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How can digital building information modelling (BIM) facilitate climate transition in cities?

Réka Andersson, Maria Eidenskog
Business and Administration, Linköping university; Thematic Studies - Technology and Social Change, Linköping university, 58183 Linköping, Sweden
reka.andersson@liu.se; maria.eidenskog@liu.se

Abstract. Digitalization of the construction industry is considered important in combating climate change through more efficient use of resources and better control of energy calculations. Digital modelling of buildings is argued to make building’s energy use more efficient through better energy management. However, research regarding the use of the promising digital tool Building Information Modelling (BIM) has shown that BIM creates unclear roles, division of responsibilities and that cultural barriers between professional groups can be a problem. This paper focuses on how the work with BIM is organized and what conditions are needed to create effective workflows with BIM. The methodology consists of a literature study of digitalization processes in the construction industry and workshops with different professionals. Workshops as a research method provides an exploratory way to understand complex issues, as well as knowledge processes, in relation to digital tools. The co-productive format of the workshops facilitates conversations where different professional groups meet and share experiences of working with BIM. The study shows that several requirements needs to be met to fully make use of the BIM potential. Communication between different professions, knowledge transfer over project boarders, different standards and competence, both within and in relation to the clients, are important components when working with BIM. There is a need for interdisciplinary work practices which are complicated by the project organizational form most used in construction industry. For BIM to be utilized as a tool to combat climate change in cities through effective resource planning, the organizational settings and workflows needs to be interdisciplinary and communication between departments, clients and professions must be standardized while still flexible.

1. Introduction

Digitalization of the construction industry is considered important in combating climate change through more efficient use of resources and better control of energy calculations.[1] Digital modelling of buildings can make energy calculations of building’s energy use more efficient and keep them updated throughout the project planning. However, research regarding the use of the promising digital tool Building Information Modelling (BIM) has shown that BIM creates unclear roles, division of responsibilities and that cultural barriers between professional groups can be a problem.[2] Likewise, the handover to facility management phase is considered problematic in a Swedish context, as there are many uncertainties about division of responsibilities and knowledge transfer.[3]

The aim of this paper is to explore the challenges and potential for working more efficient with BIM presented by professionals and in current research. Digital tools are expected to revolutionize the
Swedish construction industry [4,5] and this research can contribute to a nuanced view on how this revolution can be contextualized and show the need for new ways of organizing knowledge transfer and cooperation between different professions. This paper contributes to a broader understanding of the challenges of digitalization in organizations in the construction industry, captured through BIM. If digital tools produce the promised efficacy in work practices and resource management, this will create important contributions to several of the sustainable development goals from United Nations, such as goal 11: Sustainable cities and communities, by creating more sustainable and affordable housing. Moreover, it relates to goal 7: Affordable and clean energy, since if BIM is used in an optimal way, energy models are included and updated throughout the planning process, which, according to research, can result in more accurate calculations.

Digital tools are in this paper understood as carriers of work practice conditions, since they both are an outcome and a prerequisite of the practices at the workplace.[6] This view of digital resources is conceptualized by Orlikowski and Iacono when they write about IT artefacts as a social structure: “IT artifacts are usually made up of a multiplicity of often fragile and fragmentary components, whose interconnections are often partial and provisional, and which require bridging, integration, and articulation in order for them to work together.” [7] (p. 131)

The complex interactions that constantly are in motion in the collaboration between professional actors with digital tools in construction projects should be understood as a social and material web including organizational practices, traditions and taken for granted understandings of the use and access to these tools. For example, research on energy models has shown that responsibility for the future and the individual's own feelings affect how energy models are handled.[8] In this paper we understand BIM as a tool with the aim of creating more efficient and seamless working practices. Previous studies on BIM show that it is important that the system is adapted to its context.[9] Research has also shown that the new ways of working with BIM creates unclear working conditions [2] and in some cases is BIM considered to be so complex that it is difficult to use it in practice.[9] There is good knowledge of how BIM can technically contribute to energy efficiency [10], but there is a gap in research on how knowledge transfer is best organized between actors when working with BIM [11] and how BIM can be organized to create the most effective work with energy calculations and efficient resource management.

The paper is structured as follows. First, we give an overview of the applied methods and argue that the co-productive character of workshops is valuable method that offers new insights into the challenges of the organization of work with BIM. Thereafter follows the result section, where we bring up the challenges that were brought up during the workshops and relate it to existing research. We end the paper with a critical discussion of the use of BIM and question its potential to achieve a more efficient planning process without a foundational re-organization of working practices and organizational structuring.

2. Methodology

The methodology consists of a literature study of digitalization in the construction industry and workshops with different professional groups.

2.1 Literature study

The literature study of digitalization within the construction industry was conducted with the help of the database Scopus. Searches were limited to open access articles and reviews in English, from 2009 and onward. The used keywords were a combination of digitalization or digital technology and construction industry or building sector. Our search in Scopus resulted in 90 documents, categorized in 10 subject areas. To create a general overview of digitalization within the interdisciplinary field of the construction industry, we did not limit our literature study to one specific subject area, but included articles from the social sciences (24), business, management and accounting (10), the environmental sciences (20) and engineering (42). Of the relevant articles, there was a clear focus on BIM implementation, specifically the constraints and barriers within specific countries [12,13], but also in for example megaprojects.[14] However, there was one longitudinal study that reported on a successful BIM implementation.[15] Other
relevant themes relating to BIM were problems with compatibility with other technology [16] and the creation of a digital divide between various types of companies.[17] Another area of focus in the literary study was platform companies or platform co-operation due to digitalization [18] and digital technology on the construction site.[19]

2.2 Workshops

Workshops as a research method provides an exploratory way to understand complex issues, as well as knowledge processes in relation to digital tools.[20] This is a rarely used method for studying BIM. Integrating academic and practitioner knowledge and perspectives, the workshops had a co-productive format, which brought together different professional groups and facilitated the conversations between about the experiences of working with BIM and problematizing how to make the planning process of new buildings more efficient and overcoming the challenges with BIM. Emphasis was on discussing the organization of work practices in relation to BIM. The results will be used for developing a new collaboration model to develop the working processes surrounding BIM. The new model will be implemented and tested during spring 2020 through a case study within the framework of the research project.

As a part of a larger research project, we conducted three workshops with employees from a private company within the construction industry. The company is a large, international consultancy firm within the construction industry with 5000 employees in Sweden. The workshops consisted of 7-10 participants, who had different professions, including architects, environmental consultants, BIM coordinators and managers. The participants had different levels of experience with BIM, from novice to experts. However, since participation in the workshops was voluntary, there were few critical voices to BIM, which suggests that interest in BIM was a driving force for participation. Furthermore, most participants were relatively newly employed. Some of the participants knew each other, but most of them had never meet before.

During the first workshop, the researchers and participants decided on the underlying question of the workshops to be: how do we want to cooperate more effectively with digital tools? Even though focus was on digital tools in a wider scope, the discussions in the workshops almost exclusively revolved around BIM. The aim was to identify the conditions, challenges and good examples of co-operating with digital tools and establishing some focus-areas. In workshop two, the researchers related the focus-areas to current research and there were joint discussions on developing ideas for how to improve the company’s work with digital tools. Some of these ideas were chosen for further development, using feasibility and impact factor as criteria. Finally, in workshop three, based on the researchers’ synthesis of ideas and critical input, the participants worked in smaller groups with creating hands-on action-plans for developing the company’s work with BIM.

3. Results

In this section we focus on the areas that the workshop participants brought up as important for co-operating more efficiently: communication, competence, standards and partnering. In order to deepen the understanding of how to facilitate the work with digital tools in general, and BIM in particular, the results from the workshops are contextualised with relevant research.

3.1 Increasing communication and building competence

The main themes during the workshops were communication and competence. The participants described communication between various disciplines and between projects as common challenges in working with BIM. The use of different terms and language, the lack of understanding of other disciplines perspective and a lack of knowledge transfer between professional groups and projects were brought up as problematic for efficient cooperation with digital tools in general, but especially BIM. In a similar manner, having the right competence, as well as necessary competence was a commonly brought up issue. These interlinked themes were approached from a broad range of aspects, which resulted in the following developed ideas for increasing effectiveness in work practices.
3.1.1 Making competences within the company visible Discussions during the workshops showed that there is a lack of overview and knowledge of the available competences within the company. As the workshops included both experts and novices in BIM, a discussion about project start-ups within the company raised awareness that certain professional groups have been unconsciously excluded in the early phases of planning, due to their lack of BIM competence. Consequently, the area of competence of some of the participants, in our specific case environmental consultants, were entirely missing in the beginning of projects and were not included in the negotiations with the clients. As a result, the competence of these professionals was only included at the end of the construction process, when there was no room for any planning and negotiations. This example shows that with the introduction of a digital technology, competence regarding the digital tool BIM became prioritised, which could potentially make other types of competences invisible. For this reason, the professionals suggested that it is vital that all competences within the company are mapped and available through the company website. Furthermore, they argued for the development of the internal digital working place to establish an internal project-network in the company. They pointed to the need of a shared platform where company contacts were automatically connected to CV and reference projects for a better overview of competences and for ensuring inclusive competence planning.

3.1.2 Establishing a basic competence level in BIM According to the workshop participants, there is a wide variation regarding competences in and experiences of the digital tool BIM within the company. While some have expert knowledge of BIM, as for example BIM coordinators, other employees have limited, or no experience and knowledge of it. For a strengthened efficiency and cooperation, the workshop participants have suggested that the company should establish a basic level of competence regarding BIM. These results from the workshops are in line with research. Bosch-Sijtsema and Gluch [21] argue for the development of BIM competence to become a common knowledge within the construction industry and not limited to specific individuals, so called “BIM enthusiasts”, who are often BIM coordinators with expert knowledge of BIM. For the work with BIM to function optimally, there is a need for the establishment of a mutual competence level of BIM across the building process.

To achieve basic competence in BIM, the workshop participants argued for the development of an internal education, that all company employees would be expected to complete. Webinars were considered a time-efficient and affordable solution, as employees can themselves decide when to carry them out and they do not demand heavy resources from the company.

3.1.3 Organizing for knowledge transfer Communicating and sharing knowledge within and between projects was a concern that came up at both workshops. The studied company is a project-based organization, which is predominant in the construction industry.[22] As a result, the professionals work in temporary groups consisting of different specialist skills and carry out a project for a limited time, within a set financial framework. Due to this project based organizational form, there is an intrinsic tension between individual temporary projects on the one hand and the permanent organizational context on the other.[23] Since project timeframe demands that professionals focus on accomplishing the task at hand, the workshop participants argue that they do not have time to reflect and document the knowledge that projects provide and can be of wider use within the organization. Consequently, knowledge that could be used in other projects and would benefit organizational learning and development is not stored and passed on. In order to prevent knowledge loss from earlier project experiences, the workshop participants suggested the creation of a knowledge database. The development of such a database was discussed in detail, as for the database to be useful, complex knowledge must be easily retrieved. An equally important factor for knowledge transfer that the workshop participants brought up was making time for reflection during and after ongoing projects, as well as thinking new within projects. Time constraint is in general established as a barrier for knowledge transfer within research [22] although reflecting over lessons learned from projects can be a useful organizational asset both in improving existing working practices and fueling innovativeness.
In order to facilitate knowledge transfer within projects, the workshop participants suggested organizing working spaces according to projects and making sure that the team members have offices next to each other. Working in proximity to each other facilitates communication and creates common understanding. However, relying on knowledge transfer that builds on physical proximity and thereby informal relationships can be problematic, if some of the team members are located in the offices outside of the project head office.[24]

3.2 Lack of coherent standards
During the workshops the participant raised different standards as an issue when working with BIM. The large company has several different subdivisions and there are no overall standards that could be used to guide processes integrating different professions. The participant raised issues with conflicting standards both within and outside the company. There are no widely accepted business standards for BIM, which is seen as a risk in the use of the technology.[11] The need for clear standards is seen as one of the most important strategies for supporting the development of BIM both globally and locally.[25] For example, there are national CAD drawing standards in which naming conventions of materials are discussed, but in relation to BIM, this becomes problematic. Since materials are imported and exported to the BIM model in several steps, it is vital that the characters do not cause confusion in the different databases. Thus, the standard naming conventions might not work in relation to BIM.[26]

For the participants in the workshop, the lack of business standards is evident, but the lack of company standard is even more problematic. Since the competence of working with BIM is not evenly distributed in the company, it is hard to organize awareness of the need of common practices. One part of the problem is that some written standards for organizing working processes are hard to find on the company intranet. Another part is that some standards are either lacking or not written down and seen as tacit knowledge. It thus becomes problematic for the employees to know what methods and standards they will use in different project. One example of problematic standards presented in the workshop is how different ventilation units is symbolized in BIM. Another is how the same type of arrows in design drawings could mean different things for different professions. Since these practices are tacit knowledge there is seldom discussions about them until problems arise. The participants did not think that overall standards could solve all problems, since some professions have established routines that could be hard to change. Thus, for each project, the working processes need to be discussed to avoid misunderstandings. Moreover, the participants asked for a guiding standard for starting a project but without rigid rules over working practices. The participants in the workshop argued that a flexible level of decision making could facilitate a better adoption to the different projects and professional preferences.

To be able to have standards for working practices that both guide processes and allow for contextual adaptiveness, it is vital that the company work with a long-term perspective, according to the participants in the workshop. This could be accomplished through a focus on the outcome over time instead of a narrow budget perspective where each project must be as profitable as possible. A clear leaderships initiative was also raised as important in order to bring about recognition for new standards.

3.3 Lack of client interest and knowledge
A recurring theme on the workshop was the clients lack of competence and interest in BIM. According to the workshop participants, clients do not see the use or need of working with BIM in the maintenance of the newly built houses. Furthermore, since BIM in this stage bring about more expenses and longer planning phases, the clients are often negative to the use of BIM in constructions projects. Some clients, such as municipality owned housing companies, are very engaged in the development of BIM and have competence to use BIM in the maintenance of their buildings. These clients are most often seen as exceptions to the more common client who wants a house as cheap as possible and do not have a more long-term perspective on property development. This becomes an issue for the consultants when they have invested in BIM in their working practices and the clients do not want to add on cost for creating a BIM model in the early phase of the planning process. In general, the participants see a challenge in
convincing clients of the advantages of BIM as they have no ways to “prove” the effectiveness of BIM, since all building projects are unique.

Previous research confirms this problem [12] but there are ways to work to include the clients more in the early phase and thus create both more interest and competence. One such way is the use of partnering. Partnering is a term that is broadly used for collaborative management approach that facilitates openness and trust between partners in construction projects. Partnering can increase the client’s competence of using BIM, which can result in them being more resource effective in their maintenance av buildings through working with BIM. Partnering and involvement of the clients in the early phases of the planning of new constructions projects makes it possible to educate the client and create an understanding and interest in the use of BIM in relation to the client's future use of the building.

Another strategy is to work on long-term business partnering, in which the client and the consultant firm together develop BIM practices through several project and thus evolving a more trusting relationship.[27] The trust between the partners in construction project is an important factor to be able to use the potential of BIM.

4. Discussion
Digital tools can be a way to create more efficient processes in the construction industry and thus contributing to the UN sustainable development goals (such as the goals related to sustainable cities and energy efficiency). However, BIM has not yet reached its potential and this research can provide insights to how both research and professionals understand the way this potential can be put in use.

The literature review showed that there is a multiplicity of challenges and barriers in the implementation of BIM. Some of these challenges, as lack of competence, time restraint, the client’s lack of knowledge and interest about BIM, are also evident from the workshops. Looking at the literature on digitalization within the construction industry, we have seen that many countries have adopted policies in favor of BIM implementation. However, the extent of BIM implementation processes varies greatly between countries. Western countries as Sweden are considered to have come further due to economic resources, then developing countries like Italy and China.[12, 13, 14] Specifically, BIM needs to be adapted to each countries’ context and the overall digitalization process that takes place.

Company size is also a factor that matters in relation to digitalization within the construction industry [17], especially when it comes to the higher maturity levels of the technology. Financial constraints are often seen as one of the reasons for not investing in BIM, in particular within SME’s.[12,17] Although the company in this study is a large organization, investing in BIM competence for all employees is not self-evident. Nevertheless, the workshop results suggest that a basic competence in BIM is necessary in order to streamline working practices. While research suggests that successful BIM implementation demands an integrated way of working for reaching the higher BIM maturity levels [28], the workshop participants did not see the need of all professionals reaching an advanced level of BIM.

Digitalization within the framework of project-based organizations also brings specific challenges to consider. Knowledge processes are limited since temporary projects are prioritized before organizational learning and innovation. Furthermore, the digital technology, BIM, is the carrier of the working conditions and constraints that exist in the studied organizational form [6]. As earlier research has pointed out, BIM lacks an integrated knowledge management process which could help transferring and reusing knowledge throughout the whole building process [29] and between projects. In order to improve future projects routines, there is a need of coordination to transfer knowledge within the organization. In addition, the organization of professional work with digital technology needs to be carefully done, as it affects which type of knowledge and competences are made visible and valued. The workshops and the literature presented in this paper further show the dual need for both standards and flexibility. Every construction project is unique, and the involved professionals have their own established working practices which sometimes needs to be adapted to the current project. Thus, there is a need for flexibility and adaptability for the processes that organize the work with BIM over professional boarders. Even so, some of the problems with BIM is the lack of business standards. There are too many different practices which often cause confusion and problem in the experience from the
participants in the workshops. There is a need of a strong leadership combined with some standardized processes that still allow for adaption for the different projects.

The co-productive format of the workshops was a novel method for researching BIM, aiming to integrate academic and practitioner perspectives. This format gave new insights regarding the organization of work with BIM. It made organizational structures that prevented the spread of BIM visible, as participants with and without BIM skills participated. Additionally, it created contact between professionals from different parts of the organization and with different professions that did otherwise not exist. Furthermore, it broadened our study, and created the possibility for us to attend to problems that the participants themselves raised through a dialogue, which we could not have achieved through interviews. Since participation in the workshops was voluntary, the participants were mainly employees with a positive attitude towards BIM. Despite a wide range of experiences and knowledge about BIM among the participants, a striking number of them were newly employed. Since new employees have limited experiences in the studied company, this can be a restraint to their scope of action for organizational change. The participants themselves raised concerns about what mandate there was to carry out future changes regarding BIM.

Despite these discussed constraints, the research in the literature study enact the implementation of BIM as an inevitable part of the future for construction industry and when we raised a question on alternatives to BIM in the workshop, the participants had trouble to vision a future in which BIM did not hold a strong position. However, working with BIM on a more advanced level requires an integrated way of working [28] which stand in contrast with the contemporary working practices in project-based organization commonly used in the construction industry. With this background, it is not self-evident that BIM can achieve a more efficient planning process without a fundamental re-organization of working practices and organizational structuring. There is a need for collaboration over professional boarders, both internally in the company and externally between companies. Trust between clients and entrepreneurs, shared knowledge and competence is vital for the integrated model that is at centre for BIM. Through more collaborative working practices, the potential of BIM can be reached which in turn will lead to more efficient use of resources. In this way, BIM can be a tool to facilitate climate transition, however, it requires new ways of organizing, planning and cooperation in the construction industry.

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