Diffusing BIM – knowledge integration mechanisms and their effects

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Abstract

Building Information Modelling (BIM) has for a number of years been seen as a systemic inter-organizational innovation that will have great impact on the efficiency of the construction process as a whole. In this study both successful and unsuccessful attempts to diffuse a BIM-service in the construction sector by a building material manufacturer has been studied through multiple data collection methods. Of special interest has been in what ways knowledge has been integrated, i.e. what mechanisms has been used in the case, since it is a key area for diffusion, and this is described and discussed. Furthermore, the contextual characteristics of the construction sector have been highlighted as influential on diffusion, especially when it comes to areas such as learning, flow of knowledge and feedback loops. Therefore, the context of the different cases and in what ways this affects the knowledge integration process is also described and discussed.

Keywords: Building Information Modelling, Diffusion, Systemic Innovations, Knowledge Integration Mechanisms

BIM, Building Information Modelling or Management has in many ways been seen as an innovation that will result in drastic changes for the construction process at large (see for instance (Succar, 2009, Elmualim and Gilder, 2013). Eastman et al. (2011) describes BIM as the change of moving from paper-based modes of communication, i e using drawings on paper through the construction process to a process based on using electronic information and tools. This change has taken place and been developed through the use of ICT with web-pages, 3D CAD tools etc, avoiding some of the problems connected to the traditional process. The implementation and diffusion of BIM also generates a number of difficulties (see for instance (Succar et al., 2012). This can in many ways, among others, be related to the general problems related to diffusion of inter-organizational innovations, also called systemic innovations. Systemic innovations are holistic and relational to their nature (Colvin et al., 2014), require change of processes in a coordinated fashion by multiple firms (Taylor and Levitt, 2005, Taylor and Levitt, 2007) and cover multiple relationships (Powell, 1998). Systemic innovations can be a number of innovations that together perform new functions, the relationship in-between the innovations are explicit, but most often there will be effects on other components or systems as well (Slaughter, 1998). Manufacturers and suppliers who are unaware of the changes required to implement their innovations, either in the links to other components, processes, or systems or in the product itself are likely to meet resistance in the spread of their products (Slaughter, 2000).

ICT development focus has for long, maybe too long, been on technical issues, and not on the diffusion perspective (Peansupap and Walker, 2006). BIM is in its nature inter-organizational with its focus on managing information throughout the construction process, and for construction, diffusing inter-organizational innovations poses many challenges. The characteristics of construction can be described by: the physical nature of the products and the structure of sector, the production of single/unique structures, the different types of clients (Briscoe, 1988), the importance of maintenance (Manser, 1994), iterant process, and the derived nature of demand (Bon, 1998). Production in construction is project-based and encompasses a large number of actors from different industrial sectors (Salter and Torbett, 2003).

Attempts at systemic innovation may prove to be problematic. Taylor (2006) has highlighted a number of constructs that influence diffusion of systemic innovations. These relate to the magnitude of the innovation and the level of change it has on affected parties and processes; the amount of "new" involved actors in each project, I e the *organizational variety*; the *interdependence between tasks*; *the boundary strength* or rigidity between trades; *span*, I e the number of affected professions and finally the alignment of the innovation with the work allocation in the network. A key issue related to these constructs it that they influence the ability for inter-organizational knowledge to flow. Knowledge creation and exchange is a key issue in the innovation process and its inherent diffusion (OECD, 2005). According to Rundquist et al. (2013) an ineffective flow of knowledge and limited knowledge integration constitutes a barrier for innovation. An additional complicating factor for construction is that in construction projects different types of professionals come together to work for a limited time; architects, engineers, project managers, craftsmen etc. These professionals have different knowledge types that needs to be managed through knowledge integration, i e combining new and previous knowledge (Wijnhoven, 1999, Rundquist, 2012). Knowledge integration can be done through different

types of mechanisms that depend on different amounts of social interaction (Van De Ven et al., 1976, Grant, 1996). Due to these factors, choosing the most efficient mechanisms is central and following this, *the aim of this research is to investigate what mechanisms has been used in one case when diffusing BIM, since it is a key area for diffusion, and this is described and discussed. Furthermore, the context of different cases is described and its effects on knowledge integration are discussed.*

1. Knowledge integration, mechanisms and knowledge types

Knowledge is at the centre of the research presented in this paper. Knowledge is viewed as information, technology, skills and know-how in line with Grant (1996), with a view on objective information as codified knowledge (Grant, 1996, Nonaka and Takeuchi, 1995). Codified knowledge is of special importance since it facilitates the transfer of knowledge (Prencipe and Tell, 2001). Finding ways to use codified knowledge for knowledge management is of interest for construction (Styhre and Gluch, 2010), although construction research has shown that construction is hesitant to codify and formalise knowledge (Styhre, 2008, Bresnen et al., 2005, Scarbrough et al., 2004). Senaratne and Sexton (2008) mean that codification could increase, but an important factor is that it should be done in balance with soft personalization strategies.

In research on knowledge management in general many different sub-concepts are used, and construction is no exception. Examples in construction are knowledge management (Robinson et al., 2004), sharing of knowledge (Styhre and Gluch, 2010, Styhre, 2008), and knowledge sharing and creation (Bresnen et al., 2005). In a comprehensive review on the concept of knowledge integration and concepts with similarities, Rundquist (2009) treats the concepts knowledge transfer, knowledge sharing and knowledge application. A main point in the review is that knowledge integration is a broader concept that covers the other concepts. This view is shared in this research. In Rundquist (2012), knowledge integration is defined as a process of combining new and previous knowledge. A similar definition is made by Wijnhoven (1999) saying that knowledge integration refers to the process of acquiring, sharing, and making use of knowledge by incorporating new knowledge into an existing knowledge base. Although both authors mean the same thing, Wijnhoven (1999) is a bit more explicit and forms a basis for this paper.

An objective for mechanisms is to integrate knowledge as efficiently as possible and mechanisms can be classified on a scale ranging from low interaction to high interaction. According to Johnson (1992) technological change requires more social interaction like dialogue and conversation and the more advanced innovations, scientifically and technically, the more complicated communication processes are required. Another implicating factor according to Van De Ven et al. (1976) is insecurity, i e difficulty and variability in the conducted work also affects what mechanism to use. This means that it is not just the level per se that sets affects what mechanism to use, but also how the work is perceived is influential. More insecurity requires more personal mechanisms. Another useful way of classifying mechanisms used in

construction research relates to explicit and tacit knowledge, and a division of mechanisms into tools and techniques. Tools rely on the use of IT to share explicit knowledge. Techniques use a more human-centered approach to transferring mainly tacit knowledge (Carrillo et al., 2006, Carrillo, 2004).

Our main focus here is to have the level of interaction as a point of departure. We use four types of mechanisms defined by Grant (1996) as a point of departure that range from a scale of low to high interaction for integration of specialized knowledge; *Rules and directives* are un-personal methods such as plans, schedules, forecasts, rules, policies and communication systems; *Sequencing* treats organizing production activities in sequence to enable every specialist to do what he or she should; *Routines* are performed automatically and can be conducted simultaneously when the person conducting them are well acquainted with them and sees them as natural activities that we do without giving them much thought. The first three can be seen as a way of avoiding costs for learning and communication, and the last mechanism *Group problem solving and decision making* is as the title shows a mechanism with communication and interaction. The need for this mechanism increases with the growing complexity and insecurity in the activities that should be conducted as stated by Grant (1996).

2. Method

The study presented in this research focuses on a reinforcement company, the construction process of which the company is a part and their development and diffusion of BIM and BIM-related solutions and services. The study consists of data collection in two steps. The first step of data collection was initially used to map the situation of the case company through a broad approach focusing on the development of the company and its context. The initial mapping focused on content (what has changed), process (how has it changed), why has it changed (context) which is an important interplay for understanding changes (see (Pettigrew and Whipp, 1991, Carlsson, 2000). The collection of data in step one lasted for about 6 months and comprised analysis of company documents, websites and 24 semi-structured interviews with company (internal) and external respondents. The semi-structured interviews provides a structure for meaningful interviews and discussions but also flexibility (Andersen, 1994, Merriam, 1994). The questions addressed the business situation of the company, including its development, objectives and challenges. The character and context of the construction industry, its development and IT related issues were also included. Development aspects are considered interesting from a diffusion point of view since they provide a picture of what ideas, solutions, products and services that are spread (diffused) and not. The interviews lasted from 30 minutes to two hours and were recorded. After the interview the whole interview was listened through and transcribed, although not transcribed in detail. Time-positions was written into the transcripts if sections of the recording were needed to listen to again. The material was summarized in a company report and the extraction has been done from this material and the transcripts, with a focus on the purpose of this paper and *on BIM as the change of moving from paper-based modes of communication, i e using drawings on paper through the construction process to a process based on using electronic information and tools.* The broad collection of data provided useful understanding for the findings.

Based on the extraction of data a new round of semi-structured interviews was conducted with four company internal actors; the technical manager, a sales representative working towards manufacturers of prefabricated elements, one team leader for the BIM/reinforcement engineers and one BIM/reinforcement engineer. These actors are working with diffusion related activities and the new round enabled an update of the situation from the first round and questions regarding the purpose for this paper were raised. The highlighted definition above was communicated in the interviews and the additional questions this time regarded what type of BIM and BIM-related solutions and services that has been diffused, to whom, why and under what circumstances. The compilation of data from the first round served as a support material and also enabled specific questions about the development of specific services. Company information about BIM and BIM-related solutions and services was also overviewed. The time between the two steps of empirical collection was afterwards considered useful to provide a view on development is progressing. The material was overviewed, summarized and analyzed a number of times to find themes and categories that relate to the aim of the study. This was made from the collected data and the section *Results from and analysis of the study* show the final compilation of the collected data.

3. Results from and analysis of the study

The case study company is an international supplier of reinforcement and the Swedish affiliation was studied. The Swedish company has undergone development in line with the steel industry at large, with closures, mergers driven by a focus on economies of scale. This has led to increased competitive pressure not least from low cost countries. Due to the development and the extremely low development potential in the material, reinforcement, the company has put a lot of efforts on developing complementary services to strengthen the company´s competitive position. Among these are electronic solutions or solutions that build on such. The company has worked extensively with 3D-models with included information and 3D-visualisation, and on managing transfer of information back and forth from different systems. By using company solutions, information can be transferred between different systems and much can be automatized, for instance electronically generated specifications lists, visual planning is enabled, print-outs from different views and documentation. The company has introduced a new software in which reinforcement is specified, and it has many add-ons enabling electronic transfer between systems especially with the CAD-software. The company had a predecessor to the software, with many users, and by stopping development of that software, they have forced users in to the new version. Other services that are offered are assembly instructions and a service called color sorting and labelling. In short, this means that reinforcement comes sorted and labelled for simplified assembly. A result from the company´s development is that the company has created their own niche as a technically competent player with BIM and BIM-related solutions and services affecting customer's processes and approaches.

3.1 Contextual factors

In the study it is evident that contextual factors affect the diffusion of BIM and knowledge integration regarding BIM, which are presented in the following text.

Project stress, short term view and a divided chain: Especially in the first round of interviews these factors were highlighted as affecting development and diffusion in general and thereby also BIM. An effect was that actors use the same solutions as they always, for instance to reduce insecurity and risks. By moving from one project to another without a proper evaluation and use of experiences this is not facilitating diffusion of new solutions such as BIM. It was also stated that different parts of the chain work with their part, not interacting to the extent needed. Subcontractors, like the case company often also come in to late in the RFP-process eliminating room for improvement and possibilities to come up with ideas and solutions.

Organizational width and rules: For starters a key issue is that individuals and organizations need to see benefits with the solutions and has an overall process focus. In the study, actors in the end of the construction chain were not considered pushing development further to a large extent. One approach enabling diffusion was that some of the large construction companies have decided that some projects should be defined as BIM-projects. This is of course of help for diffusion. A highlighted barrier from the external interviews was also that development needs investment that in turn needs to be paid, which many small companies cannot afford, so much development must be driven by larger companies. Since BIM spans many actors, organizations and process steps, the interviewed actors in step 2 all mean that organizations covering many steps of the chain and has a broad business are highlighted as most interesting and also pushes development forward in a way that others don´t. It might be that by working with BIM, activities in the chain are moved and changed. There might be additional work for one part of the chain but with a benefit for the overall efficiency. A possible explanation highlighted is that they can see overall effects of different solutions. However, it was also highlighted that rules within the companies, which can be rigid in larger companies, could be a barrier for implementation, for instance when installing software, support is needed from an IT-department and there could be rules regarding what software that is allowed to install. One mentioned example was also that turnkey contractors have other possibilities to develop solutions from their overall perspective and can be of great importance to move development forward. Another slight point was also that commitment and push from top management was evident in the more forward moving companies.

Personal characteristics and maturity: One of the key factors highlighted in the study is the impact of "IT-ability" among people as having impact on the diffusion of BIM. Many interviewees also thought that construction was lagging behind other sectors when it comes to IT-usage, especially interviewees with experience from other sectors. One of the external companies also had a clear strategy of NOT being first in the development of ICT-solutions, but instead implement solutions when it is clearly shown that they work. Overall, an opinion was that IT-usage should improve as the amount of young people increase, since they are more used to using ICT in their everyday life. Cloud-services, integrated services etc are common in much social media that is used today. The main factor that was enabling diffusion was however individual characteristics. People who are interested and use ICT-solutions enable diffusion.

Implementation in real projects and ease to implement: One of the key factors for diffusion highlighted in the study is to present and implement solutions in real projects. When showing

the solutions in real projects, the company has been able to immediately use the solutions and show their immediate effects. An additional key factor has of course also been that the solutions are easily learnt and installed and not requiring too much additional efforts. The coloring services for instance, although not having to do with BIM, was considered easy to implement since they required no additional efforts by customers. 3D-visualisation as a discussion tool was for instance greatly helped by an adobe-application in which 3D-objects could be opened and rotated. It was also highlighted in both rounds that knowledge about IT-implementation has improvement potential especially in the area of supporting IT-implementation on construction sites, for instance to accomplish knowledge integration between developers and operative personnel in understanding user needs and prerequisites and to educate on site. An additional point is also that when the company got external users in their solutions, this created an interest for the company´s other solutions.

Product type, usage and usefulness: Since a main part in BIM is 3D-models, this was specifically discussed and also led to highlighting other factors. It was concluded that 3D-models/visualization was useful to create an understanding for what a product or a specific object looked like, how it could be handled, and what problems that could arise and enabled lowered differences in interpreting the product. However, it was also stated as important not to overuse visualization since they were most useful for complicated objects. In the first round it was also evident that interviewees thought that it was most important to focus on increasing effectivity in relation to everyday operations, instead of having focus on the more visionary aspects. As the technical manager pointed out, everything is expected to go fast and simple.

3.2 Used mechanisms and their effects

The contextual factors presented above are important for the used mechanisms to become successful. Diffusion has been done through various types of mechanisms from high to low interaction with varying results, such as information letters, brochures, sales presentations, information meetings etc. The diffusion of the services has internally been considered moving slow, but the interest for the solutions has increased heavily. The company has presented solutions at various occasions. At first they were seeking interest from customers to implement the solutions and a first modest strategy was to get the solutions “out”. The company used a push-strategy to diffuse solutions in real projects with consideration to the contextual factors presented (these factors are also results from failed implementation and diffusion). Implementing the solutions in real projects has been done in several ways. Often instructions were sent out to users and a YouTube video has been used as a mechanism. Often when the company has made follow-up calls they have referred to this video and new users have been able to start up solutions by themselves. Company representatives have also been present at start-up meetings having time to help new users set up their solutions and they have also provided support for users not just by answering questions, but also by being pro-active and making follow-up to get users going. An indication from this is that more interaction intensive mechanisms are needed at the start but then users work easily by themselves.

One of the regional managers also stated the importance of being present and show oneself physically at the customers. This is important to create trust and it is also a method that sells products and services. This emphasizes construction as sector with face to face contact. An example of the usefulness of being present and work in projects is that the company has visited projects with 3D-visualizations of real project objects. By using this push strategy, people in projects have been "forced" to work with the solution and many have also stated that they really could see the benefits. Anyhow, according to the interviewees, customers seldom ask for 3D-models and the demand was actually stated as larger in-house for complicated, welded products, since the 3D-models visualized what the product should look like (which of course is a benefit to the customer since the product is correct). An important part as stated by the technical manager is also that when the company launches new solutions, it is important for them to educate and create a demand for the services. This in itself highlights the need for more interaction intensive mechanisms for starters and when the need is established, other mechanisms can be used.

3.3 Summary of findings

To summarize the findings, the study shows that there are a number of contextual factors that influence diffusion and the knowledge integration that is needed for diffusion of BIM and BIM-related services and solutions. Thereby, the contextual factors also influence the choice of knowledge integration mechanisms. More interaction mechanisms are most likely needed in the start of a diffusion process and a key determinant for the choice of mechanism(s) is the knowledge base of the target groups.

4. Discussion

Speaking in metaphors, BIM can in many ways be the same as changing language. This metaphor is useful to create an understanding of the sometimes large magnitude of change that the entrance of electronic solutions constitutes in relation the former use of printed drawings and other paper-based methods in construction. Once again it is evident that contextual factors of construction complicate diffusion. *Project stress, short term view and a divided chain* has been mentioned many times in previous research and it also becomes evident that these characteristics form a basis for the rest of the contextual factors. A point regarding the divided chain is that by not interacting, knowledge integration is efficient from the perspective of "getting the job done", but from a knowledge development perspective, potential new knowledge useful for the overall effectiveness of the chain is not being integrated.

For a systemic innovation like BIM, inter-organizational to its nature, diffusion in construction seems to require customers with control over several parts of the construction process. Both in the study and in previous research it has been shown that controlling the chain is of importance, either as having the overarching responsibility/control as emphasized here and in for instance Hjort et al. (2014) or by ownership of resources as highlighted in Taylor (2006). In the same manor, this can also be a barrier for diffusion, with actors having the prerequisites not using their power to implement and diffuse new ideas. What´s interesting in the case however, is that

a supplier has the possibility to push the development forward and affect customers also, by taking contextual characteristics into account. As noted in the case and by Taylor (2006), it can also be concluded that the amount of adaptation in the process affects diffusion.

Another interesting point in the study is that construction seems to have a lot of potential in developing their change management and implementation skills. A key topic seems to be to make different actors of the construction chain meet and thereby start a knowledge integration process. In a way, knowledge integration is efficiently managed by different parts working autonomously together as emphasized by Grant (1996), but for knowledge development to take place it is necessary to incorporate new knowledge into an existing knowledge base as in the definition used in this paper (see Wijnhoven (1999)). As the in the study, the reinforcement company seems to take their point of departure in the existing knowledge base and also seems to have accepted the current situation in construction. Based on the point that young people have another knowledge base regarding IT, a potential impact is that it will probably be easier to diffuse BIM in the coming years as there is a shift in active generations. The overall maturity regarding IT should therefore increase, but this is of course also dependent on solutions becoming easier to install and implement. Older generations have most likely created a habit on how to do things based on their experience and for many this is based in an era where IT was not as visible as today. Besides taking the knowledge base into account, the study also points out the need to solve day-to-day issues besides working with visionary aspects to start the change process. By solving "easy" problems, I e bringing forth solutions that solve problems with little or less effort from customers AND showing the potential in real projects, an interest for other solutions from the company becomes interesting.

When it comes to mechanisms the study does not contradict the preferred use of soft-personal modes in construction and the combination of mechanisms as pointed out by Senaratne and Sexton (2008) . If the existing knowledge base does not deviate to a significant amount in relation to the "new", personal contact can be said to be preferred in the start-up phase, but then codified knowledge can be used, i e more interaction intensive mechanisms starts the diffusion process and then codified knowledge can be used. Traditional codified knowledge, i e information in written form, seems also in this study less useful in construction. On the bright side, it is indicated that a useful mechanism to diffuse codified knowledge are instruction films (You Tube). This points out the potential of spreading codified knowledge using other mediums and in line with Senaratne and Sexton (2008) it advocates codification in balance with soft personalization strategies, i e highlights *combination of mechanisms* as useful. However, it´s not just about choosing the right mechanism to diffuse a solution, it´s also about having future adopters in focus, support these in the best way and make set-ups and systems simple.

It can be noted by the results that more interaction is needed along the chain with a more overarching focus which points in the same direction as pointed out by Taylor (2006) when comparing BIM implementation in Finland and USA. One of the key differences was differences in viewing the chain, where the US had a short term view and divided approach in the construction chain and Finland had a more long term view and a more cooperative process.

A conclusion was that BIM-implementation was more favorable in Finland due to a more integrative view on the construction process.

5. Conclusions

Based on previous research and this study it is evident that *Project stress, short term view and a divided chain* affects knowledge integration necessary to diffuse BIM and BIM-related solutions. Due to this and the decentralized work-model, it is of significance to create a demand from the projects to use BIM and BIM-related solutions. A push-strategy has been found useful as a phase one strategy in order to create a need for BIM-solutions and thereby creating a pull from the "market" i e the projects. The influence from the organizational width and its set up of rules is also visible, where an organization with a wider set-up of businesses along the construction chain is more likely to successfully implement BIM due to the ability to control the construction process. At the same time, the study shows that a small niche player also can affect the diffusion of BIM and its customers if contextual characteristics are taken into consideration in the implementation process.

With BIM and the transformation into an electronically managed information chain, different parts connect and become more dependent on each other. In addition, a key issue in the study is that adaptation to the existing knowledge base is of central importance for the diffusion of BIM. It is indicated that a major problem for the diffusion of BIM is the level of general knowledge about IT in construction. A higher knowledge level regarding IT seems to facilitate diffusion and as younger generations come into the sector the diffusion of BIM will most likely become smoother and faster. This is further enabled by the development of solutions that are easy to implement and understand. The study validates soft-personal modes as most useful and frequent in construction and validates the combination of different mechanisms as useful for efficient diffusion. The study furthermore indicates that new media can improve the diffusion of codified knowledge. Finally, an important aspect highlighted for the mechanisms is the necessity to introduce solutions in real projects, to show immediate advantages and discuss actual problems.

A final indication from the study is the need to develop change management and implementation knowledge to implement and diffuse solutions. Of interest for further studies is therefore to study approaches of implementation and change management in construction and evaluate what approaches that are specifically useful in construction research. Since the study also highlights that general knowledge regarding IT is of help for the diffusion of BIM, it can be of interest to study how knowledge in general or from other sectors can be used and implemented in the construction context and also what barriers that exist. In addition, the study has treated the aim in general and to validate the results further it could be interesting to go in more in detail in specific cases to get a picture of the diffusion from both inside the company and outside the company.

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