Associating Knowledge-in-Use with Technology-in-Use While Comparing Building Information Modeling (BIM) in Finland and in Quebec

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Abstract

Building Information Modeling (known as BIM) implementation has been pushed by various initiatives in Finland, Norway, USA and many other countries. Each country has its own vision towards its implementation. In this article, the BIM implementation has been discussed in Quebec, in comparison with Finland. A theoretical understanding of technological use, as technology-in-use, has been adopted to conduct this study, from the multi-dimensional way. The main problems of the constructions industry were described as rooted in the long-established work-practice and traditional managerial approaches in this specific industry. Further more, a concept of knowledge-of-use has been emphasized by actors' users of BIM, considering the technology as one thing, and knowledge acquisition in using technology in order to incorporate the use as another thing. In addition, managerial implications are discussed.

Keywords: Building Information Modeling, Technology-in-use, knowledge acquisition

Introduction

Building Information Modeling (BIM) implementation has been pushed by various initiatives in the Finland, Norway, USA, Denmark, Singapore and Hong Kong. Each country has its individual vision of BIM implementation, history and approach for the push. However, there is still inertia in Quebec for the adoption of BIM where large proportion of projects are still delivered in a traditional way (Poirier et al. 2014; Tahrani et al. 2015). BIM is a collaborative way of working, underpinned by the digital technologies, which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product, asset data and a virtual 3D model that can be used for effective management of information throughout a project lifecycle – from earliest concept to operation #(Eastman et al. 2011)#.

In 2012, Quebec’s construction industry accounts for $ 51 billion of Quebec investments, 14% of Quebec's GDP and 234,000 direct jobs per month on average (Forgues et al. 2010). The adoption of BIM should result in significant productivity gains in the industry. However, Forgues et al. (2010) highlighted a growing gap in the mastery of BIM between Canada and the United States, which resulted in a significant loss of competitiveness between the industries in these countries. An in-depth understanding of the causes of Quebec’s delay would allow different players (construction industry, professional associations, regulators and customers) to identify the levers that could allow Quebec to better position themselves on the global scale. In order to evaluate the delay of Quebec industry, we consider the construction industry in Finland as our reference point since this industry is a world leader in the implementation of BIM.

This gap requires explanations and must lead to the identification of the underlying causes of this delay. As a unit of analysis, we choose actors (managers, architects, engineers, customers and representatives from government body) working in different areas of knowledge in construction industries of Finland and Quebec. Actors will help to reveal the mechanisms that are likely to explain the causes of this discrepancy. At present, most research is focused on technological aspects of BIM, such as data interoperability, management of information exchange and a development of new tools and technologies to expand BIM capabilities. Therefore, the organizational, procedural, social and contextual aspects of a construction project, which are central to the creation of an appropriate environment for a successful operation of BIM, have been largely neglected in the literature (Dossick and Neff, 2010; Jung and Joo, 2011). Few researchers stress that a successful BIM deployment and encouragement of innovation in the project networks, the integration of practical design, construction and organizational restructuring should happen in parallel with technological deployment (Harty, 2005 and Jung Joo, 2011; Taylor and Levitt, 2007). Literature shows that the construction industry is formed through project networks, consisting of differentiated social worlds that are built around practices (Taylor and Levitt, 2007), yet the knowledge on the subject is accumulating slowly (Niiniluoto, 1993). By examining the four knowledge spaces in both countries - explained later - and building on technology-in-use, our research will identify visible and/or invisible mechanisms, presumably of socio-contextual nature, and explain the delay in the implementation of BIM in Quebec compared to Finland. This way, it may also contribute to technology-oriented and system-oriented literature.

Research Objectives

BIM is an integrated and dynamic process supported by a digital platform, which allows for all involved actors in a project to visually share key physical and functional characteristics of a building before, during and after construction (Azhar et al, 2008; Azhar, S., 2011; Succar, 2009). According to Itami and Numagami (1992), a set of technologies, such as a digital platform, is primarily a systematized body of knowledge based on the principles of behavior of natural things and their interactions with artificial things. BIM is a logical system that combines a body of knowledge on building design and construct. As a logical system, BIM requires new knowledge and sharing spaces (Nonaka and Toyama, 2003). When implemented in knowledge spaces, BIM imposes high complexity associated with managing a virtual 3D mock-up design, which requires the actors to represent their actions at higher levels of abstraction and apply formalisms and standards that may question the performance of traditional business practices. Quebec design and construction practices have mastered the established traditional management approach to projects and are very slow to adopt innovations. In contrast, Finland is one of the world's most advanced countries in the implementation of BIM. The question arises as why there is such a large gap between the deployment of BIM in Finland and Quebec and how can we propose a mechanism for implementation of BIM in Quebec. The current research project aims to answer the question on the Finland - Quebec difference in BIM implementation in the construction industries. Finland was chosen as country with small population, specifics of language and history, that can be associated with Quebec population, language and history.

This paper is trying to answer to the main research question as following: How to combine both conceptually and methodologically *technology-in-use* and *knowledge-in-use* approaches to better understand this phenomenon?

The originality of this study is to conduct a research based on knowledge-in-use and technology-in-use (Orlikowski 1992) concepts and approaches.

Relevance of the approach and the theoretical framework

Knowledge-in-use

In this research, BIM mock-up is considered as a cognitive artifact and BIM process as a cognitive system that is based on three levels described in cognitive sciences: representational level (knowledge), functional level (algorithms and functions) and material level (materiality of a BIM system). The three levels are interconnected in a recursive way.

The research aims to understand the interactions taking place - in Quebec and Finland - in four knowledge spaces, each exhibiting four main poles (Lillehagen et al, 2008). For Lillehagen et al. (2008) the poles within the community and institutions are: value, initiative, infrastructure and resources. At this level we can apply the concepts and theories of business ecosystems (Teece, 2007; Fransmann, 2010) to investigate who, i.e. actors, actors or institutions, takes initiatives in the industry, with what resources, and how to install infrastructure to generate a value. Preliminary research shows that, in Finland, public initiatives are key to BIM deployment.

The poles within the business strategy knowledge space are: service, project, organization and network platform. At this level, we apply the usual theoretical frameworks of positioning a strategy and the resources theory, adding what is known about digital strategies. This research will identify the actors that form the organizational network(s) able to carry out a construction project at this level.

The poles of the innovation knowledge space are: product, process, organization and system. At this level, activity theory allows to observe the nuances between business processes and business routines. Professional practices are in effect built around tools attached to each specialty. BIM could be seen as an integrated and multidimensional platform replacing series of construction management practices and artifacts. Our research for this level is based on activity theory (Engeström, 2000), situated action and situated cognition.

The poles of the individual work knowledge space are: information, task, view and role. The new BIM, which redefined individual knowledge space, questions the professional identity in the face of technological BIM artifact. This project therefore seeks to understand the role of the professional identity of the various stakeholders in a project that involves a group of inter-disciplinary workers.

Practices are considered to be complex and heterogeneous networks that consist of various actors and artifacts (Latour 2008). In order to facilitate our more sophisticated activity of building construction, we are creating and using cognitive artifacts that are more knowledge-laden, smart and autonomous. Knowledge and related concepts, such as expertise and intelligence, increasingly define our activity in the knowledge-based society. In order to conceptualize and understand the nature of work and activity in this society, one has to learn to understand the various types of knowledge and how they are used and made to grow (Paavola & Hakkarainen, 2005).

Within those knowledge spaces, we focus on knowledge-in-use because BIM requires actors to use or utilize knowledge to create real new built environments (Figure 1). This knowledge-in-use is a synthesis effort logically of abduction/effectuation nature.

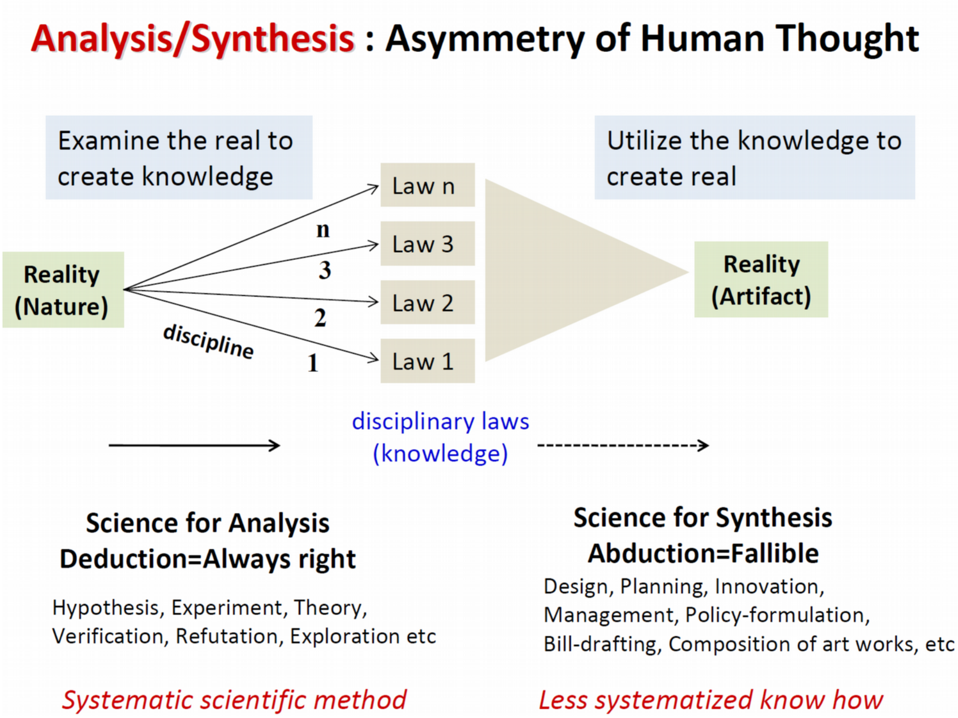

Figure 1. Analysis/Synthesis: Asymmetry of Human Thought Sustainability Science, Hiroyuki Yoshikawa, AIST, ICSS2009, Feb. 6, 2009, University of Tokyo, PAGE 19.

In fact, Sarasvathy (2008) defines effectuation as the logic of entrepreneurial expertise: “By logic, I mean an internally consistent set of ideas that forms a clear basis for action upon the world. A causal logic is based on the premise: To the extent we can predict the future, we can control it. An effectual logic is based on the premise: To the extent we can control the future, we do not need to predict it.” For Sarasvathy (2008), effectuators see the world as open, still in-the-making (p.17). That kind of effectual logic is discussed in innovation literature under the abduction label and connected to leadership in innovation, what BIM is really about.

Those reflections on leadership and innovation should be connected to knowledge exploration and exploitation at organizational scale. This innovation logic is at work into “Dynamic fractal organizations” that build and utilize a triad relationship of knowledge that integrates and synthesizes tacit and explicit knowledge and creates a third type of knowledge, phronesis (Nonaka and al., 2014; Berg & Rosenthal, 2012). For Kinsella and Pitman (2012) phronesis - defined as practical wisdom - is missing in our organizations. There is a practical disjuncture between the knowledge required for practice (i.e. knowledge about BIM) and professional schools’ current conceptions of what constitutes legitimate knowledge (i.e. architecture and engineering schools).

Technology-in-use

The prescribed use of technology by the designers of technology is not always followed when the technology is deployed in an organization. Usually, the technology development and technology usage are accomplished in different organizations; and hence, different perceptions of technology usage are constructed (Orlikowski 1992). In other words, while the technology permits a range of possible uses, it is the technology-in-use that determines its value; and that value is significantly influenced by the set of activities that intervene in the way people interpret and interact with the technology #(Orlikowski 1995)#. At the same time, we can consider that the implementation of configurable technologies, such as BIM, is strongly influenced by users' understanding of their own requirements and the properties, and the functionalities of the technology (Orlikowski 1992). Thus, the actual use of the technology is also influenced by people's knowledge, experience from previous projects and external factors such as market needs.

In this research, we investigate the process of implementation of BIM via technology-in-use and technology-in-practice lens. Technology-in-use was introduced widely by the work of Wanda Orlikowski, especially from her article of 1992 (Orlikowski 1992), in which she theorized the duality of technology, inspired by the ideas of Anthony Giddens (Giddens 1987b, Giddens 1979, Giddens 1984) and his Structuration Theory. By duality of technology, Orlikowski means that technology is a product of human action while it also considers structural properties. Moreover, by the duality of technology, she considers that technology is physically constructed by actors (who are knowledgeable and reflexive) working in a given social context. It is socially constructed by actors through the different meanings they attach to it and the various features they emphasize and use. She also considers that agency and structure are not independent, and it is the on-going action of human agents in the use of a technology that objectifies and institutionalizes it. In that and subsequent studies such as Orlikowski (1995), she proposes that there are two aspects to be analysed in a technology use: the scope of a technology and the role of a technology. Scope of a technology is referred to hardware part of the technology, while the role of technology is a philosophical opposition of foreseeing technology as a social object, where it is seen as a product with shared interpretations and interventions. In the same vein, she considers that technology is understood as a social object, which means that it is defined by its context of use.

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As technology is used within a given context, the users are structuring the use of the technology. The structuring of technologies-in-use refers to the process through which users manipulate their technologies to accomplish work and the way in which such actions draw on and are reproduced in the particular context of their work (Orlikowski 1995, Barley 1986). The process of structuring technology-in-use, as described by Orlikowski (1995), is an interaction between technology as an artefact and its actual use, which influences and also constructs and re-constructs the institutional properties of the organization.

After theorizing on the duality of technology (Orlikowski 1992), Orlikowski expands her earlier work and presents a practical lens through which it is possible to examine how people interact with structures of technology use. Users' interactions with technology are thus recursive: in their recurrent practices, users shape the technology structure that in turn shapes their use (Orlikowski 2000). Technology structure is not external or independent of human agency, but exists in the form of a set of rules and behaviours and the ability to deploy the structures (Walsham 2002) that emerge from people's interactions with the technology at hand – technology-in-practice (Orlikowski 2000, Pozzebon 2003). Orlikowski (2000) considers technology-in-practice to be sets of rules and resources that are constructed and reconstructed in people's on-going and situated engagement with particular technologies. These engagements from her point of view are specific interactional structures that are routinely enacted as the users work with a specific technology, technique, appliance, device or gadget in particular ways in their everyday situated activities. She also believes that users decide to use a technology; and in doing so, they are also choosing how to interact with that technology. Thus, users may deliberately or inadvertently enact different rules and resources from those anticipated by the developers. This phenomenon suggests that technology-in-practice could be different from place to place and from one context to another. According to Barley and Orlikowski (Barley 1988, Orlikowski 2000, Barley 1986), on-going enactment of a technology-in-practice tends to reinforce or re-structure (transformation) the social system. Reinforcement means that the actors enact essentially on the same structures with no noticeable changes, whereas transformation means that the actors enact on changed structures, with changes ranging from incremental to substantial modes (Orlikowski 2000).

According to Corradi et al. (2010) viewing the use of technology as a process of enactment enables a deeper understanding of the constitutive role of social practices in the on-going use and change of technologies in the workplace.

Methodology

The methodological approach builds on a logic of process (Langley 1999,2009), where the researchers are involved in a process of finding the answers to the posed questions on the study of BIM development and its use in the four knowledge spaces in Finland and Quebec, both as a reality and as social construct. Qualitative research suits in-depth investigation of research phenomena that is social and contextual (Patton 2002). On the other hand, quantitative approaches are generally used as means of understanding objective phenomena (this could include variable, factors, and hypothesis) (Crotty 1998). Main issue of research is to understand technology implementation and its consequences. It is requiring rich description and multiple perspectives. Qualitative research thus presents advantages in human science research. One of the main aspects of qualitative research that have been articulated by many authors is its contextual nature. High ranking scholars such as (Patton 2002; Yin 2009) have emphasized the importance of context in these types of research. Furthermore, qualitative research was appropriate for this research as there was a need for a holistic understanding of participants' experiences in complex matters of usage of technology.

The methodology includes three major steps:

1. Creation of conceptual and theoretical framework related to the happened events in four knowledge spaces in design and construction industries of Finland and Quebec.

2. Exploration of 24 in-depth semi-structured interviews of BIM experts involved at four knowledge spaces.

3. Confirmation of findings.

The first phase: Exploratory phase: included the discussions with collaborators, experts in social science and BIM deployment, study of historical context. This phase has helped to frame the research questions, articulate interview questions and future steps. The study of history of BIM development in Finland through a very detailed timeline has provided a ground for the bringing together the pieces of BIM development puzzle and involved actors. This has helped to select interviewees.

The second phase included a conduct of 28 interviews: 20 interviews were conducted in Finland and 8 in Quebec until now at four knowledge spaces. The process of interviewing the first person has brought new names. Interviewees were recommending BIM pioneers in the field. More interviews were conducted, more people were referred for the interviews by interviewees (snowball effect selection). Although twenty interviews in Finland have been conducted, it is clear that more people can be added to the list. With such long history of constellation of networks, joint efforts and intensive collaboration, potentially more people will be interviewed as the research will continue to bring insights and needs for information. Currently, the list of interviewees consist of BIM managers, BIM coordinators, top management from construction, architectural offices, software developers, research scientists, largest owner and representative from governmental funding agency. The interview questions were based on the long semi-structured interview approach by (McCracken 1988). The interview guide contained the following key thematic:

1. History of the general use of ICT in the construction business ecosystem and the emergence of BIM;

2. Barriers, benefits and challenges of BIM as experienced by the informant to the occupied level;

3. Proposition of mechanisms able to accelerate the implementation of BIM in the industry.

During the interview, the researcher maintained a contact with the interviewee by spontaneous and planned prompts. Scheduled prompts were classified as contrasts, categories, memories of incidents and planned stimuli (McCracken 1988). Planned stimuli were composed out of historical events of BIM development where the fragmented pieces of projects, documents and actors were listed. During the interview, the researcher also provided all the necessary explanations on the progression of the themes of the interview and reasons for her questions. The topics discussed were evolving according to the experience and expertise of the interviewee. However, from the beginning it was clear that additional questions should be added such as how the interviewee felt the change from hand drawings to CAD technologies and from CAD to BIM, or how business model was changing over the years, what were the drivers in BIM development. Once the interviews in Finland were completed, interviews in Quebec have started based on findings from the Finnish experience. It was very important to let experts to share their memories, talk about experiences in projects and concerns that were evolving over the years.

Process of analysis

Discourse analysis was adopted for data analysis. Language is the chief modality for observations concerning linguistic behavior and interpretation, an understanding of language was taken into consideration for the analysis (Fairclough 1999, Alvesson and Karreman 2000).

In order to examine our findings, research process presented by Langley (2009) was taken into action. In this vein, the implementation of BIM was studied over the course of time. This historical process, enabled to trace back and find the historical issues related to the construction industry, which is important in the core of our study.

It is important to have gathered the information in routine ways and by creating an agenda of the daily works that. This enabled to gather a more in-depth inventory of files, audio interview files, photographs and documents and be ready to begin the process of analysis. Interviews are fully transcribed and process of analysis has been started using NVivo software for qualitative data analysis.

Results

The problems of construction industry were described by many scholars as they are rooted in the long-established work-practices and traditional managerial approach that slow the adoption of innovations. Although, the industry has undergone two technological changes from hand drawings to CAD and from CAD to BIM, the productivity has not improved yet at large scale. The initial preliminary results from the first phase of the study on existing literature, and discussions with experts in BIM and social science have showed that there is a need for better understanding of BIM definition and underlying causes of slow adoption. Conduct of interviews in Finland has clearly showed a pattern in the perception of experts that the problems that they had a decade earlier are still present nowadays despite the maturity of design and construction industry. The major underlying causes of slow adoption are still misunderstood or not properly articulated even after such a long history of BIM development and pioneering in Finland. Interviewees were unsure to confidently articulate these underlying causes for slow adoption of BIM, but preliminary results show that the major component derived from the examples and explanations that interviewees have provided are in social and organisational structures of business context. In Finland, the knowledge towards BIM is way higher than in Quebec. In Quebec, according to the analysis, there is firm framework from the government neither from the industry on the adoption of BIM. On the other hand, the long history of BIM pioneering in Finland has been based on pure enthusiasm and passion for technologies. Effectuation was at work through visionary people while Finnish government was funding those actions motivating the industry actors toward more research and development. This has been in contrast with conservatism of established practices generating mental barriers among the strongest ones. Nowadays, Finnish design and construction industry is in mature state and they are moving to last phase of intensive integration of the whole construction supply chain, but there are still challenges associated with Facility management in BIM and visions that are yet to be realised. Figure 2, illustrated below, shows how visions of the industry were changing. Fragmentation of traditional practices that was envisioned to be changed once all the stakeholders would collaborate in one shared platform has never been realised and will not be in practice, instead multiple stakeholders use sub-systems that are coordinated and shared in certain circumstances and are supported by external communications.

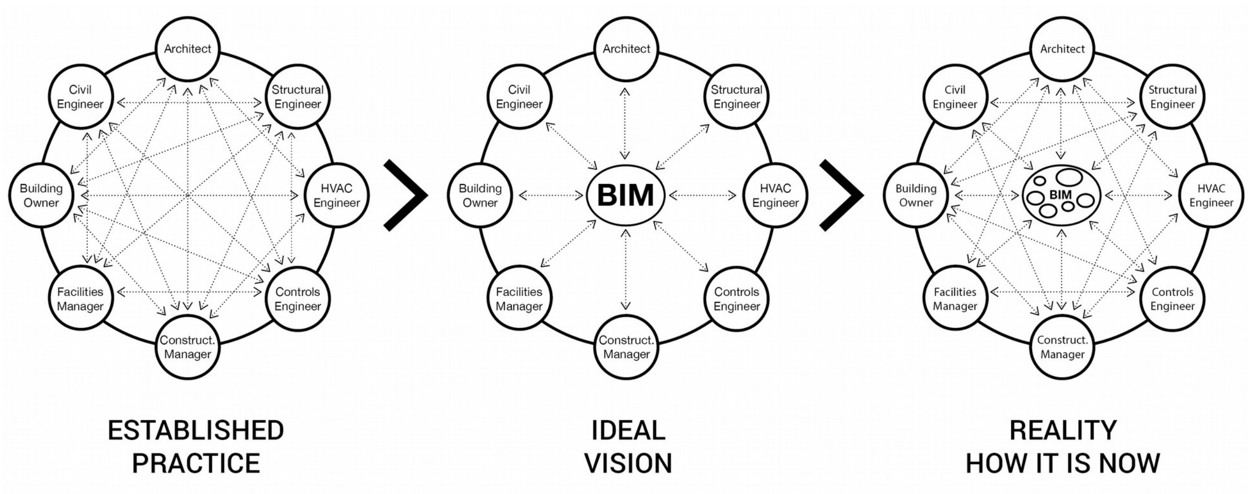

Fig 2. Aksenova, G. (2014) A Cultural-Historical Activity Theory Approach to Manage BIM-Driven Practices in AEC Industry, ETS, Montreal

Discussion

Context of use of technology is one of the main influential parts in reshaping and re-using technological practice. For example, one of the interviewees in Finland mentioned that:

> When we look at the value chain, what happens is that we have to think about cities: maybe here is the user, then here is the owner, then construction company, construction production and then we have BIM services like architects and engineers or what so ever… Different participants use these different services. And

> then you have somewhere BIM technology users somewhere here (FIN 12).

On the other hand, for example, one of the interviewees in Quebec, mentioned that:

> The BIM we are in the Quebec, we are trying to do it (and integrate the technology), but currently there is no running back, there is no leader in the implementation of the BIM in Quebec. There are leaders, but there is no leader, which is government or standardization, it is an aggregation of several stakeholders and BIM is like that. Everyone comes and puts what they know best to improve, but it still takes a running back (QC 11).

In additional, knowledge-of-use has been emphasized by actual users of BIM, and they consider technology as one thing, and knowledge acquisition in order to incorporate and use another thing. In this vein, the participation of various stakeholders (such as architects, building owners, engineers and etc.) in order to re-shape the use of BIM in every building construction project is highlighted. The focus of BIM is not only on the project-based organizations (building construction projects), but also on business model shared in the construction business ecosystems. Therefore, not only technology-in-use is reshaping the structure of every project, but also it is re-shaping the entire building construction ecosystem, with everyone that has different knowledge of technology. We propose knowledge-in-use and technology-in-practice perspectives to incorporate and re-shape the industrial ecosystem of building construction. For example, one of the interviewees suggests the following:

> It is a good question; the biggest difference is that before it was a focus on technology. Now we have to look at the business model. It should change the thinking model. /…/ But it is not anymore a technology, it is the question of innovation. You can create the whole diffusion of innovation as a commercialized idea. /…/. I always say that to do research (R), development (D) and innovation (I) work, you have to understand what are ‘those works’ because they are different from each other. The big thing for the top management is that these R D I are never the target. It is our tools. You have to differentiate targets and tools. If these are the tools, what are the targets? They said that the definition of innovation is to commercialize their idea (FIN 14).

On the other hand, in Quebec, there is no structure for BIM adoption. According to interviewees, the leadership should come from the government to require the implementation of BIM. On of the interviewees mentioned the following:

> If the government asks people to sit down together to find a solution, that will bring another way of doing things. BIM is a philosophy that brings technologies that require changes in practices that require different business relationships, it is difficult to change (QC 11).

Conclusion

Technology-in-practice lens enables deeper understanding of BIM implementation processes in both countries. By conducting qualitative research with means of semi-directive interviews, we have established a track of research, which is not much elaborated in design and construction industry. Once all data analysis is completed, we aim to propose a set of recommendations and needs to generate a change in the Quebec design and construction industry practices.

Several interviewees pointed to the educational problems (knowledge) as an underlying cause for slow adoption of innovations. Preliminary data suggests that the knowledge-in-use and knowledge-in-practice are the main drivers of technology adaptation in design and construction industries. The anticipated conclusion is that the business model is not yet changed in Finland and Quebec to fully embrace the potentials of BIM. Moreover, contractual forms are still based on established practices and how to integrate BIM into contractual relationships is still very unclear. BIM is not used as a service yet, but more as an aid in design process. The way people earn money did not change; change 0f orders during the construction process brings money to certain players in the construction process, therefore they are not willing to move to new processes. Therefore, there is a need for a deeper understanding of business models in design and construction ecosystem that should be supported by BIM use. This change might go beyond the business model towards a qualitative understanding of ecosystem's proponents of these industries with a long-term vision.

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