ADOPTION PROCESSES FOR EDM, EDI AND BIM IN THE SWEDISH CONSTRUCTION INDUSTRY

Olle Samuelson, olle.samuelson@tyrens.se
Tyréns AB , Sweden

ABSTRACT

Three strategically important uses of IT in the construction industry are the storage and management of project documents on webservers (EDM), the electronic handling of orders and invoices between companies (EDI) and the use of 3-D models including non-geometrical attributes for integrated design and construction (BIM). In a broad longitudinal survey study of IT use in the Swedish Construction Industry the extent of use of these techniques was measured in 1998, 2000 and 2007 (Samuelson, 2008). The results showed that EDM and EDI are currently already well-established techniques whereas BIM, although it promises the biggest potential benefits to the industry, only seems to be at the beginning of adoption. In a follow-up to the quantitative studies, the factors affecting the decisions to implement EDM, EDI and BIM as well as the actual adoption processes, were studied using semi-structured interviews with practitioners, in autumn 2009. The theoretical basis for the interview studies was informed by theoretical frameworks from IT-adoption theory (e.g Cooper and Zmud, 1990; Davis et. al., 1989; Gallivan, 2001) where in particular the UTAUT model (Venkatesh, et. al., 2003) has provided the main basis for the analyses presented here. The contribution of this paper is to use general IT adoption theory in the IT construction context to explain, and increase the understanding of, how different types of IT innovations can be implemented in the sector.

The results showed that the decisions to take the above technologies into use are made on three different levels: the individual level, the organisational level in the form of a company, and the organisational level in the form of a project. The different patterns in adoption can to some part be explained by where the decisions are mainly taken. EDM is driven from the organisation/project level, EDI mainly from the organisation/company level, and BIM is driven by individuals pioneering the technique.

Keywords: IT, innovations, construction, adoption, implementation, Sweden.

1 INTRODUCTION

In the same way as in other industries and in society in general, IT has had profound effects on the way the construction industry conducts its business. Already in the 1970s computers facilitated the technical calculations needed particularly in structural design. In the 1980s the PC arrived and made the production of written documents as well as previously tedious tasks like cost calculation and budgeting much easier. In parallel Computer-aided Design (CAD), first using dedicated workstations and later also on PCs, made the production of drawings much easier. The 1990s saw the advent of the Internet, which has facilitated the access to documents in projects, electronic ordering etc. The proliferation of mobile phones has also been of tremendous help to this industry where much of the work is done on site. The first decade of the 21st Century has seen few new basic tools emerge, but rather the maturing use of many of the technologies mentioned above, for example the changes in processes that have started as a result of increased BIM use and ongoing discussions of virtual construction, as well as an ever-increasing integration of computers, mobile devices and networks.

This paper focuses on three particular IT innovations: *Electronic Document Management* (EDM), *Electronic Data Interchange* (EDI) and *Building Information Modeling* (BIM). In the following text the acronyms will be used to denote these.

The chosen innovations all build on communication and information exchange between actors in the sector. The information exchange is also characterised by many-to-many relationships, since the actors (companies) tend to cooperate in new constellations, which change from project to project (Slaughter 1998). This also means that there is a need for standards for information exchange, for instance concerning methods for document storage in EDM, formats and contents for data fields in EDI or object definitions in BIM. The productivity and quality benefits of a wide-spread implementation of these innovations for the whole sector have also been envisaged as high (Thomas 1999).

The three technologies differ in some essential ways, which is one of the aspects to be studied. The differences concern in particular the complexity of the information handled, where the management of document meta-data in EDM must be regarded as the simplest. The standardised messages which are used in EDI are more complex since the degree of standardisation must be so specific that all the data needed from the price of a product to the confirmation that it has been delivered and paid for, can be handled, including a number of special cases which might be needed in a step-by-step process. BIM has been described by Eastman (2008) as containing all information about the product and the process throughout the whole life-cycle of a built object. The definitions, hierarchies and relationships, which are needed for a stringent management of such information, are on totally different level of complexity compared to the other two areas.

The purpose of the paper is to increase the understanding of the adoption processes of IT in the construction and real estate sector, focusing on the three areas EDM, EDI and BIM. The goal is, with the background of the authors' previous studies, and existing innovation theory, to describe factors that influence the decisions of these innovations on different levels.

2 RESEARCH METHOD

2.2 Method

The project IT-barometer (Samuelson, 2008) which aimed to measure the development of IT use in the sector in a longitudinal perspective, has been the background for the study. This study was conducted in autumn 2009 and forms a continuation of the IT-barometer project. The aim of the study was to gain an understanding of the three focus areas EDM, EDI and BIM, and here the basis included general IT adoption theory which is briefly described in sector 2.2. In the interview study the focus was on the decision and implementation processes for the three focus areas EDM, EDI and BIM. This paper focus on the decision process which are described as adoption. The implementation process is further described in Samuelson (2010).

A criterion for inclusion in the study was consequently that the company in question had reported implementation within at least one of the focus areas. The choice of companies was made based on the responses to the 2007 IT-barometer survey and the aim was to include companies from all of the five categories: architects, technical consultants, property managers, contractors and material manufacturers/suppliers. Of the companies who fulfilled the requirements, eleven companies were chosen in total, with one interview per company, see table 1 below. It was also valuable to include companies, which were not implementing all three technologies, so that also the arguments of non-adopters could be studied. The “Yes” and “No” in table 1 specifies if the company has implemented the technology or not. The focus area for each interview is indicated with bold text and grey background.

Table 1: Distribution of respondents in the interview study.

Category	Number of employees (company group)	The respondent’s roll in the company	BIM	EDM	EDI
Architect 1	20-199	BIM Program coordinator	**Yes**	No	No
Architect 2	≥ 200	IT manager	No	**Yes**	No
Technical consultant 1	≥ 200	Regional Development manager, project Manager BIM	**Yes**	Yes	No
Technical consultant 2	≥ 200	Vice IT manager, responsible of CAD development	Yes	**Yes**	No
Property manager 1	≥ 200	Vice president, responsible of project- and property development	No	**Yes**	No
Property manager. 2	20-199	IT Project manager	No	Yes	**Yes**
Contractor 1	≥ 200	Project manager	Yes	Yes	**Yes**

Contractor 2	≥ 200	Logistics manager	No	**Yes**	Yes
Contractor 3	≥ 200	Project manager BIM	**Yes**		
Materials Manufacturer /supplier 1	20-199	Head of design department	**Yes**	Yes	No
Materials Manufacturer /supplier 2	≥ 200	Logistics manager	No	Yes	**Yes**

The process for the case study was divided into three parts: Preparation, Performance and Analysis-Synthesis. The preparation phase included problem definition, scope, interview form and scheduling. Semi-structured interviews were chosen as the interview form as it allows a wider discussion, together with a structured approach, which is needed to hold together the interviews around the defined areas and the selected theoretical frameworks. An interview plan was developed based on the three focus areas and the groups of factors described in the UTAUT model in figure 2.

In the performance phase the interviews were carried out, covering 1 - 1.5 h per interview. The interview plan consisted of two main parts in which open questions were asked, partly regarding the factors that influence the decision, partly regarding the implementation process and which parts of the process the company had reached for each focus area. The interviews were documented by recording the whole interview and by complementing notes. The phase ended with transcription of the interviews where some comments were submitted, which could be relevant to the analysis.

The final phase Analysis-Synthesis consisted of data reduction, where the data were sorted out and categorized; Pattern matching (Yin 2009) where data were matched towards the selected theoretical framework; and finally the formulation of conclusions and critical review of these. In practice, the analyses consisted of interpreting the answers and statements, in their context, in the interview material; and then break out and encode them in a table, based on the concept in the theoretical framework. The synthesis has then been performed by studying the coded data, finding the patterns which can be interpreted and summarize the patterns in a table. A summary of the found pattern is reported in Table 2.

2.3 Theory

Most of the research on IT in Construction, has dealt with different aspects of new ways of using IT to improve parts of the construction process or the process as a whole. Important topics covered have included technical aspects as well as standardisation, organisational and process changes and their effects. There have however been few studies of the mechanisms that affect how these innovations are implemented and spread in the construction sector. There is a lack of research that has used existing theories in diffusion of innovations and IT adoption to study IT innovations in construction. Since theories and models about diffusion and implementation of IT are central to this study, the models that have been used are described and discussed briefly in this chapter.

The contribution of this paper is to use general IT adoption theory in the IT construction context to explain, and increase the understanding of, how different types of IT innovations can be implemented in the sector. However, there is no existing model in innovation theory that can explain all the aspects of the topic, including the different levels of implementation that will be discussed further in the paper. Instead, a number of existing models are combined with the purpose to explain the whole picture. According to Cooper and Zmud (1990) the research in IT adoption can be divided in three categories: Factors research (static factors leading to successful implementation); Process research (dynamic factors leading to successful implementation) and Political research (differences in interests between the involved stakeholders). These three categories has been discussed and used in the theoretical framework for the study. This paper will focus mainly on the factors research and political research. The category process research is further described in Samuelson (2010).

2.3.1 Levels for decision – political research

To decide to take into use and apply an innovation is made by individuals. The individuals who make the decisions can however act on different levels and with differing levels of influence over other individuals and systems. In this research these levels have been split into three groups:

- Individuals
- Organisations

- Inter-organisational systems

This classification emerged during and as a result of an earlier interview study in the project (Samuelson 2010). The individual level refers to the lowest level, where individuals in their professional roles, decide to use or not use an IT innovation, primarily for their own benefit. The organisational level typically concerns a company, but can be another form of hierarchical organisation with a clear decision procedure, such as a project. The highest level is called inter-organisational system, i.e. a network of several organisations that need to interact, but without a clear decision procedure. One example is different types of industry collaboration, designed to find common approaches for common benefits. Another example is the supply chain in an industry, i.e. dependences between multiple companies in a chain of business. A construction project can be said to belong also to this category because it consists of individuals from different companies with different business processes, IT platforms and cultures. The project is thus both an organisation per se, but also influenced by the inter-organisational system that the individual companies belongs to.The three groups describe the social systems where the innovation is spread and where decisions can be made by an individual or several individuals about the adoption of a particular innovation within the system in question.

Rogers (2003) suggests that there are three types of innovation decisions: *Voluntary decisions*, where the individual himself decides to implement or not; *Collective decisions* which are formed by some sort of consensus within a given social system and where all members of the system are expected to follow the decision; and *Authority decisions*, where somebody is in a position to make a decision which several others belonging to a system have to obey. These are closely related to the three levels discussed above and can usually be found in the combinations: individuals – voluntary decisions, organisations – authority decisions and inter-organisational systems – collective decision. This is, however, a strong simplification of reality and there are several variations where aspects of voluntary choices, authority and consensus can be found.

The different variants that can occur in an organisation, where both the organisation and the individuals in the organisation has to make a decision, is by Gallivan (2001) described in the four field model shown in figure 1.

		Does the organization adopt the Innovation?	
		Yes	**No**
Do employees in the organization adopt the innovation?	**Yes**	Authority-based innovation adoption	Bottom-Up adoption
	No	Adoption but no deployment	Non-adoption

Figure 1 Combinations of individual and organisational decisions for adoption, (Gallivan 2001).

2.3.2 Levels for decision – Factors research

The research on how innovations are adopted and spread is a research area in which the attitudes and behaviour of potential adopters are studied. Rogers (2003) must be regarded as the leading researcher in what is called Innovation Diffusion Theory (IDT). Other important contributors have included Ajzen (1991), Taylor and Todd (1995) as well as Davis et al (1998).

A number of models describing factors influencing the use and spread of IT-innovations have been reported in the literature. Tornatzky and Klein (1982) review 75 articles that describe in all 30 different variables influencing the use and spread of IT-innovations, and comment that the number of these variables is continuously increasing and that the variables keep changing names. Instead of developing further models, Venkatesh et.al. (2003) have made a thorough analysis in comparing eight different models and synthesizing an integrated model from these, firstly by making the different concepts and categories used coherent, and secondly by validating the resulting model empirically.

The model, which is called UTAUT – Unified Theory of Acceptance and Use of Technology, is described in figure 2. In summary the three first main groups of factors influence the intention to use a system. The resulting intention together with the fourth main group of factors, Facilitating Condition, influences the real use. Venkatesh et. al. (2003) also proposes four moderating factors, which indirectly influence the factors in the main groups. In this study, the authors have chosen to remove the two moderating factors age and sex. These are purely demographic, non-avoidable factors. If this kind of factors should be included, there are many others as well, such as education, social class, cultural background, etc.

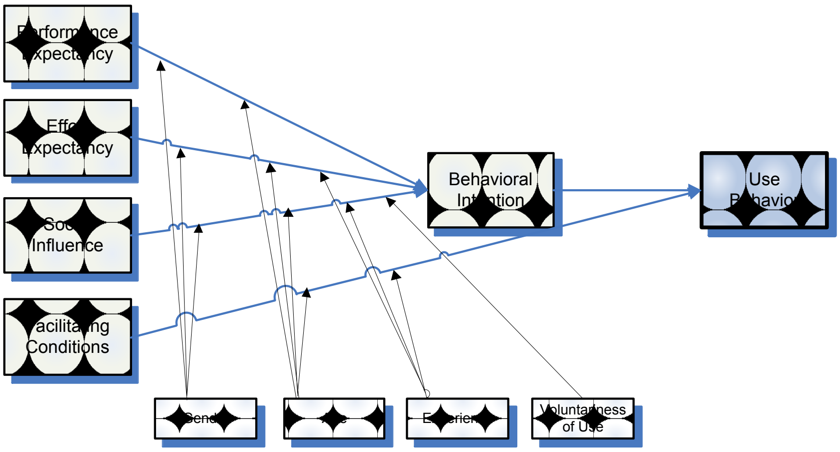

Figure 2 The Unified Theory of Acceptance and Use of Technology, UTAUT, model (Venkatesh et. al. 2003).

The UTAUT model above (Venkatesh et.al. 2003) is focused on the individual level. However, since also organisations consist of individuals making decisions based on for them relevant factors, the model can also be said to have some relevance in organisations but on different levels in parallel and with different possible outcomes. In general terms all the factors of the model are relevant both for a decision maker on the highest level and the individual who is expected to take into use the innovation, although the variables can have different effects and even conflicting results between the levels. An innovation which supports the company's processes and which improves its profitability need not be perceived as supporting by the individuals who have to apply it. Likewise an innovation which is positively experienced on the individual level can be of limited benefit for the organisation if for instance the "Facilitating Conditions" are missing or the "Effort Expectancy" on the level of the organisation is too big.

3 RESULT AND DISCUSSION

3.1 EDM

The case companies shared the same view of EDM implementation in projects. All agree that the decisions to use this technology are taken in the individual projects. The consultants say that the clients' requirements are a driving force, and in those companies that act as client organisations the wishes of the individual project leaders are what matters most. Sometimes there are pre-existing agreements with software providers, which internally or externally push towards using a certain EDM-system, but usually there are no explicit requirements on the company level, and hence the decision to use EDM is made in the projects. It is also clear from the interviews that the benefits accrue in the projects.

There are some indications that the individual project participants do not have such great personal benefits of EDM, although the contrary is also claimed. However, everybody realizes the benefit for the project as a whole, and that structure is needed in information sharing and communication. Many of the companies see conflicts between internally stored documents and project-EDM, which supports the conclusion that the individual company does not get benefits from project specific EDM in its business processes.

3.2 EDI

EDI investments are decided by the individual companies, in some cases with a certain amount of pressure from a client, regarding faster implementation. None of the interviewed experts have, however, quoted client pressure as a main reason for their own investment. Instead all the companies who use EDI have done their own analysis in which the benefits/savings have been bigger than the costs. In EDI, there is more dependence on the investments of other companies than in EDM, where there are hardly any economic or technical thresholds for starting to use the technology. Despite this the investment decisions of others has not significantly influenced the decisions of the case companies. Nevertheless, the company experts regard the actions of others as important in order for the technology to spread further. Of the three focus areas EDI is the one in which it is easiest to carry out cost-benefit analyses and to clearly see the advantages for the individual company in terms of more efficient processes and of lower transaction costs. Of the interviewed companies, the contractors are the ones who have utilised EDI most, and where EDI also seems to affect the actual processes in the projects.

The business models of the big contractors include major material flows in which good control over procurement, deliveries and prices is a key determinant of the achieved profit rate. The benefit definitely arises in projects, but it is on the company level that the decisions are made and where the big revenues also occur. An individual project can claim that it optimizes its profit using conventional methods, but it is through big volumes, long term agreements and standardized procedures that the profit is optimised on the company level. For this reason the technology adoption decisions of the contractors have a higher degree of authority decision than among the other companies. It is clear from the interviews that for EDI the decisions are made and that the benefits occur on the company level.

3.3 BIM

As indicated earlier BIM is the area which is hardest to describe in a simple way; partly because BIM as a concept is broad, partly because the concept has different meanings for different actors. This is also reflected in the analysis of the interviews where several pictures emerge. There are nevertheless some common denominators. Among both architects and technical consultants, as well as in the case of one of the material producers, the first initiatives have come bottom-up and have emerged based on a clear benefit for the individual in his professional role. After that the companies have formed different types of decisions, higher up in the management hierarchy, to develop BIM further, either through concrete projects or via policy statements.

Among the interviewed contractors and the building client organisation, this is not as clear. It should be noted that the client organisation included in the cases had not implemented BIM, but had started to work with the issue. One of the contractors showed a similar reasoning as the consultants, in that there had been earlier work in different parts of the company to coordinate information, and these efforts had now been assembled by top management under the umbrella of the BIM concept. Otherwise the interviews seem to indicate that BIM efforts to a larger extent are initiated top-down among contractors and clients, than among consultants.

Authority decisions concerning BIM are not discernible on the company level. Among consultants the development is characterized by long term intentions to broaden the usage and to encourage individuals to change their way of working. Among contractors and building clients the development is done in pilot projects and with focused efforts. There are some requirements on BIM use in projects, but these are perceived as unclear by the consultants. This fuzziness could be due to insufficient knowledge about the technology and to uncertainty about which concrete benefits could be achieved. Likewise there is critique going in the other direction, that there is a lack of model based templates and that BIM models are difficult to produce despite client requirements. Thus it seems not uncommon that consultants produce their own models for each phase and fail to reuse the information available in the existing format.

3.4 Summary

Table 2 summarizes the influencing variables which have become visible during the interviews and sorts them under the four headings in the UTAUT model. Variables listed under "Performance Expectancy" are supporting or encouraging factors for decisions to adopt or implement, and those under "Effort Expectancy" are inhibiting factors and imply some form of effort for the implementation. "Facilitating Conditions" and "Social Influence" are either supporting or inhibiting to implementation, which has been indicated for each factor in the table, both in text, and with a plus (+) for supporting or a minus (-) for inhibiting.
Since the factors may cause different effects on the various implementation levels as discussed earlier, this has been noted for each factor for individual and organisation level respectively. The organisation level may apply to either a company or a project. N/A indicates that the factor does not affect the level. In some cases, there are combinations in which various organisations or individuals may experience the factor in different ways. An example of this is the Performance Expectancy factor for BIM "More efficient information flow throughout the process as a whole", which is supporting for the client organisation, but in practice, N/A for the individual companies in the process.

Table 2: The impact of different variables on the adoption and implementation of EDM, EDI and BIM.

	Performance Expectancy		Effort Expectancy		Facilitating Conditions		Social Influence	
EDM	Quality assurance of information		Double handling, internal and external		Technical infrastructure – supporting		Individual aversion – inhibiting	
	Ind. **+**	Org. **+**	Ind. **-**	Org. **N/A**	Ind. **+**	Org. **+**	Ind. **-**	Org. **-**
	Better order in handling information		High threshold for use in small projects.		Different structures of information – inhibiting		Cultural attitudes that supports structures – supporting	
	Ind. **+**	Org. **+**	Ind. **N/A**	Org. **-**	Ind. **-**	Org. **-**	Ind. **+**	Org. **+**
	Common and safe accessibility of information.		Rules for information structures are too inflexible		Skills and user experience – mostly supporting.		Different views on the structures between actors – inhibiting.	
	Ind. **+**	Org. **+**	Ind. **-**	Org. **-**	Ind. **+**	Org. **+**	Ind. **-**	Org. **-**
	Improved communications.							
	Ind. **+**	Org. **+**						
EDI	Improved invoice process.		Other actors' dedication (suppliers and customers).		Time and resources to pursue the matter – inhibiting.		Slow approach to change in parts of the sector – inhibiting.	
	Ind. **+**	Org. **+**	Ind. **N/A**	Org. **-**	Ind. **-**	Org. **-**	Ind. **N/A**	Org. **-**
	Lower transaction costs.		Initial effort in technology and process.		Easy to calculate return on investment – supporting.			
	Ind. **N/A**	Org. **+**	Ind. **-**	Org. **-**	Ind. **N/A**	Org. **+**		
	Improved reporting and decision support.				Standards exists, they are however not uniform. – mostly supporting.			
	Ind. **N/A**	Org. **+**			Ind. **-**	Org. **+**		
	Long-term contracts and contract loyalty							
	Ind. **-**	Org. **+**						
BIM	More efficient information flow within the sub-processes.		Other actor's commitment.		Compatibility between programs, user of standards for transmission– inhibiting.		Individual inertia to change ways of working – inhibiting.	
	Ind. **+**	Org. **+**	Ind. **-**	Org. **-**	Ind. **-**	Org. **-**	Ind. **-/+**	Org. **-**
	More efficient		Need for change in		Knowledge exists –		Image around BIM –	

	information flow throughout the process as a whole.		approach, processes and responsibilities.		supportive. Inhibiting where it is missing.		supporting.	
	Ind. **N/A**	Org. **+/N/A**	Ind. **-**	Org. **-**	Ind. **+**	Org. **+**	Ind. **+**	Org. **+**
			Requires greater effort in early stages.		Technical infrastructure – supporting.		Different and fragmented views on and definition of BIM – inhibiting.	
			Ind. **N/A**	Org. **-**	Ind. **N/A**	Org. **-**	Ind. **-**	Org. **-**
					Time and resources - supporting if they are appointed.		Missing consensus on the view of processes – inhibiting.	
					Ind. **+**	Org. **+**	Ind. **-**	Org. **-**
					Processes – economically supportive for process as a whole. Redistribution of work needed – inhibiting.		Sector culture, optmi-zed at individual/com-pany level, no process owners - inhibiting.	
					Ind. **+**	Org. **+**	Ind. **-/+**	Org. **-**

The conclusions about on which level the initial decision and then the implementation takes place, can be discussed with figure 1 as a basis. Each technology starts with its initial decision in different fields in the figure and is then moving when the assimilation process takes place. The figure includes the individual and the organisational level, where the organisation consists of either of the company or the project as stated earlier. The management of the project organisation decides on the use of EDM and the project workers follow this decision, which is an authority decision. EDM is therefore directly placed in the upper left field in figure 1.
The company management decides on the use of EDI and the adoption process starts with building the technical and work flow infrastructures. In the early initiation and adoption phase, EDI is consequently placed in the lower left field where the organisation (company) has decided, but not yet the employees or the business partners. The implementation then takes place in succession via consensus or authority decisions in client- or subcontractor relationships, and via authority decisions internally in the company and in the projects. It could thus be said that the decision moves from the lower left field to the upper left in figure 1.
The use of BIM is initially mainly decided on by individuals with a high level of knowledge via pilot projects and initiatives of their own, i.e. it starts in the upper right field in figure 1. The project and company management, which realise the potential benefits, further pursue the matter but with a low degree of authority. BIM implementation therefore initially takes place “bottom-up” and then moves towards the upper left field, towards decisions on the organisational levels.
Another conclusion to be drawn from the result above concerns the project as a level for decision. As stated earlier in the text, the project can be regarded as an organisation, but also as an inter-organisational system. This is made even clearer when studying the focus areas above. The project works as an organisation in the EDM case, with well-defined decision paths and hierarchies, where the project management are able to make demands on the participant, as long as the demands are not in conflict with the IT-platforms, processes and culture in the companies of the participants. For BIM on the other hand, the project becomes an inter-organisational system. A single project or its management cannot decide that the hired companies shall use a specific IT-platform for creating and using model based information, if the platform doesn´t exist in the companies. To decide to use these platforms are long-term strategic decisions for each company and demands both investments in licenses and in education and training for the employees. Instead, the project is dependent of the overall development in the sector regarding IT tools, but can require the use of them if they exist among the companies. For these kinds of innovations, the project will become part of the inter-organisational social system that handles the cooperation between companies in the sector.

4 FINAL COMMENTS

The data collection for this study was made in Sweden, which is also reflected in the title of the paper. There are, however, reasons to believe that most of the conclusions can be generalized to other countries, since the construction industry stakeholders and the organisation of construction projects are quite similar in different countries. External factors such as government laws, regulations, industry maturity etc. which can be different, would not be likely to affect the main factors considered in this study. Nevertheless, this has to be investigated, and can be subject for further research. A statistical validation of the UTAUT-model in the context of IT innovations in construction would also be an interesting topic for further research. Besides the fact that the data collection exclusively was made in Sweden, the research is limited of a relatively low number of interviews. Within the studied focus areas, especially in BIM, the development and implementation is changing rapidly at present. The nature of this research, which in some sense is to shoot at a moving target, is therefore also a certain limitation.

ACKNOWLEDGMENTS

This article is based on earlier unpublished parts of the Ph.D. thesis of Olle Samuelson, which was successfully defended at the Hanken School of Economics in September 2010 [24]. Bo-Christer Björk acted as supervisor of the thesis and contributed to this article. The valuable comments of Mikael Laakso are acknowledged. The study would not have been possible to carry out without the financial support of the Sven Tyréns foundation.

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