BIM as a project resource in a large-scale healthcare construction project – implications for project management

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Abstract

The construction sector has for a long time been considered as an unproductive and non-innovative sector (Egan, 1998). At the same time there are numerous scholars that emphasize that innovative activities are taking place within construction (Slaughter, 1998). Especially the use of ICT-tools have been discussed as one way of handling escalating inefficiency in construction projects (Boland et al., 2007). Within this development increased trust has been placed on the implementation of Building Information Modelling (BIM) (Bryde et al., 2013). BIM can be used to geometrically depict any building by connecting building objects to specific information such as size and materials etc. BIM interconnects information which can be used to facilitate the construction process along with the operation management of buildings. The increased interest in BIM has also revealed a difficulty in defining what it is and what the effects of using it are, for instance it has been referred to as a "tool" (Bryde et al., 2013), a "methodology" (Succar, 2009), a "technology" (Whyte, 2003), a "software" (Fox & Hietanen, 2007), and an "innovation" (Davies & Harty, 2013). With these definitions, it is evident that while BIM can be used for project management purposes, it appears a highly elusive technology with a variety of purposes and uses. The outcome of its use appears to lie in how it is being used and for what purposes. This is further complicated by the highly inter-organizational nature of construction which has resulted in an organizational fragmentation where involved actors have their own interest in the construction project. In turn, these special characteristics of the construction industry are regarded as providing special conditions for the implementation of new resources (Gann & Salter, 2000). Since BIM is used for improving the collaboration among project actors, we aim for an analysis of how the use of BIM as a project resource affects the interaction among the actors, and how this interaction affects which services that BIM can provide. Based on the industrial network approach we investigate BIM as a resource (cf. Håkansson & Waluszewski, 2002). More specifically we investigate how the use of BIM is formed as a project resource through interaction processes among project actors. Through a case study of a large healthcare construction project, this paper aims at better understanding BIM as a resource in managing complex projects.

Keywords: Construction industry; project; project management; resources; BIM

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Introduction

The construction sector has for a long time been considered as conservative, non-innovative and displaying a high degree of resistance towards change (Egan, 1998: Winch, 2003). Moreover, the sector has been accused of suffering from inefficiency with escalating costs and low productivity. At the same time there are numerous scholars that emphasize that innovative activities and changes are taking place within the industry (Slater, 1998; Miozzo & Dewick, 2004; Grann & Slater, 2000). Especially the development and use of ICT-tools have been discussed as one way of handling escalating inefficiency and costs in construction projects (McKinnley & Fischer, 1998; Boland et al., 2007, Bouchlaghem et al., 2005; Taxén & Lillienskӧld, 2008; Whyte, 2002; Whyte & Levitt, 2011). Within this development - to create better and a more cost-efficient construction process through the use of digital technology - increased trust have been placed on the implementation of Building Information Modelling (BIM) (Bryde et al., 2013). BIM can be used in geometrically describing any building by connecting building objects to specific information and characteristics such as size, color, costs, materials etc. By using BIM it is possible to interconnect information which then can be used to facilitate the construction process along with the operation management of the building.

The increased interest and use of BIM has also revealed a difficulty in defining what it actually is and what the effects of using it are. It has for instance been referred to as a "tool" (Volk et al. 2014; Bryde et al., 2013), a "methodology" (Succar., 2009), a "technology" (Whyte., 2003; Davies & Harty, 2013), a "software" (Bryde et al., 2013; Fox & Hietanen, 2007), and a "project innovation" (Davies & Harty, 2013). It is implemented with the aim of increased efficiency by facilitating the management of "accurate building information over the whole LC" (Volk et al., 2014: 110) and "improving collaboration between stakeholders, reducing the time needed for documentation of the project and, hence, producing beneficial project outcomes" (Bryde et al., 2013: 972). Sebastian (2011: 180) describe BIM as a "shared knowledge resource" which indicates that its use is complex and not controlled or determined by any one actor or user. BIM can be used to improve efficiency of the construction project by using BIM for a number of different purposes such as visualizations, clash control, cost control, purchasing and logistics along with time management (Bryde et al., 2013; Succar,2009). With the above definitions it is evident that while BIM can be used for project management purposes, it appears a highly elusive technology with a variety of purposes and uses. The outcome of its use appears to lie in how it is being used and for what purposes. This is further complicated by the highly inter-organizational nature of construction: the construction of a new building or road is dependent on a variety of stakeholders including contractors, material suppliers, sub-contractors, consultants, local communities, governmental authorities etc. The high degree of specialization of the different actors has resulted in an organizational fragmentation of the sector (eg. Grann & Salter, 2000) and the involved actors have their own interest in the construction project. This is described by Heravi et al (2015: 985) in the following way: "Many stakeholders, individuals and groups are involved in the provision and delivery of construction projects and each has their own role, requirements and objectives". In turn, these special characteristics of the construction industry are regarded as providing special conditions for the use and implementation of new resources in construction (Gann & Salter, 2000; Slaughter, 1998).

From the standpoint that BIM is used for efficiency purposes in terms of improving the collaboration among project stakeholder, we aim for an analysis of how the use of BIM as a project resource affects the interaction among the stakeholders, and in turn how this interaction affects which services that BIM can provide. The key issue is thus the interplay between BIM as a resource and the interaction between the stakeholders that use it. In performing this type of analysis we turn to a theoretical approach based on more than thirty years of empirical studies of interaction processes between firms and their engagement in technology development; the industrial network approach (INA) (e.g. Håkansson, 1982; Håkansson and Snehota,1995). These empirical studies have described the adaptation processes taking place between firms as they attempt to increase the efficiency of their operations, and it has been shown that through such processes firms can engage in learning, knowledge development and innovation (Waluszewski, 1989; Lundgren, 1994; Laage Hellman, 1997; Håkansson & Waluszewski, 2007; Håkansson & Waluszewski, 2002). Through interaction actors form social bonds, combine resources and link activities across the organizational boundaries of individual firms, which result in that any organization or company becomes a part of a network context of relationships (Håkansson & Snehota, 1995). Based on the basic assumptions of this approach we define BIM as a resource that gain particular services and value depending on which other resources it is combined with (Penrose, 1959; Håkansson & Waluszewski, 2002; Baraldi et al., 2012).

There are several studies that take into account the importance and role of stakeholders for the implementation of BIM, for instance Davies & Harty (2013) especially put forward the importance of informal relationships among construction staff on site as important when implementing BIM in a large healthcare project, while Bryde et al (2013) call for a more integrated design approach among stakeholders in order to use the potential of BIM to a larger extent in construction projects. Sebastian (2010) point out that the changing roles and power of main project stakeholders due to changing work processes when using BIM. Hence there are studies focusing on the importance of stakeholders in using BIM but no study explicitly investigates how the use of BIM is formed as a project resource through interaction processes between actors, their resources and activities - i.e. the use of BIM as both the result of and tool for interaction within a project network. Therefore, this paper aims at better understanding BIM as a resource in managing construction projects. More specifically, we define two related research questions:

How is BIM formed as a project resource through interaction processes in the project network of a large construction project?

Which services and value can BIM provide as a result of such interaction processes?

The paper is organized as follows. The following section presents the theoretical review by first discussing the importance of stakeholders in projects, continuing with change and innovation in inter-organizational projects and the discussion ends with proposing a model to investigating the embedding of a resource in a project network, the resource interaction model. Thereafter follows the method in which we argue for the choice of a unique large construction project constituting the case study and how we collected the data. We continue by presenting the case study followed by an analysis of the case. The paper ends with a discussion in which we present our conclusions including theoretical and empirical contribution along with managerial implications and limitations of the study.

Literature review

Complex projects and stakeholders

Several scholars in project management have emphasized the general dependence on stakeholders to achieve successful project outcomes (Youker, 1992; Söderlund, 2008; Kolltveit & Gronhaug, 2004; Yang, 2010; Newcombe, 2003; Brady & Davies, 2011). In managing the international project environment Youker (1992: 226) mentions the importance to: "try to establish power relationships which can help them [project managers] to 'manage' the key actors and factors on which successful implementation depends". Due to increasingly complex projects, the project environment becomes increasingly uncertain which affects the possibility to complete the project on time (Altonen, 2011). With the increased literature on stakeholder impact on project outcomes several scholars have emphasized the importance of information and communication among project stakeholders in order to achieve positive project outcomes (Olander & Landin, 2005: Olander, 2007; Cova & Salle, 2006). Heravi et al. (2005: 995) describe it as: "In addition, deciding on the most accurate methods to implement the processes [of determine participants] needs a perfect understating of the project and its specific features. Indeed when participants do not possess adequate and correct information, or are not expert enough, implementing such processes cannot be fully facilitated". Any project entails a variety of stakeholders, and thus a variety of project roles, it is important to increase the understanding about main stakeholders and their perspectives and expectations on the project (Yang, 2010). In the same vein Flyvbjerg et al. (2003) and Jha & Iyver (2006) emphasize the importance of engaging the project owner at an early start in the construction project, while Low Sui & Ke-Wai (1996) emphasize the establishment of a project team early on in the construction process in order to reach 'total quality' throughout the project.

Several scholars call for more studies on the relational aspect of projects by pursuing investigations of the project network of stakeholders (Boland et al. 2007; Ruuska et al. 2011). While there are studies that view projects as networks of relationships between several stakeholders with its own perception of the project (e.g. Crespin-Mazet & Gauhri, 1997; Pryke, 2006), project management scholars call for more studies of project networks and relationships among project stakeholders. Aaltonen & Sivonen (2009: 140) describe it as: "..it [project management literature] does not take into account the interaction within the project network of several organizations". In the same vein, Newcombe (2003) calls for more studies adopting a wider stakeholder perspective when investigating construction projects. While the main part of the studied construction projects are investigated from the perspective of the client, Newcombe (2003) calls for widening the scope to include the perspective of other project stakeholders due to the fact that different stakeholders have different "stakes" and power in a particular project. The complexity of handling a whole range of project stakeholders is put forward by Ruuska et al (2011: 648) as: "A large project can be viewed as a dynamic network of organizations that combines the resources, capabilities and knowledge of the participating actors to fulfill the needs of the owner…each actor is directed by its owner and often partially implicit objectives of expectations". Hence, Ruuska et al. (2011) emphasize the necessity of project stakeholders to be able to connect, exchange and combine their resources in order to complete a complex project task, while tensions between stakeholders can arise however due to different perceptions of the project.

Change and innovation in construction

In general, the construction industry is not regarded as very innovative and it is seen as suffering from low productivity (e.g. Egan, 1998). Two main reasons for this that have been pointed out is its project-based character (e.g. Winch, 2003) and the adversarial type of relationships between the different actors that seem to characterize the entire supply chain (e.g. Miozzo & Dewick, 2004; Bygballe et al., 2010). There thus appear to be direct linkages between organizing in projects, the type of interaction between the different project stakeholders, and how innovation can or cannot come about. The project-based character means that most of the activities related to construction are divided into separate and timebound projects: purchasing, marketing, production etc. For each project, a suitable project organization needs to be set up, and the common practice is that this is selected through tendering procedures in all parts of the supply chain (Bygballe et al. 2010). The disintegration of both activities and actors across separate projects has been identified as creating discontinuity and therefore resulting in barriers for learning and knowledge development (Miozzo & Dewick, 2004; Dubois and Gadde 2002). In the same vein, the construction industry has been referred to as a "loosely coupled network" in which intense interaction takes place within projects, so called "temporary networks", that has little relation to the more "permanent networks" of construction (Dubois and Gadde 2002). There is thus a disconnection between what is going on and learnt within projects and how this is transferred to other projects, to the permanent organizations and to the overall structure of the industry (Bygballe & Ingemansson, 2014). The problems of transferring knowledge and innovation from the single project to the wider organization and to other projects is recognized both within the project management literature (e.g. Hobday, 2000; Principe & Tell, 2001; Engwall & Jerbrandt, 2003; Scarbrough et al., 2004) and the construction literature (Gann & Salter, 2000; Miozzo & Dewick, 2004). Selecting partners on the basis of tendering procedures indicates that the project stakeholders have never worked together before, and there are indications of hierarchical type of relationships between contractors and subcontractors characterising the industry (Dainty et al., 2001). This is seen as part of the problem of achieving change such as learning and innovation over time.

However, due to this very same nature of projects, intense interaction between a unique set of actors that come together to complete a specific task (Lundin & Söderholm, 1995; Söderlund, 2004), projects are also seen as an arena for change. For instance, there are scholars that put forward the advantage of projects for innovation since it represents a flexible type of organization (Bresnan et al., 2013; Principe & Tell, 2001; Winch, 1998). Moreover, it is also brought forward how working intensely on a specific task within projects results in a high level of collective learning and problem-solving (Ayas & Zenuik 2001; Scarbrough et al., 2004). This means that in construction a large part of the innovative activities takes place within the borders of individual projects. However, due to their inter-organizational character, and in addition consisting of a set of different stakeholders with different perspectives and objectives, all new solutions need to be negotiated with one or more actors (Winch, 1998). The project-based and inter-organizational character of the construction industry thus creates both possibilities and constraints on introducing change such as new solutions or new ways of working. What appears clear is that this is highly related to the interaction among the project stakeholders. Therefore, in order to better understand how BIM is implemented as a new way of organizing and managing construction projects, we need to take into consideration the interaction processes among the project stakeholders and especially how resources among stakeholders are interconnected. For this purpose the next section deals with the Industrial Network Approach (INA) and resource interaction.

Industrial Network Approach and resource interaction

The Industrial Network Approach is a research stream with more than 30 years of empirical studies of business exchange in a business-to-business context (see Håkansson, Ford, Gadde, Snehota & Waluszewski, 2009). The basic notion underlying the INA approach is that any company or organization is dependent on other organizations to develop its business due to the fact that it is impossible to possess all the necessary resources within the boundaries of one company, hence the 'incompleteness' of single organizations results in the establishment of an inter-organizational network of actors with interconnected resources and activities (Håkansson & Snehota, 1995). The assumption is thus that access to other actors' resources and activities is fundamental for industrial development, this also means that any change, such as a new solution or an innovation, needs to be embedded into a network of others (Håkansson & Waluszewski, 2007; Håkansson & Snehota, 1995; Holmen, Pedersen & Torvatn 2005).

INA is inspired by the seminal work of Penrose (1959) along with Alchain & Demsetz's (1972) where the notion of resource heterogeneity and co-production is put in the fore. This suggests that the value of a resource is not given; instead it is dependent on what other resources it is combined with (Håkansson & Waluszewski, 2002; Håkansson & Snehota, 1995). An important consequence is that the services and value of a resource are not given; instead, its features are developed through interaction processes of actors mobilizing resources and combining them across the organizational borders of the individual firm (Håkansson, 1987). In these interaction processes of attempting to achieve increased efficiency in their operations, firm's adapt their resources as to create a better fit, which over time creates interdependencies across organizational boarders. The mobilization and combining of resources through interaction is thus the means through which existing resources can gain particular values and new resources and resource combinations is developed. Resource interaction is therefore seen as the basis for achieving change and innovation.

The model is divided into four classifications of resources; products, facilities, organizational units and organizational relationships. The first two are referred to as technical or physical in its character while the latter two are referred to as organizational. Products as resources can be goods or services such as components, raw materials, services etc., while facilities refer to equipment or tools used to produce particular products. Organizational units refer to a company, a division within a company, or an individual which develop skills, knowledge, experiences and routines etc. over time. Organizational relationships emerge when two or more organizational units interact and organizational units mobilize and develop products and facilities through interactive relationships. In viewing the organizational relationships as a resource in itself, Håkansson (1987) relies on the notion that relationships to other organizations constitute the main resource of individual organizations, without relationships 'incomplete' companies cannot connect, develop and combine resources across organizational boarders. The resource interaction model can be used both to classify resources and to reveal how resources interact. Resource interaction results in resource interfaces; the "contact points" of two or more resources in which the resources interact, adapt and change in relation to each other (Baraldi, 2003). The resource interface between two resources reveal how they relate to each other, and which services they are "allowed" to provide as a consequence.

By using the resource interaction model it is possible to investigate for instance how a new product is embedded in relation to other resources and what value and services it brings to the network of resources (products, facilities, organizational units and organizational relationships). It therefore appears as a suitable investigative approach in studying how BIM is formed, developed and embedded as a project resource through interaction with other resources brought into the project through the stakeholders, and to identify what value it brings to the focal construction project and main project stakeholders in the project network.

Method

In being able to capture how BIM is used as a resource in a construction project and how it is affected by and affects project stakeholders the authors selected a case study approach (Eisenhardt, 1989; Denzel & Lincoln, 2000) In understanding complex and dynamic interaction processes and relationships among stakeholders case studies are put forward as a suitable methodological approach (Dubois & Gadde, 2002b: Dubois & Arajo, 2007).

The study is part of a larger investigation of innovation in the Swedish construction industry initiated in 2012. The authors performed four in-depth case studies of four particular construction projects to identify and investigate innovations and how these came about. One of the in-depth studies was the investigation of the construction of the Skandion Clinic, a healthcare facility in Uppsala, Sweden. The Skandion Clinic is a unique and complex healthcare building with particular demands on the construction which resulted in several construction innovations taking place in the project. In the study BIM was identified and pointed out as one of several innovations visible in the project also the project was referred to as a BIM pilot project. Due to the importance of BIM as an innovation the authors decided to use the Skandion Clinic project as a suitable case for illustrating and investigating how BIM is used and formed in a large complex construction project.

The case study is mainly based on interviews, but the authors also did three on-site visits throughout the construction process. In total 20 face-to-face interviews were performed (see appendix 1). All respondents held managerial positions and represented a variety of main stakeholders in the project: the developer, the construction company, the radiation supplier, the user/tenant, the planning coordinator, the architect, the installation. The questions asked during the interviews were semi-structured (Hesse-Biber & Levay , 2011) and aimed at understanding the role of the stakeholders in the project and how the different stakeholders interacted with each other and what resources they combined and exchanged throughout the project.

The case study

In the following case study we will introduce the background of the project and its complexity. This is followed by a description of the main stakeholders of the project. Thereafter a narrative follows highlighting how BIM is used and formed as a resource in interaction with project stakeholders.

Introducing the Skandion Clinic project and its main stakeholders

The background of the Skandion Clinic originates from a national investigation concerning future cancer treatment in Sweden presented in 2002. The investigation highlighted the need for providing cancer treatment with proton therapy, a therapy form that causes less effects on surrounding tissue compared to traditional therapy. The investigation resulted in the decision to establish a new proton therapy clinic in Uppsala, the Skandion Clinic. The new clinic is the first clinic in Northern Europe to provide cancer treatment using proton therapy. The cost of the new clinic is estimated to around US$ 104 million; US$ 52 million for the construction of the clinic, while the remaining US$ 52 million constitutes the cost for the radiation equipment, the cyclotron.

The construction project was challenging for many reasons however foremost due to the function of the building - providing healthcare with proton technologies - a technology that that generates radioactivity. To create a ‘radiation safe building’ the walls and ceilings in the treatment area were made out of iron ore concrete of more than 4 meters in width, on top of this the cyclotron itself was a heavy piece of equipment of more than 500 tons. Hence one main challenge was to create a stable ground work (more than 750 poles were drilled down to bedrock). Within the thick walls large quantities of canalizations was necessary to supply the radiation equipment with electricity, cold water and gas sprinkler systems, however large quantities of canalizations increased the likelihood of splices in the concrete that could jeopardize the radiation safety. As the description of the project indicates the construction of Skandin Clinic was complex, uncertain and challenging. We can identify six main project stakeholders involved in the construction of the Skandion Clinic.

Kommunförbundet Avancerad Strålbehandling (KAS): is the main user/tenant of the new clinic. KAS is responsible in providing cancer treatment.

IBA: is the supplier of radiation equipment (the cyclotron).

Akademiska Hus (AH): the developer and the owner of the new clinic.

NCC Construction: (NCC): the construction company in charge of physically set up the new clinic.

Sweco: the technical consultant company appointed to coordinate the planning and design organization (i.e. specialized technical consultants and the architect).

Link Arkitektur: the architect firm responsible for developing the design of the new clinic along with coordinating the BIM-model.

BIM as a project resource and its embeddedness in the Skandion Clinic project

BIM and the importance of partnering

Akademiska Hus (AH) was appointed to set up and manage the new clinic and the company can be seen as the project owner. The company is the second largest a real estate developer in Sweden specialized in buildings for higher education such as auditoriums, lecture halls or laboratories. Hence AH have long experience from developing and handling construction projects but lacked experience from healthcare facilities. In being able to set up the new clinic AH signed a partnering agreement with NCC. The two parties had an established business relationship dating back 20 years, just prior to Skandion Clinic the two parties had worked closely in three large construction projects. The choice to engage in partnering is closely related to the use of BIM in the project. AH and NCC had both prior experiences from BIM but mainly used is a 3D tool for visualizations. The partnering agreement opened up for using BIM on a higher level. The Skandion Clinic project was decided to be a BIM-pilot project for AH with the aim to result in a written BIM-manual to be used for future AH projects. The project leader at AH describes the initiation of BIM in Skandion as: ”We took the step from 3D planning and design towards a BIM oriented work in a very structured way” with the aim to “…achieve increased quality, better quality and a better house, including better economy”.

In order to be able to use building information structurally AH and NCC needed to jointly develop a basic BIM instruction for Skandion. An internal BIM manual from NCC along with BIM information and documents of 2-3 other AH projects were used as a point of departure in developing an instruction. It was not enough to only use resources from AH and NCC, instead the two parties realized the need to include the architect and the planning coordinator in specifying a basic BIM instruction for Skandion. Luckily Link Arkitektur belonged to a large

Norwegian architectural firm with experiences from BIM-heavy healthcare projects along with experiences from a variety of BIM-tools. Due to Links BIM-experience the company was not only appointed as main architect but also as BIM-coordinator in the Skandion Clinic project. Moreover Sweco already had an established relationship with both AH and NCC and had also acted as a project coordinator on the three AH projects just prior to Skandion. The planning coordinator had attended training in BIM-tools such as Navisworks and Solibri, and had worked with these tools on prior projects. Through a number of BIM-meetings and a specific workshop AH, NCC, Link and Sweco scrutinized the collected BIM documents from prior experiences and projects in order to define a BIM instruction for Skandion. This way of jointly setting the frames of BIM in Skandion was reflected on by the main architect from Link as: “A lot of collaboration was between us and the partnering actors. Together we did an instruction from the beginning on what to use the models to and how to work with the models. So we did an instruction from the very beginning that we have followed”. The planning coordinator from Sweco comment on the benefits of the intense work with AH, NCC and Link as: “For my work it means that it will be a smooth coordination since we have reached consensus in what to achieve at an early stage. This is unique and something that we have not done before. Early on decide what to model and why”.

Deciding on BIM-tools and lack of user construction knowledge

It was decided that the design and planning of Skandion should be performed with BIM-tools. Since all planning of the project departs from the design provided by the architect, the early design model developed by the architect was the point of departure for the planning organization. AH has a special requirement that dRofus should be used as room functioning software, hence in order to be able to create an interface with dRofus the architect decided to use Solibri as main BIM tool. Solibri uses an open Industry Foundation Classes (IFC) -system with the ability to read and handle information regardless of which CAD-system used for modelling. This meant that the specialized technical consultants in planning could provide their information into the model while BIM-coordinator could update and synchronize the information from all consultant groups into one model. In being able to do the basic design work Link was dependent on that the user/tenant of the clinic would be able to provide necessary information in dRofus. This information was both general but also detailed information such as the number of sockets in each room and material on the walls and sizes of windows. Normally in construction projects users/tenants have their own organization with construction expertise such as a building unit. In Skandion this was not the case, instead the KAS organization only consisted of 2-3 individuals with expertise in cancer treatment and efficient patient flow. To handle construction related issues KAS appointed a consultant firm, however with little experience from large complex healthcare projects. Due to the weak organization of KAS other stakeholders needed to determine the information on behalf of KAS. This was reflected on by the architect as the following: “Also we had a tenant and the tenant is in charge of writing a program, they tell us what they want in a program. It is this that the project been suffering from since the tenant did not have an organization. Instead it is a new established organization and during a long long time it only consisted of two people…everyone [Link, Akademiska Hus, NCC] tried to make the tenant to organize and deal with the questions but we did not succeed in time. Hence now a lot of changes are made and that is a shame when we are almost finished”.

KAS also realized that they did not have expertise in construction after some time in the project and the Chief Physicist concluded: “We know very little about the construction industry”. The lack of construction knowledge at KAS resulted in that false or not enough information was inserted in the model. Moreover the lack of knowledge is visible in how KAS perceives the use of BIM in Skandion. KAS had little understanding about how costs are generated in the BIM-model, questions such as how can a model have a cost and how can changes in the model result in cost was difficult for KAS to understand. KAS only understood BIM as a visual mode, not a model including information to set up and manage the building.

BIM and the radiation equipment

In being able to perform treatment with proton therapy KAS signed a purchasing agreement with the IBA in supplying the radiation equipment (the cyclotron). IBA is the word-leading supplier of cyclotron for proton therapy and the company has supplied more than 25 healthcare facilities world-wide with proton therapy equipment. Since the cyclotron generates radioactive radiation IBA have certain requirements on the construction of the building in order to install the equipment. In the agreement with KAS IBA defined its requirements on the building through the Integrated Building Documents (IBD). The documents are more than 100 pages and 40 different drawings with detailed information about how the treatment rooms should be constructed to install and deliver safe treatment with proton radiation. The IBD documents changes between every project since IBD need to correspond to the unique conditions for every project, for instance in Skandion the IBD needed to correspond to the demands of Swedish Radiation Safety Authority. The detailed requirements from IBA were commented on by the Architect as: “The supplier of the equipment had a thick description on how the building would be designed, measure wise and material wise and how large the door openings should be and I mean everything. It has been a lot of work just on that”.

In order to proceed with the physical construction of the treatment area IBA needed to approve the production document provided by the planning organization (Sweco), hence IBA needed to interact with both Sweco and NCC. The cyclotron and the IBD document affected the work with BIM and it was also clear that the IBD-information was difficult to incorporate in the BIM-model, or as the BIM-coordinator describes it: ”They [IBA] were not compatible with us. So it [information] came on dvg-files, it was flat in a way. Thereafter the architect and the structural engineer needed to interpret it, unfortunately. It was really a pity”.

To translate and interpret the information into readable BIM files, the rest of the central stakeholders needed to be engaged and the translation was developed in interaction between the planning organization and IBA. In order to facilitate the translation Sweco, AH, NCC and Link paid visits to IBA reference projects in Europe and the US. In facilitate interaction a special meeting forum was introduced, NAV-meetings in which AH, Sweco, IBA and NCC met face-to-face. Moreover a formal software communication tool was also used, iBinder, the tool was connected to the BIM-model.

BIM as facilitating planning and production

AH and NCC jointly decided to use BIM on a high level for Skandion, this required to tightly link the planning and production organization in Skandion. Hence NCC joined the planning organization with Link and a number of technical consultants coordinated by Sweco. Through the initial BIM instruction it was easy to convince the whole planning organization how to use BIM for planning. It was decided to use ‘increased modeling’, hence the program information was very simple with low level of details, while the detailed level increased for system drawings and finally for production drawings. For each planning meeting the planning consultants supplied information that was synchronized by the BIM-coordinator into one model, all in all 13 people supplied BIM information to the model.

Even though the planning is characterized as “smooth” by Sweco the high level of BIM in Skandion have required more time, in terms of number of meetings and increased interaction among planning stakeholders, than traditional planning. A lot of time was put on investigating and discussing ventilation and energy supply along with installation clashes and collisions while developing the BIM model. The increase cost in planning by using BIM is commented on by Sweco as: “It [using BIM] can have cost more in the planning in order to do the modelling in BIM but we have gained in the fact that there are few faults on site”. While the project leader of AH comments on the use of a combination of partnering and BIM as determinants in increased meetings throughout the project by saying: “Partnering in itself creates more meetings and together with BIM it creates even more meetings. But I guess it is the main point of it all that we together perform at our best. The right house, to the right prices to the right quality”.

Due to a tight time schedule, planning and production took place in parallel. Or as the planning coordinator puts it: “the building was not ‘locked’ before we put the shovel in the ground”. Consequently, the planning and the production of the clinic needed to be coordinated alongside each other. The planning was steered by NCC that decided on the production and divided the clinic in sections by using BIM, hence NCC decided on what production drawings the company needed at what time, which determined planning time and resources schedule put up by Sweco using the tool MS-project. Even though the planning and design phase was time consuming it minimized on-site adaptations in production. NCC used BIM foremost as a tool for planning production activities, i.e. informing foremen and workers what to do along with introducing new subcontractors on site. In order to facilitate the use of BIM in production the NCC production team got basic BIM training and was equipped with Ipads. All relevant documents, protocols and other BIM information could be accessed through a system of drop boxes through the software iBinder. Moreover, in reducing the use of drawings NCC invested in a plotter with the possibility to print drawings if BIM could not be used on site. However NCC also used BIM for purchasing activities by calculating quantities, this was also indirectly related to planning the logistics of purchased materials.

Analysis

In the following section we are focusing on analyzing BIM as a project resource; firstly, how BIM is affecting the resource interaction among the focal stakeholders and secondly, how the resource interaction among these stakeholders affect the use of BIM, i.e. which services BIM can provide the project because of resource interaction. The analysis is divided into four situations in which BIM is affected by and is affecting resource interaction among the stakeholders, a similar division such as the case description. The first section analyses BIM in relation to the established relationship between the project owner AH and the main contractor NCC. This is followed by a second section analyzing BIM in relation to the tenant, KAS. The third section discusses BIM in relation to the medical equipment supplier IBA, while the fourth discusses the role of BIM as a tool to bridge the planning and production organizations tighter together.

BIM and the partnering between the developer and the construction company

The case reveal that the established relationship (more than 20 years) between AH and NCC was important in determining the use of BIM and the level in Skandion. It is evident that the internal knowledge and experience of the two units affected the decision to use BIM on a 'high level' in Skandion. NCC had used VDC in more than 100 projects prior to Skandion, while AH had experiences as a developer and use of BIM but on a lower level. The fact that the established relationship between AH and NCC was further developed into a partnering agreement to handle the construction of Skandion deepened the relationship and the interaction even more. The partnering agreement was important in identifying Skandion as a BIM-pilot project. The partnering agreement also resulted in a high level of transparency between the project owner and the main contractor that in turn affected the interaction among the other stakeholders, such as the planning coordinator Sweco and the architectural firm Link. Hence the established relationship between AH and NCC was an important resource for the development of the partnering agreement and increased transparency among stakeholders, which in turn facilitated the introduction of using BIM on a higher level than before. However, in being able to use BIM as a mutually shared resource, new arenas for interaction among the stakeholders needed to be developed. Therefore, AH, NCC, Link and Sweco decided to initiate a new type of joint meeting forums such as BIM-meetings along with workshops. These forums constituted as arenas for interaction among the units. Hence, faceto-face interaction was necessary to determine why and how BIM would be used for the construction of the Skandion Clinic. These meeting arenas can be seen as a result of the partnering agreement that encouraged transparency, interaction and joint decision-making among the stakeholders. In handling these interaction processes Link played a key role due to its internal knowledge experience from other projects. As a consequence Link was appointed as BIM-coordinator for the project.

BIM in relation to the tenant/user

Compared to the established relationship between NCC and AH no stakeholder involved in Skandion had any previous relationship with the tenant KAS. Also the KAS organization in itself was immature and under development, with no established internal routines and knowledge. Among the 2-3 employees KAS's main expertise was cancer treatment and had no earlier experience from construction. However in pursuing the construction of Skandion and especially the use of BIM in the project, interaction between KAS and other stakeholders were necessary. In being able to produce the system drawings and develop the planning, Link needed KAS to insert technical information into the room functioning program (dRofus), however with lack of experience from construction KAS had difficulties in supplying necessary information. The case point out that Link had to help KAS a lot in defining the information but also AH and NCC was affected and needed to act on behalf of KAS at many occasions. It is evident that KAS as main user of the new clinic plays a significant role in determine the building since it is "custom-made" for proton radiation treatment; it is difficult to construct a "custom-made" building if the user does not have the knowledge of defining its demands. In the end the immature user KAS resulted in that NCC needed to make on-site adjustments along with the Sweco needed to revise the production documents after the actual construction due to changed user demands. The interaction between the resources of KAS and that of the other stakeholders thus obstructed a more full use of the BIM model. There was no earlier relationship to build on and the organization itself was highly specialized on other types of activities than construction. The lack of knowledge of this stakeholder of how and why to use BIM affected the interaction that was needed in the rest of the project network in order to extract value from using the model.

BIM in relation to the radiation equipment supplier

Another stakeholder that none of the others had an earlier relationship to was the equipment supplier, IBA. The specialized and unique stakeholder IBA was important when constructing the healthcare building, which was completely dependent on a core resource, the cyclotron. Due to that IBA supplied this core facility, the firm constitutes a main stakeholder that the other stakeholders needed to adapt to. Therefore, as there was a lack of early interaction between IBA and the other stakeholders it became problematic to develop the production documents of the treatment area in Skandion. Through the experience of installing more than 26 proton cyclotrons world-wide IBA supplied detailed demands on the technical aspects of the treatment area in the IBD. However some of the technical information in the IBD needed to be imported into the BIM-model. AH, Sweco, NCC and Link had difficulties in understanding the IBD and sort out what information needed to be incorporated in the BIMmodel. To solve this, increased interaction among the stakeholders and IBA was necessary. Moreover to understand the IBD in practice AH, Sweco, NCC and KAS visited several IBA facilities in Europe and the US together with IBA. Through these visits the stakeholders could ask the right questions to IBA concerning the IBD documents which facilitated the translation of IBD-information into information inserted in the BIM-model. In facilitating the interaction, AH introduced NAV-meetings at the site, these meetings were necessary for AH and NCC in understanding the demands by IBA. During the meetings BIM was used to visualize the building but also information related to the BIM model was discussed. Informal meetings were also taking place since the IBA project manager was based on the Skandion site throughout the project, and he could clarify the IBD demands to stakeholders such as AH, Sweco and NCC. Hence in order to understand each other as stakeholders meeting forums were established to support the development of relationships among stakeholders.

BIM as a tool to bridge planning and production organizations

In Skandion, BIM was used as a resource to better integrate planning and production because of a tight schedule and thereby create a more efficient construction process. The case shows that BIM is used as a tool to facilitate the interaction between these phases but also necessitates more interaction among the stakeholders. In handling the parallel planning and production the NAV-meetings constituted the main interaction arena in which AH and Sweco linked the planning and design issues with production issues together with NCC and IBA. During these meetings BIM was used to discuss details of the new building. However in handling parallel planning and production NCC needed to invest in Ipads for workers and foremen on-site along with provide both organizational and technical BIM training of the production team.

By using BIM consistently for planning and production in the Skandion Clinic project the costs for planning increased compared to traditional planning methods. This is mainly due to the increased level of interaction among the stakeholders. On the other hand the increased cost in planning is balanced by less on-site adaptations since the production drawings have contained little faults along with the production and installation on-site have been facilitated by the use of BIM. Hence it is evident that the value of BIM is not always direct and spread evenly across the project, instead its value can be indirect and only noted by some of the stakeholder such as AH, NCC, Sweco and Link. All units with prior experiences from BIM and construction projects emphasized the high ambition level of BIM in Skandion and all units saw the benefits of using BIM in Skandion, while the other “non-construction” stakeholders (IBA and KAS) did not pay attention to the values it gained

Concluding discussion

In the final discussion we will focus our attention to answer the two main research questions posed in the introduction.

How is BIM formed as a project resource through interaction processes in the project network of a large construction project?

In answering the first question concerning how BIM is formed as a resource it is important to understand that the way BIM was used and how it was used in the project was new to all stakeholders involved. However that BIM was initiated on a high level was dependent on earlier knowledge and experience of the separate actors and on earlier relationships. It also depended on the deepened interaction that took place due to partnering agreement with its increased transparency. The way that BIM could be used in a much broader way and in a more specific ways thus depended on the interaction processes that had taken place before the project (in other projects) among some of the stakeholders, along with the specific interaction processes that took place among several stakeholders within the project. In these interaction processes the resources of the different stakeholders where combined in new ways: the knowledge of Link, the competence of AH, the production requirements of NCC, the earlier experience of Sweco, along with the specific requirements of the equipment supplier, IBA related to the physical resources of the building. In this way BIM could be used for some purposes which then was directed towards the specific needs of the clinic. Hence BIM is cocreated and co-produced among the project stakeholders in the similar way as suggested by Davies & Harty (2013), whereas the difficulties is how to diffuse a project innovation to other projects and/or permanent organization remains.

Which services and value can BIM provide as a result of such interaction processes?

In answering the question what value BIM can provide due to the interaction processes taking place it is evident that different stakeholders could extract different values from the use of BIM: AH could use it for maintenance of the building, and develop a BIM manual for future projects, NCC could use it for purchasing and logistics purposes, for IBA it was more of a facilitator to construct the shell around the medical facility, while KAS could not really see the benefits of BIM at all due to lack of knowledge and understanding of BIM as a tool.

The resource analysis of BIM thus shows that there is not one value of BIM as such rather it is created through interaction processes among several stakeholders. As a result BIM gains particular features and values: some of which can be used mutually by the stakeholders and some of which is only valuable for one or some of the actors. The implications of this is that it is very hard to standardize the use of BIM, its use and the services it can provide will always depend on which other resources, both physical and organizational, that it will have to interact with within the project. Moreover these resources also have a previous history which have been shaped in relation to other resources, which can result in difficulties in finding compatibility with a new resources such as BIM, for instance as for the stakeholder IBA in the case.

The understanding of the use of BIM as primarily determined through the specific interaction processes among project stakeholders has three important implications: 1.) that the value of BIM is highly project-specific, 2) that the costs and benefits of BIM is spread unevenly among project stakeholders, 3.) that BIM can only be evaluated after the project is completed. This is due to the difficulty of predicting the outcome of combining different heterogeneous resources, which in this case is being brought into the context of project; as the services of resources are determined by how they are combined with other resources (Penrose, 1959), we can only know the value of separate resources once we see which features they obtain through interaction with other resources.

As mentioned earlier a lot of project management literature focus on the role of stakeholders in project (Youker, 1992; Brady & Davies; Newcombe, 2003; Altonen, 2011; Olander 2005; Olander, 2007) however this paper contributes to the project management literature by opening the 'black-box' of interaction among stakeholders. Hence we do not see interaction as fixed and/or given, instead it is a process between stakeholders. In the same vein as Ruuska et al. (2011) we contribute by revealing the network of organizations related to projects and especially by investigating the interaction processes taking place among project stakeholders and what resources they combine. Our findings suggest that it is the interaction processes that determine the possibility to introduce and use new innovations and solutions in projects. For project managers in the construction sector this study show that BIM is difficult to standardize in relation to unique projects but these findings can be of interest especially when identifying and evaluating potential project stakeholders when introducing BIM. In evaluating stakeholders managers need to evaluate the 'history' of potential stakeholders, hence what resources, knowledge and experience from BIM do the stakeholders possess and how can this be used in combination with other stakeholders' resources.

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Appendix 1: Interviews

Organisation	Role of organisation	Position	Duration	Date
AH NCC	Customer Contractor/construction company	Project Leader Project Manager	1 hour	10/10/2012
Sweco	Supplier of consultant service	Planning Coordinator	1.5 hours	02/11/2012
NCC	Contractor/construction company	Project Engineer	1 hour	02/11/2012
KAS	Tenant	Chief Physist	1 hour	04/11/2012
AH	Customer/owner	Project Leader	1.5 hour	21/11/2012
IBA	Med-tech supplier	Project Leader	1.5 hour	21/11/2012
NCC	Contractor/construction company	Site Manager	1 hour	22/11/2012
Bravida	Supplier of electricity installation services	Project Leader ventilation	1 hour	04/12/2012
NCC	Contractor/construction company	Project Manager	1.5 hours	19/04/2013
AH	Customer	Construction Manager	1 hour 15 min	13/10/2013
AH	Customer	Project Leader	1 hour	16/10/2013
AH	Customer	Project Leader	1 hour	22/10/2013
Link Arkitektur	Supplier of the architectural drawing	Architect	1.5 hour	10/25/2013
Art	Supplier of consultant services within art	Art Consultant	1 hour	10/25/2013
Sweco	Supplier of consultant service	Planning Coordinator	1 hour	10/29/2013
KAS	Tenant	Director	1 hour 15 min	10/30/2013
NCC	Contractor/construction company	Site Manager	1 hour	08/11/2013
AH	Customer	Project Leader	1 hour	08/11/2013
IBA	Med-tech supplier	Project Leader	1.5 hours	14/11/2013
Link Arkitektur	Supplier of the architectural drawing	BIM Coordinator	1 hour	27/11/2013