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Abstract

Within the Swedish construction industry, new ICT in the form of Building Information Modeling is implemented in construction design. Even though, the new ICT has been around for some years, it is only recently that more and more design teams are working with this technology and therefore it is relevant to study how this process unfolds in inter-organizational construction design projects. The objective of the study is to understand how new ICT influences the way of work, work routines and roles in inter-organizational construction design projects. The study is based on a constructivist perspective and focuses on technology-mediated change through changes in routines and roles. The study applies a qualitative interview and observation method in which three cases of construction design projects are studied. The study contributes with empirical examples of the how new ICT changes routines, meetings and roles in inter-organizational project.

Introduction

In the Architecture, Engineering and Construction (AEC) industry new ICT is currently implemented and used in a wide context. The construction industry is in the early stages of a historic shift in the way the design of the building process is conducted. The industry is moving from 2D drawing based design towards a digital model based design using Building Information Modeling (BIM). The building information model is a computable 3D-representation that contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building (Eastman et al. 2008). The new ICT, called BIM supports the whole life cycle of a building and is currently used in the design and production phase of construction. BIM provides a platform for sharing information and supporting communication between different actors in the AEC industry. The use of BIM has become very popular in the construction industry worldwide; however, few firms apply and implement the full potential of the technology and realize its implications for work processes and working culture (Froese, 2010). Although this particular type of ICT is relatively new, several studies have identified changes in work practices and development of new roles (Gu & London, 2010; Jaradat, Whyte and Luck, 2013; Sebastian, 2010), new forms of accountability (due to a new form of traceable electronic data) (Jaradat, et al., 2013) and a closer integration and communication between different stakeholders in a project (Hartmann & Fischer, 2007; Jaradat, et al., 2013; Wikforss & Löfgren, 2007).

Even though, the new ICT has been around for some years, it is only recently that more and more design teams are working with this technology and therefore it is relevant to study how this process unfolds in inter-organizational construction design projects. The objective of the study is to

understand how new ICT influences the way of work, work routines and roles in inter-organizational construction design projects. The study is based on a constructivist perspective (Leonardi & Barley, 2012) and focuses on technology mediated change through changes in routines, roles (Feldman & Pentland, 2003; Pentland & Feldman, 2005; Volkoff et al., 2007) and practices (Orlikowski, 2000).

The article is based on a qualitative interview and observation study. The methodology used to collect and analyze data is discussed in the next section. After the methodology the theoretical perspective is discussed in more detail which is following by a combined section in which findings are related to literature in a discussion and conclusion section.

Keywords

Technology mediated change, routines, construction industry.

Method

The study is based on a constructivist perspective (Leonardi & Barley, 2012) and focuses on changes in working routines and roles (Feldman & Pentland, 2003; Pentland & Feldman, 2005; Volkoff et al., 2007) A comparative case study approach (Eisenhardt, 1989) is applied of three construction design projects. In order to study changes in roles and routines not only interviews were held (18 interviews), but also structured observations (27 hours of observations) based on a clear observation guideline were performed (the structured observation guideline was based on Fruchter & Bosch-Sijtsema, 2010). The observations can give unique insights into the day-to-day working practices (McDonald, 2005), and data was collected through extensive notes, photographs and the structured guideline. Next to observations semi-structured interviews (18 in total) were held with members from the case study projects, management roles, and organizational ICT managers.

In table 1 the data collection is shown of the three case studies. All three case studies are based on construction design projects, which were managed by a contractor firm (contractor-led). The three cases are projects held in three different contractor firms. In case BoStu, 6 interviews were held and three meetings were observed of all 5 hours each (total 15h of observations). Case BoDes is based on 6 interviews, and 6 hours of observation of one workday, and Case ScanInf had 6 interviews and observations of three meetings of 2 hours (in total 6 hours of observations). Case BoStu and BoDes are both working with an integrated or concurrent engineering approach in which the multi-disciplinary and inter-organizational design project teams work together for a full day at a collocated workplace at the contractor's site. Both cases consisted of members from different firms (4-6 different firms) and team size was between 10 (BoStu) to 14 (BoDes) team members. The Cases BoStu and BoDes worked with the design of apartments. Case ScanInf (team size was 13 members) was an internal team of which its members were geographically distributed over four locations in Scandinavia. Case ScanInf worked with the design of a road trajectory. They held shorter meetings supported by video conferencing and other ICT. Data was analyzed with help of the grounded theory analysis method (Glazer & Strauss), in which data was coded into several themes. Four main themes are discussed below; those are changes in working routines, meetings, roles and the change process.

Theoretical perspective

From research in management and information systems we know that the implementation and use of new IT can lead to technology-mediated change in organizational routines. These changes can concern inter-group relationships, responsibilities, development and transfer of knowledge, development of new routines, roles, and ways of working (Leonardi, 2011; Leonardi & Barley, 2012; Volkoff, et al., 2007). This literature distinguishes between ostensive or structural aspects of routines and performative aspects of routines consisting of actions - routines in practice (Feldman & Pentland, 2003; Pentland & Feldman, 2003). Pentland and Feldman (2005: 795) define organizational routines as depending on connections, the stitching together of multiple participants and their actions to form a pattern that people can recognize and talk about as a routine. Artifacts, like IT or the workplace are physical manifestations of organizational routines and can enable or constrain. However, other authors mention that IT is not only an artifact; IT also changes the relationship between routines and roles by embedding this relationship into the system (Leonardi, 2011; Volkoff et al., 2007). Leonardi (2011) discusses in this respect, strategies how people enact their human agency (i.e., ability to form and realize one's goals) in response to a technology's material agency (i.e., capacity for nonhuman entities to act on their own). Earlier discussed strategies are to reject the technology, change the technology, or adapt the use of the technology in terms of changing routines (Leonardi, 2011; Volkoff et al., 2007). Many studies that focus on technology mediated change focus on IT implementation in an organization. Few studies focus on how ICT impacts change in inter-organizational temporary projects and project-based firms.

The construction industry often works in project-based organization forms (Gann and Salter 2000), in which several organizations work together on a particular project for a limited period of time. Literature in this field discusses the difficulties of learning over project boundaries and the sharing of capabilities and knowledge between the different project partners (Bosch-Sijtsema & Postma, 2010; 2009; Prencipe and Tell 2001). Even though many state that projects are temporary and partners in the projects change, literature has also stated that especially the construction project-based industry is strongly subjected to institutionalism and there is little variation in the organization between different projects (Kadefors, 1995). Projects' structures and procedures are heavily influenced by organizational and historical context (Engwall, 2003). Although a number of studies focus on IT in the construction and project-based industry (Karrbom-Gustavsson et al., 2012; Hartmann & Fischer, 2007; Wikforss & Löfgren, 2007), few studies discuss the impact of new IT on organizational routines in inter-organizational projects. Therefore, this study is particularly interested in applying the framework of technology-mediated change in organizational routines and roles to inter-organizational project context.

Discussion and Conclusion

In the discussion and conclusion section the paper lifts up a number of themes found from the data and connected them to literature, i.e., changes in working routines, meetings, roles, and change process.

Changes in working routines

The data shows a change in individual (i.e. drawing routines) as well as group work (i.e., coordination, responsibility) routines. Several of the interviewees discussed that their work routine changed once they started working with the new ICT. The way of drawing 3D models changed to some extent for certain roles (e.g., architects). Some elements in the digital model needed to be drawn rather differently in order to extract information out of the 3D model. This information was

earlier measured and calculated by hand and could with a change in drawing style in the 3D model be calculated automatically. However, it was noticed that not all project members changed this routine during the design projects, which made it more difficult to extract the information in a similar way during the project design.

Furthermore, the process of how to draw what part of the model, and who would draw what part of the model changed as well. An example from BoStu is mentioned by a structural engineer who noticed that the process changed in such a way that the drawings were made quicker. However, on the other hand, the new process in BoStu implied that the structural engineer had less individual control over the model and felt less secure with the outcome. In this case it was clear that the change in processes also implied a need for new decision-making procedures on who is accountable and responsible for certain parts drawn in the 3D model. Even though projects have a temporary nature, the roles and procedures in design projects are to some extent similar and there is little variation between building projects (see Kadefors, 1995).

The ostensive or structural aspect of routines (Feldman & Pentland, 2003; Volkoff et al., 2007) were discussed by the interviewees and observed, and the performative aspect of working routines is different in the three design project contexts and design teams. However, with the implementation and use of new ICT, the tasks, roles as well as accountability is impacted, implying that not only the performative routine adapts to the change in context, but also the structural or ostensive routine alters. The new ICT applied in the construction industry is a relatively new development and few studies focus on technology mediated change in routines of project-based firms as well as in the design projects. However, some studies confirm that new forms of accountability arise (Jaradat, et al., 2013). Other studies mention that communication and integration between project stakeholders and members changes and becomes tighter with the support of new ICT (Hartman & Fisher, 2007; Jaradat et al., 2013; Wikfors & Löfgren, 2007).

Change of Meetings

The two cases of BoStu and BoDes applied a more concurrent design type of meeting in which members were collocated in one work room in which different elements like time planning, request for information, and the 3D designs were visible in the room (either on the walls or projector). In these cases the new ICT supported discussions on particular design solutions, i.e., team members asked specific questions, were drawing on the whiteboard on which the model was projected and members stood in front of the model to show and discuss particular design solutions. In case of ScanInf the members were distributed over four locations. With help of the new ICT they were able to go jointly through the 3D model in shorter meetings and were able to discuss particular design solutions. The models were shared via a file-sharing service to all four locations and the team members were able to go through a list of discussion points, made design decisions and divided tasks and responsibilities of the design facilitated through the projected and visible 3D model. A person from ScanInf mentioned the following:

> *Another problem is that the person who is drawing in the model is not the same person as the one who is calculating which in turn is not the same person who is deciding. So the person who is changing in the model has to be in contact with the person who is deciding. Phone contact wouldn't do it because mostly it is not possible to give permission without seeing the problem more closely* (firm interview ScanInf).

These findings confirmed other studies that discuss the benefits and impact of visualization of the new ICT, in terms of supporting stakeholder integration, communication, decision-making, as well as innovation (Boland et al., 2007; Hartman & Fischer, 2007).

Changes in roles

Next to changes in the way the design group works and how individual routines are changing, also roles and responsibilities are changing through the use of new ICT in the design phase. Many interviewees discuss the importance of the BIM model coordinator (as seen in all case studies). The ICT (BIM) coordinator is a role that has developed from a CAD (Computer Aided Design) coordinator role, which was present earlier. The ICT coordinator is responsible for placing all the 3D drawings of all design team partners in one viewer in order to see if the different drawings of different disciplines are correct and if there are any clashes between the drawings. The ICT coordinator develops a joint model and shows this during the design meeting either for supporting discussions in the team and for showing and discussing possible clashes in the 3D drawings of the different disciplines. During the observations it was seen that the ICT coordinator played an important and active role during the design discussions. The ICT coordinator role developed from a more technical role, towards a coordinating role in terms of coordinating discussions concerning the 3D model.

> *An ICT-coordinator is like a parallel function next to the design project manager who … coordinates models, communication files, does collision detection. It is not only a technical role, but a parallel function to the design project manager*. (Consultant case BoStu)

Next to the ICT coordinator role, one of the cases had a new role as facilitator who operated next to the ICT coordinator and the project manager (in case BoDes). This facilitator (contractor) managed the information and communication flow between the team members during design meetings. This role facilitated the working approach of concurrent design in terms of the application of a number of working methods like joint planning, decision-making support, and information needs and deliverables.

The implementation of the new ICT not only develops new roles, but also changes the content as well as the responsibility of existing roles. From the observations (especially case BoStu and ScanInf) it became clear that the change in roles, responsibility, as well as accountability, also brought a change in power in the team. During the clash detection meetings (in which the team goes through the digital 3D model to see if there are clashes in the digital design), the ICT coordinator (in charge of the model) is organizing and leading the meeting and is in control of navigating through the 3D model. This ICT coordinator also specified important points that need to be discussed and decided upon with help of the model. Important was to notice that this ICT coordinator's role is not only a technical role, but in order to steer the clash detection meetings, communication and coordination become important characteristics. One of the members of the BoStu case mentioned the following:

> *But the design project manager's role is changing. This really means a big change for the project managers of both our firm and the client. They lose a little power, they must let go of this and have not really control. And they have to learn new things and that is really the big challenge* (Consultant BoDes).

> *In the BIM-meeting it's only me who has the control of the model and the comments related to it* (ICT coordinator firm ScanInf).

Another role that changed was the more traditional roles present in most construction design teams. For example in BoStu the senior structural engineer and senior architects presented the ideas, concepts and structures, but were not the persons responsible for making the 3D designs in the

digital models. This role was taken over by a more junior person. However, this impacted the communication in the team, as well as expectations of team members concerning particular roles. One example mentioned was:

> *It has been difficult for some of the senior ones in the project. I am only there to draw (in 3D) and if there are questions or changes, I am not taking part of that; however, this is difficult for people to understand. They can receive the technical, structural solutions - but not from me (*but from the senior structural engineer). *However, they will not receive the 3D digital drawing solutions from our structural engineer, but those they will receive from me. This has been difficult in the team, that this role has been split in two* (3D-drawing structural engineer, BoStu).

The findings from the interviews and cases confirm literature that discusses the development of new roles when the new ICT of building information modeling is implemented in the construction industry (Gu & London, 2010; Jaradat et a., 2013; Sebastian, 2010), in which not only the ICT coordinator role is new, but also a role concerning document control becomes important. Although the new ICT has been around for some years, it is only recently that more and more design teams are working with this technology and therefore it is relevant to look at the process of how this process unfolds in projects and project-based firms.

Change process

In the construction industry it is clear that this change process consists of a set of alternating cycles as suggested by Volkoff et al., (2007), in which routines and material aspects align, interact, constrain, and lead to new interactions between the material and the ostensive routines. When following Volkoff et al., (2007) the process of technology-mediated change in construction design can be structured in the structural conditional phase, the interaction phase, and structural reproduction. During structural conditioning, the new ICT was designed by third parties and implemented in project-based firms. The implementation of the new ICT impacted the work in design projects as well and contractor firms (or clients) require from their project partners to work with a similar ICT tool in order to create joint benefits during the design projects. The use of the new ICT impacts the performance of practice and routines. According to Volkoff et al., (2007) this is done through social interaction. Through the use of the new ICT both ostensive and performative routines interacted (see as well Feldman & Pentland, 2003; Pentland & Feldman, 2005) and changed in terms of a new procedure to draw drawings, changes in accountability, and changes in roles and responsibilities were found. During this interaction cycle some of the interviewees and case study members, especially structural engineers and architects, noticed that the new ICT constraints their way of working to some extent. During the structural elaboration cycle it was clear that the case study members had different ways of dealing with the changes of working with new ICT.

Leonardi (2011) found that when technology is perceived as a constraint, people tend to change the technology; while when technology is perceived as beneficial, people change their routines. However, in this study the perception on the technology is not the only factor for changing either technology or routine, the power of the actors in the project network played another role. Especially in a project-based firm in which different organizations work together in a project, it became clear that the different organization partners also reflected and behaved differently upon the use of the new ICT. All three cases were contractor-led design projects, and the contractor firms, sometimes had the possibility to make some adjustments to the ICT in order to create a more beneficial use in their organization. Furthermore, they had the opportunity to demand the use of this technology of the smaller players in their project. However, the smaller firms had less power to influence the technology. Many of the smaller players involved in the design teams felt constraint and several

parties performed their work double in both the traditional and the new approach (e.g., producing traditional 2D drawings as well as additional 3D drawings), while others reproduced their traditional way of working. Especially in projects with multiple organizations cooperating, the technology mediated change cycles were rather different per project partner, which had an impact on the whole of the design project team. The technology-mediated change is impacted by the different organizational routines of the firms participating in the construction design projects and future work needs to be performed in order to understand how change processes unfolds in project-based firms and inter-organizational projects.

Concluding, this study contributes with empirical examples of the how new ICT changes routines and roles in temporary project organizations and in particularly in construction design projects in which multiple organizations are cooperating to jointly develop a design. The study is limited to one industry and in particularly contractor-led design projects, however, indicates future research in particularly on the impact of new ICT on inter-organizational projects and their individual organizational as well as project routines.

Tables

Table 1: Data collection

Case study	Interviews	Observations
BoStu	6 Interviews	15h. (three work days of 5 h. each)
BoDes	6 Interviews	6 h. observations (one work-day)
ScanInf	6 Interviews	6 h. observations (three meetings of 2 hours)
Total	18 Interviews	27 hours of observation

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