influence of personal characteristics on effectiveness of construction site managers. *Construction Management and Economics*, **18**, 29–36.

Fryer, B. (1979) Managing on site. *Building*, **236**, 15 June, pp. 71–2.

Hardin, B. (2009) *BIM and Construction Management: Proven Tools, Methods, and Workflows*, Wiley Publishing Inc, Indianapolis, IN.

Harty, C. and Whyte, J. (2010) Emerging hybrid practices in construction design work: role of mixed media. *Journal of Construction Engineering and Management*, **136**(4), 468–76.

Henderson, C. (1999) *On Line and on Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering*, the MIT Press, Cambridge MA.

Kerosuo, H. (2006) *Boundaries in Action: An Activity-theoretical Study of Development, Learning and Culture in Health Care for Patients with Multiple and Chronic Illnesses*, Helsinki University Press, Helsinki.

Li, H., Lu, W. and Huang, T. (2009) Rethinking project management and exploring virtual design and construction as a potential solution. *Construction Management and Economics*, **27**, 363–71.

Marshall, N. and Bresnen, M. (2013) Where's the action? Challenges of ethnographic research in construction, in Pink, S., Tutt, D. and Dainty, A. (eds.) *Ethnographic Research in the Construction Industry*, Routledge, Taylor & Francis Group, London and New York, pp. 108–24.

McDonald, S. (2005) Studying actions in context: a qualitative shadowing method for organizational research. *Qualitative Research*, **5**, 455–73.

Miettinen, R., Samra-Fredericks, D. and Yanow, D. (2009) Re-turn to practice: an introductory essay. *Organization Studies*, **30**(12), 1309–27.

Miettinen, R., Kerosuo, T., Mäki, T. and Paavola, S. (2012) An activity theoretical approach to BIM, in Gudnasen, G. and Scherer, R. (eds.) *eWork and eBusiness in Architecture, Engineering and Construction, Proceedings of the European Conference on Product and Process Modeling*, Taylor & Francis, London, pp. 777–81.

Mintzberg, H. (1970) Structured observation as a method to study managerial work. *The Journal of Management Studies*, **7**(1), 87–104.

Nicolini, D. (2009) Zooming in and out: studying practices by switching theoretical lenses and trailing connections. *Organization Studies*, **30**(12), 1391–418.

Pink, S. (2004) Visual methods, in Seale, S., Gobo, G., Gubrium, J.F. and Silveman, D. (eds.) *Qualitative Research*

Practice, Sage Publication, London, Thousand Oaks, New Delhi, pp. 391–406.

Pink, S., Tutt, D., Dainty, A. and Gibb, A. (2010) Ethnographic methodologies for construction research: knowing, practice and interventions. *Building Research & Information*, **36**(6), 647–59.

Pink, S., Tutt, D. and Dainty, A. (2013) (eds.) *Ethnographic Research in the Construction Industry*, Routledge, Taylor & Francis Group, London and New York.

Reder, S. (1993) Watching flowers to grow: polycontextuality and heterochronicity at work. *The Quarterly Newsletter of the Laboratory of Comparative Human Congnition*, **15**(4), 116–25.

Rogers, E.M. (1995) *Diffusion of Innovations*, 4th edn, The Free Press, New York, NY.

Styhre, A. (2006) The bureaucratization of the project manager function: the case of the construction industry. *International Journal of Project Management*, **24**, 271–6.

Styhre, A. and Josephson, P.-E. (2006) Revisiting site manager work: stuck in the middle? *Construction Management and Economics*, **24**, 521–8.

Styhre, A. (2010) In the circuit of credibility: construction workers and the norms of 'a good job'. *Construction Management and Economics*, **29**, 199–209.

Styhre, A. (2011) The overworked site manager: gendered ideologies in the construction industry. *Construction Management and Economics*, **29**, 943–55.

Styhre, A. (2012) Leadership as muddling through: site managers in the construction industry, in Tengblad, S. (ed.) *In the Work of Managers: Towards a Practice Theory of Management*, Oxford University Press, Oxford and New York, pp. 131–45.

Styhre, A., Josephson, P.-E. and Knauseder, I. (2006) Organization learning in non-writing communities: the case of construction workers. *Management Learning*, **37**(1), 83–100.

Succar, B. (2008) Building information modelling framework: a research and delivery foundation for industry stakeholders. *Automation in Construction*, **18**, 357–75.