Lost in Translation

A case of BIM implementation at a large public client

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Abstract

The development of new technology is constantly progressing, presenting new opportunities and enabling new and innovative solutions to both known and unknown problems. However, when technology is introduced into an organisational setting, its use often drifts away from the developer's intentions. The management of such an implementation is linked with many complexities. With technology influencing numerous interconnected actors, the complexity of the implementation increases.

Currently, the technology of Building Information Modelling (BIM) is being introduced to the Architectural, Engineering and Construction (AEC) industry. This industry is often described as being fragmented, having low productivity and with a low rate of innovation. BIM is presented as new paradigm within this industry, enabling inter-organisational collaboration, overall increasing quality while simultaneously lowering costs. But widespread BIM implementation has not yet taken place. In order to increase adoption, public client organisations have been argued to be the actors needed to initiate and drive the implementation of BIM. However, the client perspective of such implementation initiatives has not been the main focus of earlier research.

In this licentiate thesis the case of the BIM implementation process conducted by the largest infrastructure client in Sweden is studied. This organisation undergoes a process where BIM is implemented, both to benefit their own organisation but also to increase productivity and innovation within the whole infrastructure branch of the AEC-industry. With the purpose of increasing the understanding of technology driven change processes at public client organisations, the BIM implementation at this organisation is analysed as an empirical example. An example of how technology is introduced to influence a wider network of actors in order to establish change.

The case study is analysed by a theoretical framework taking inspiration from Actor-Network theory and Sociology of Translation. Based on this analysis the translation process, where key actors are identified and enrolled into using BIM are described. The analysis reveals a complex network of actors linked to the implementation in question. Instead of a single BIM concept, several different and sometimes conflicting interpretations of BIM are simultaneously being translated.

This licentiate thesis problematizes the role of client organisations in initiating change within a network of actors. The main way of enrolling actors into using BIM, found in the studied case, have been the development of new demand documents. This strategy has however been problematic as the new demands for BIM have not been accepted as intended within many construction projects. Instead, the results of this thesis argue for the importance of client organisations as negotiators, not only needed to establish demand for a new innovation.

Sammanfattning

Utvecklingen av ny teknik pågår ständigt med nya möjligheter samt nya lösningar på både kända och okända problem. Däremot förändras ofta användningen av teknik när den appliceras i en organisatorisk kontext och ofta följs inte utvecklarnas intentioner. Att styra denna typ av implementering är kopplat till många komplexa faktorer. Med teknologi som påverkar ett flertal aktörer ökar komplexiteten i dess implementering ytterligare.

Tekniken Byggands Informations Modellering (BIM) introduceras just nu i byggbranschen. Denna bransch beskrivs ofta som varande fragmenterad med låg produktivitet samt bristande innovationskraft. BIM beskrivs som ett nytt paradigm för denna bransch, möjliggörande interorganisatoriskt sammarbete, ökad kvalitet och samtidigt minskande kostnader. Däremot har BIM ännu inte anammats på bred front. För att öka implementeringstakten har statliga beställarorganisationer beskrivits som de aktörer som behövs för att initiera och driva implementeringen av BIM. Dock har tidigare forskning inte fokuserat på beställarperspektivet kring sådana initiativ.

I denna licentiatavhandling presenteras en fallstudie av BIM implementeringen på den största infrastrukturbeställaren i Sverige. Denna organisation genomgår en process där BIM implementeras, både för att gynna den egna organisationen men också för att öka produktiviteten och innovationstakten i intrastrukturbranschen som helhet. Med syfte att öka förståelsen kring beställarrollen i förhållande till teknikdrivna förändringsprocesser studeras denna förändringsprocess som ett empiriskt exempel. Ett exempel på hur teknologi introduceras för att påverka ett bredare nätverk av aktörer för att skapa förändring.

Denna fallstudie analyseras utifrån ett teoretiskt ramverk med inspiration tagen från Actor-Network Theory och Sociology of Translation. Utifrån denna analys beskrivs översättningsprocesser där nyckelaktörer identifieras och försöks knytas till att använda BIM. Analysen visar på ett komplext nätverk av aktörer kopplat till implementeringen i fråga. Istället för ett enskilt BIM koncept hittas flertal samtidiga, och stundtals motsägelsefulla tolkningar av BIM som alla samtidigt översätts i organisationen.

Denna licentiatavhandling problematiserar beställarrollen i relation till initiering av förändring inom ett aktörsnätverk. Det huvudsakliga sättet genom vilket aktörer knyts till att använda BIM har i det studerade fallet varit genom utveckling av nya kravdokument. Denna strategi har däremot varit problematisk då dessa krav inte accepterats som tänk inom ett flertal byggprojekt. Istället visar resultatet av denna studie på vikten av beställarorganisationer som varande förhandlare, inte endast viktiga för att upprätta efterfrågan för en ny innovation.

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During my first weeks of my PhD studies I was told that research is a conversation, listening to researchers who have done earlier works in the field, reflecting and collecting new knowledge and adding it conversation by the writing of new research articles. I would argue that the conversation of research goes much further, with all the interesting discussions, seminars and feedback that is constantly given and which have shaped this licentiate thesis. I want to acknowledge some of the people that have been particularly important for by development as a researcher.

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Hannes Lindblad, May 2017

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1. Introduction

1.1. Background

The Architectural, Engineering and Construction (AEC) industry has large impact on our society and there is a need for innovative and sustainable solutions. However, the industry is project based and characterised by a multitude of actors and processes, making the industry both diverse and fragmented (Bygballe & Jahre, 2009; Winch, 2010). This fragmentation is one factor in why innovation and change is challenging (Eriksson, 2010; Bygballe, & Ingemansson, 2014). The building of new roads and railways, for example, involves numerous disciplines and actors, with different agendas, collaborating in projects to produce a relatively unique solution for the client. Hence, innovation that aims to change the operation in this environment must be implemented across the inter-organisational landscape (Harty, 2008).

The actor that has been suggested to take the role of change agent in this inter-organisational landscape and stimulate change is the client (Blayse & Manley, 2004). More specific, it is experienced clients that are identified as the main institutional leaders for stimulating construction innovation and change (Winch, 1998).

One current technology driven change process with potential to change the industry is the implementation of Building Information Modelling (BIM). By the collaborative use of digital models, BIM is presented as an innovation with a large potential impact on the whole construction life-cycle (Azhar, 2011; Yan & Damian, 2008). However, studies show that the adoption of BIM in the AEC industry has been slow and expected benefits have not yet been reached (Gu & London, 2010; Smith 2014).To support this change process, public clients have been argued to play vital role as change agents (Wong et al., 2010; Wong et al., 2011; Porwal & Hewage, 2013).

Implementation initiatives are currently taking place in many countries for example: USA, UK, Finland, Norway, Denmark and Singapore (Wong et al., 2010). In UK for example there is a demand that all public contracts from 2014 and onwards must demand the use of BIM (CabinetOffice, 2011:14). A similar initiative is taking place in Sweden where the public client organisations have taken a joint initiative to requests BIM in projects (BIM i Staten, 2014). The Swedish Transport Administration (STA), the largest Swedish infrastructure client, is also developing their implementation of BIM. With the explicit target of increasing productivity in the Swedish infrastructure related AEC-industry, the STA have decided to implement BIM in all projects.

1.2. Purpose

The current implementation of BIM pursued by a major public infrastructure client presents an example of a technology driven change process argued to impact operations in construction projects (i.e. how the actual work is being performed). This process is relevant not only for individual actors but also to the whole industry, as it is expected to improve collaboration and integration across disciplines. However, expected benefits of an innovation do not assure its

transfer and diffusion (Latour, 1987). Information systems research show that the introduction of new information and communication technology (ICT) into an organisational context often drift away from the initial intentions and purpose (Ciborra, 1997; Holmström & Stalder, 2001). The initial expectations of the technology driven change might therefore not be realised. This is why it is important to acknowledge that technology driven change processes includes many different perspectives. Consequently, new technology will be formed by the organisational context, the network of actors, in which it is used and the norms that are developed within this network.

As the importance of public clients are emphasised, their role in initiating the network surrounding the BIM implementation becomes relevant. Analysis of how networks are created and what mechanisms facilitates and hinders them has earlier been done from the project perspective (Linderoth, 2010). However, there is a lack of studies that widen the scope beyond the specific projects and also include the organisational context.

The purpose of this study is to increase the understanding of technology driven change processes at public client organisations by studying the BIM implementation process at the STA. This study will describe both possibilities and difficulties related to the public client´s role in initiating change in a diverse and fragmented industry-context, such as the AEC industry.

Inspired by Actor-Network Theory (ANT) this study applies the theory of sociology of translation (Callon, 1984, 1986) as an analytical lens. This lens supports an analysis of the translation process in which the innovation is spread to influence change in a complex network of actors. Findings are drawn from a longitudinal case study of the implementation of BIM at the STA.

1.2.1. Research questions

To fulfil the purpose, the following research questions will be addressed in this study:

RQ 1: How is BIM interpreted by employees at the STA?

RQ 2: How was the BIM actor-network established?

RQ 3: What mechanisms have influenced the development of the actor-network?

This study is based on an abductive approach, where initial tentative findings have been used in the development of later research questions (Dubois & Gadde, 2002). RQ 1 was the starting point and it developed into an interest for the development of actor networks surrounding the BIM implementation. By mapping actors, an understanding of the organizational context in which this implementation – or translation – process took place emerged. The final question relates to which issues that influenced the translation process difficulties in enrolment, programs and anti-programs and how the use of BIM is inscribed in the continued work in this organisation.

1.2.2. Appended papers

Paper 1: BIM implementation and organisational change: A case study of a large Swedish public client

Lindblad, H., & Vass, S. (2015). BIM Implementation and Organisational Change: A Case Study of a Large Swedish Public Client. *Procedia Economics and Finance*, *21*, 178-184.

Paper 2: Organising the Implementation of BIM: A study of a large Swedish client organisation

Lindblad, H. (2016). Organising the Implementation of BIM: A study of a large Swedish client organisation. *Proceedings of the CIB World Building Congress 2016*, 356 – 367.

Paper 3: Translating Building information modelling: A study of the BIM implementation process at a large Swedish client organisation

Lindblad, H (2016) Translating Building Information Modelling: A Study of the BIM Implementation Process at a Large Swedish Client Organisation. In: P W Chan and C J Neilson (Eds.) Proceedings of the 32nd Annual ARCOM Conference, 5-7 September 2016, Manchester, UK, Association of researchers in Construction Management, 123-132.

2. Theoretical Framework

In this chapter, previous studies on innovation and technology driven change processes are presented. Various perspectives on how innovation can influence organisational change are presented. In order to better understand the technology that drives change, different views on BIM are presented. Finally, the actor-network theory is described.

2.1. Innovation and the client organisation in construction

The concept of innovation has different interpretations by different actors and in different surroundings. In relation to construction, the following definition by Slaughter (1998) is generally accepted both in academia and practice:

"Innovation… is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change"

Slaughter (1998) further describes several characteristics of innovations. Such innovation can be:

- Incremental – minor changes based on current knowledge and experience.
- Radical – a consequence of a breakthrough in science or technology resulting in substantial changes to the nature of the industry.

These innovations also have a varying field of impact and can be:

- Modular – a significant change in concept to an individual component that do not influence the whole system.
- Architectural – small changes to individual components that bring substantial changes to the link to other components and systems
- System – the integration of multiple integrated innovations

These models of innovation relate to the influence of the innovation, incremental to radical. Further these models represent the extent the innovation influence single actors or extent to a large system in an inter-organisational landscape.

In the general literature on innovation it is assumed that all industries follow a product development models (Winch, 1998). In this model, organisations respond to market signals to introduce new products: develop, produce and release them on the market. These products have limited and distinctive life cycles and the opportunity for innovation shifts from the development of the product in the early stages to the production of the product later on. In this model, innovation is mostly linked to the single firm. Suppliers of the innovating firm are only included to ensure that the product can be produced. As industries become more integrated more attention has been paid to the process of innovation within this network of firms. This model has been present in the understanding of innovation in construction. However, as construction often presents a quite different environment with a multitude of actors working towards fulfilling the needs of the client, other models has been developed that might be more applicable for the AEC-industry.

Complex product systems as described by Miller et al. (1995), is a model consisting of: many interconnected elements, system properties where small changes to one element can have large implications elsewhere in the system and large influence on users in the innovation process. Based on this model, Winch (1998) proposes model for innovation in construction which takes its particular contexts and characteristics into account. In this model Winch (1998) describes an innovation superstructure together with an innovation infrastructure which are connected by the actions of systems integrators. These individuals, the system integrators, manage the implementation of an innovation from a single instance to the whole superstructure of the construction sector. Nam & Tatum (1997) show that, the role of the principal architect/engineer and the main contractor is crucial for innovation in construction. These actors must be convinced of the innovation and have the right skills to utilize it for system innovation to be incorporated within the whole system. Without these prerequisites system innovation will be slow.

Both Winch (1998) and Slaughter (1998) put great emphasis on the importance individuals in mediating system innovation. Slaughter (1998) describes innovators that are: "able to exercise the technical competence and project responsibility and control to achieve coordination cooperation across the system(s)". These innovators are very similar to the system integrators of Winch (1998). That is to say, in the construction sector there is an argued need for individuals to mediate system innovations between actors in the inter-organisational landscape that is present.

In the construction sector it is generally accepted that innovation is mostly initiated in relation to one of two circumstances (Harty, 2008). Either, innovation is the result of external needs and new demands, generally formulated by clients. Innovation can also be initiated by the implementation of technology from other sectors which is introduced in the environment of construction. Of these circumstances, the first is often brought forward as an important initiator for change and especially the role of client organisations in establishing demand for the innovation. Client organisations are described as key industry participants in their position to be able to drive innovation (Blayse & Manley, 2004). Further Blayse & Manley (2004) describe clients as being able to enhance innovation in construction in these two ways:

- Specific novel requirements on the project addressed to developers, suppliers, contractors and operators.
- Pressure project participants to improve buildings performance, overall characteristics, project flexibility, and generally demand higher quality of work.

The role of client organisations as promotors of innovation is not only well established in literature. This role is also accepted by many policy makers. In the UK current policy identifies experienced clients as the "main institutional leader in stimulating construction innovation" (Winch, 1998). In manufacturing the byer is only presenting demand for innovative solutions, presenting passive incentive for change. In construction the client is not the mere byer of a product but instead a key player in the construction process. In this role, client organisations which are more demanding and experienced have been found to be more likely in stimulating innovation in projects they conduct (Barlow, 2000). The technical

competence of clients has also been found to be a major factor in their ability to stimulate innovation (Nam & Tatum, 1997). Further Nam & Tatum (1997) found that clients with high levels of technical competence tended to be more actively participating in projects execution. In this way the technical competence enables clients to relate in a timely manner to innovative proposals. Additionally, for the initiatives for innovation introduced by clients to take root, there is a need for a gain-sharing approach to be adopted. The rewards gained from the innovation should be split in the project coalition. When actors are rewarded for the innovation they are incentivised for adopting new ideas (Winch, 1998).

2.1.1. Relative unboundedness

In instances where there are strong system integrators (innovators), who can mediate the implementation of new innovation, implementation can be effectively guided. Harty (2008) describes these circumstances as relatively bounded as "there is a coherent centre that aligns the various parties and entities involved". But in instance where innovation and its effects extend beyond the control of the implementer the same patterns do not follow. In these cases innovation can be viewed as relatively unbounded. To describe how innovation is implemented with these instances Harty (2008) presents the concept of relative unboundedness. This concept does not only relate to the innovation itself, but also takes the context in which the innovation is implemented into account. This means that the implementation of the same innovation can be more or less bounded depending on the circumstances in which it is implemented. Relative boundedness establishes a situation with different challenges and thereby varying outcomes in different implementing circumstances.

The concept of relative unboundedness avoids the assumptions that innovations always take place in a homogenous and coherent setting. This view highlights "how the characteristics of an innovation are transformed and shaped in practice, rather than simply diffused as stable, unchanging artefacts with fixed characteristics" (Harty, 2008).

The AEC-industry presents an environment with high levels of fragmentation and simultaneously high demand for collaboration among a multitude of actors. In this environment, the concept of relative unboundedness becomes significant in attempts to understanding the sequences of inter-organisational project work (Harty, 2008). In this context implementation and its effects cannot always be controlled by a single organisation or individual. In order to successfully influence this relatively unbounded context, there is a need for collaboration and alignment of a multitude of actors from various disciplines and organisations.

When studying the implementation of an innovation in a relatively unbounded landscape the key issue is to trace networks of associations. The connections between the different actors and actants, irrespective of their projects or organisations, become relevant to study. These circumstances establish implementation as a negotiation between these actors and actants. The questions of whom or what is included and excluded from these negotiations as well as how these inclusions and exclusions are being conducted becomes relevant (Harty, 2008). These questions help in assessing how bounded or unbounded the innovation process is.

The concept of relative unboundedness challenges the assumptions of a coherent implementation process. This understanding of the innovation process focuses on the negotiations that make up initiatives to innovate rather than a focus on individuals, the mediator/innovator/system integrator.

2.2. IT and organisational change

The goal of the introduction of new technology into an organisation is generally to generate improvement and thereby increasing productivity. As generally accepted in the rational perspective of the BIM research, it is when substantial changes to work practices can be achieved these benefits can be gained. As described by the different maturity models presented (e.g. Succar, 2009) it is on the higher maturity levels greatest benefits can be gained. Further, as stated by Brynjolfsson & Hitt (2000) it is the changes of the organisation and its use of the technology that generate the sought after benefits rather than the technology by itself. Therefore, the relationship between new technology and organisational change becomes relevant when studying the process towards the expected organisational changes.

The relationship between new technology and organisational change has been studied extensively in the field of information systems (Markus & Robey, 1988). One way of viewing the interaction between new technology and the organisation is to study which role the technology plays in the organisation (Orlikowski, 1992). From this perspective, there are three different causal relationships that have been found between technology and organisational change: Technological imperative, organisational imperative/strategic choice and emergent perspective/ technology as a trigger for structural change.

- *Technological imperative* – In this perspective, technology is viewed as an exogenous force, which have a large impact on the behaviour of the individual and the organisation (Markus & Robey, 1988). As a premise for this perspective organisational and individual variables are measurable and predictable, further the individual's ability to develop and change technology is disregarded (Orlikowski, 1992). When following this perspective, it is argued that information technology (IT) in general or some particular constellation of features directly relate to the changes to the organisation (Markus & Robey, 1988).
- *Organisational imperative/Strategic choice* – this perspective serves as a direct contrast to the technological imperative. Instead of technology constraining or determining individual and organisational behaviour, this perspective assumes almost unlimited control over technological options and their consequences (Markus & Robey, 1988). In this perspective technology is viewed as the dependent variable, influenced by forces in the organisation and individual actors (Orlikowski, 1992). Further as this perspective assumes that technology is influenced by the context in which it is implemented, focus is placed in the organisation's perception of the technology, the development of said technology and the strategies of implementation (Orlikowski, 1992).
- *Emergent perspective* – This perspective assumes that the influence of IT on the organisation emerge unpredictably as a result of complex social interactions (Markus

& Robey, 1988). This perspective to some degrees combines the two earlier views of the relationship between IT and the organisation. In this perspective like in the technological imperative the technology is viewed as an exogenous force which influences the organisation, but this influence is affected by individuals and the organisational context (Orlikowski, 1992). This perspective explains why the same technology occasionally influences two similar organisations in varying ways with different structural outcomes (Barley, 1986).

Depending on the perspective taken different analysis can be drawn about the relation between new technology and organisational change. The technological imperative put focus on the choice of IT and its technical requirements. When the correct technology is in place and working, organisational change is expected to follow. The organisational imperative, on the other hand, put focus on the allocation of resources and improving implementation strategies while the results of the implementation is perceived to stem from the behaviour of managers and system designers. Finally, the emergent perspective finds predictions of outcomes with implementation impossible; to support changes, extensive participation in the analysis, design and implementation of new technology are advised. (Markus & Robey, 1988)

These three views of how IT is linked to organisational change do not represent all perspectives of this process. However the three show that when studying how technology influences change in an organisations it becomes relevant both to study the technology in itself and also the environment and context where the technology is to be used.

2.3. Building Information Modelling (BIM)

Eastman et al. (2011) Begins the first chapter in the BIM handbook with the following description of BIM:

"Building Information Modelling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries."

- Eastman et al. (2011)

This positivist description represents the prominent view of BIM that exist within parts of academia and most of the AEC industry. BIM is being described as a new paradigm, able to address many of the problems associated with the AEC industry (Azhar, 2011). Benefits of BIM implementation range from reduction in both time and cost of projects while simultaneous delivering higher quality (Yan & Damian, 2008). BIM is also claimed to improve collaboration within construction projects and thereby bridging the fragmented nature of the AEC-industry (Azhar, 2011). Even though this very promising picture has been presented in many case studies, the industry has been tentative in the widespread implementation of BIM (Gu & London, 2010; Smith, 2014).

Several difficulties and implementation barriers have been found linked to the BIM implementation process. It is argued that for BIM to be most beneficial, major changes have to be made, not only to the technological tools used but also to work practices and business processes (e.g. Bryde et al., 2013, Taylor, 2007). Other challenges are factors such as

interoperability, standardisation and the development of new tools (Steel et al., 2012; Azhar, 2011). Also, there are implementation barriers such as legal issues, changing work practices, training of practitioners etc. (Azhar, 2011; Aound et al., 2004; Bernstein et al., 2004).

In academia a growing stream of research is voicing critique of BIM and arguing that has not yet shown its promised benefits on a wider level (Gustavsson et al., 2012; Fox, 2014; Jung & Joo, 2011). Fox (2014) and Dinty et al (2015) claim that there is hype around BIM. Characteristics of this hype can be found in the increasing amount of literature describing technological visions, promises to change reality together with creation of new opportunities (Miettinen & Paavola, 2014). At the same time, this literature tends to disregard many of the social and organisational factors that constrains and complicate the realization of the vision. Miettinen & Paavola (2014) even call the current situation "BIM Utopia".

Client organisations in general and public clients in particular, have been put forward as change agents. The client role has been described as a driving force towards the implementation and use of BIM (Wong et al., 2010, Wong et al., 2011). Client organisations are argued to be the actor who can gain most from BIM implementation and they are also the actor who has the power to demand BIM when procuring consultants and contractors (Smith, 2014; Linderoth, 2010). Following this discussion, many governments have begun to investigate how BIM can be implemented and used within their context and how they can support industry adoption. Such examples can be found in for example: USA, UK, Finland, Norway, Denmark and Singapore (Wong et al., 2010). These countries are developing their BIM initiatives differently and some countries have come further than others. In the UK for example, there is currently a demand for all public contracts awarded from 2014 and onwards contain requirements that all project participants will work collaboratively through the use of BIM (Cabinet Office, 2011:14). Similar initiatives can be found in Sweden where a joint BIM initiative is being performed by a network of public client organisations (BIM i Staten, 2014). The Swedish Transport Administration (STA), which is the largest public Swedish infrastructure client, is currently implementing BIM with the expressed goal of increasing productivity, both in their internal productivity and the industry productivity.

2.3.1. What is BIM?

The issue of defining Building Information Modelling (BIM) has been addressed by many different scholars. The definitions include different aspects in the BIM concept but agree on the basis of BIM as the use of digital building information. Further many of the definitions include the process perspective of working with BIM, for example:

"A modelling technology and associated set of processes to produce, communicate and analyze building models" - Eastman et al. (2011)

Other definitions focus on the life-cycle aspects of BIM, for example:

"A methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" - Penttilä (2006)

In additions to the definitions found in academia, BIM interest organisations like building SMART have devised their own definitions. With no jointly accepted definition of BIM much ambiguity around the concept are present with actors tending to interpret BIM in varying ways. This has resulted in a spectrum where some actors see the use of 3D models as BIM-use while others require aspects like object orientation to call it BIM. In order to address the ambiguity of BIM Succar (2009) have devised a BIM framework to better describe the BIM concept.

The framework is multidimensional, relating BIM not only to technological aspects but rather describes the concept as being connected to three different parameters. This framework links the implementation of the technology to the actors influenced by it and describes how work processes and the organisation can change in order to take advantage of the new possibilities (Succar 2009).

- *BIM Fields* - Describing actors and their deliverables in relation to BIM
- *BIM Stages* - Describing maturity of implementation
- *BIM Lenses* - Defining the level of analysis needed no identify, assess and quantify the other aspects

By this holistic perspective, BIM is described as being related to many different actors, each of which might not be on the same maturity stage simultaneously. Especially the dimension of BIM stages relates to the difference in what the BIM concept includes and enables. The framework describes BIM as a progressive development of interacting policies, processes and technologies influencing different actors and organisations mapped in "BIM Fields" dimension. The "BIM Stage" dimension defines a starting point, a pre BIM stage, followed by three levels of BIM maturity and ending in less defined stage opening for flexibility with further developments. The BIM stages are:

- *Pre-BIM status synopsis* - 2D documents are the primary information exchange media. Even if 3D is used, the models are primarily used for visualisation and not more advanced uses such as calculating quantities or cost estimation. Relationships between actors are characterised by contractual agreements focusing on risk avoidance and lack of encouraging collaboration. In this pre-BIM stage there is low investments in technology and a lack of interoperability.
- *BIM stage 1, object-based modelling synopsis* - BIM usage is initiated in this stage by utilisation of an object-based 3D. Different actors create separate models for their respective discipline. Only limited process changes between this stage and the pre-BIM stage are present. This stage will not contain significant changes but actors will realise the potential benefit in engaging other design and construction actors with similar modelling capabilities. This will in turn encourage further development towards higher maturity sages.
- *BIM stage 2, Model-based collaboration synopsis* - At this stage, actors start to collaborate between disciplines through the exchange of models. Models are not only used locally but rather exchanged between actors to improve collaboration and integration between the actors. This exchange can take many technological forms

depending on each actor's choice of BIM tool. Some alteration will has to be made to contractual agreements as model-based interchanges start replacing documents-based workflows. This BIM-stage further emphasise fast-tracking and changing relative modelling intensity within each life-cycle phase.

- *BIM stage 3, Network-based integration synopsis* - At this stage semantically-rich integrated models are created, shared and maintained collaboratively across project life-cycle phases. During this BIM-stage, the models are interdisciplinary nD-models allowing for complex analysis. Actors now work collaboratively in the development of the project with the use of an extensive, unified and sharable data model. This BIM-stage requires major re-consideration of contractual relationships, risk allocation models and procedural flow.
- *Integrated project delivery synopsis* - The representation of the long term vision for BIM. This is a loosely defined goal for the BIM maturity which includes all relevant visions for BIM irrespective of their sources. This stage represents the endpoint for the BIM maturity. Initiating in the pre-BIM stage and continuing through the well-defined maturity stages this stage represents an open end stage with possibilities for several visions for continuation.

Many similarities can be found between this framework and other ways of describing how the use of BIM matures in an organisation. It is argued that the use of BIM is not static but rather a dynamic change towards higher BIM stages. In a study by Tylor & Bernstein (2009) they showed how the maturity stage of a certain actor depended on that actor's amount of experience with BIM. To be able to adopt the higher stages of BIM there is a need to develop inter-organisational work practices as collaboration is a key factor in these stages (Taylor & Bernstein, 2009). Simultaneously it is argued that these inter-organisational changes are beneficial to project outcomes (Tylor, 2007).

Similarly to the framework of Succar (2009), British Standards Institute (BSI) has developed a BIM maturity model for describing different stages in the BIM adoption in the UK. This model have been developed to categorise between different technical and collaborative aspects of BIM in order to enhance description and understanding of the processes, tools and techniques to be used in different stages of BIM implementation. This BIM maturity model has been adapted by many other actors currently implementing BIM in various countries.

These BIM maturity models bare several similarities to models created in the information systems field. In this research field, the relationship between new technology and benefits of its implementation has been the focus of study for many decades (Brynjolfsson & Hitt 2000, Taylor 2007). In the 80s and 90s when computers started to be implemented on large scale in many different industries a lack in expected productivity growth was observed. The relationship between investment in IT, and increases in productivity, was described as the "productivity paradox" and has long been studied (Brynjolfsson, 1993, Brynjolfsson & Yang, 1996). More recent research on this phenomenon have found four main reasons for why research has not been able to show increased productivity when implementing IT (Brynjolfsson & Yang ,1996; Brynjolfsson & Hitt 1996, Brynjolfsson & Hitt 1998); mismeasurement, redistribution, time lags and mismanagement. Brynjolfsson & Hitt (2000)

continue to describe how IT is an enabler of developing the organisation and its business processes and work practices, and that it is by these organisational changes that productivity can be increased. That is to say, information and communication technology (ICT) enable subsequent changes in work practices which in turn enable greater productivity. These results have been mirrored by Venkatraman (1994) in a model describing the relationship between degrees of Business Transformation and a range of potential benefits with implementation of new ICT.

This model is almost identical with the models describing BIM maturity developed today. In the model lower benefits are gained at lower levels of business transformation while the greatest benefits are granted with redesign of business network and redefinition of business scope (Venkatraman, 1994). These conclusions are directly in line with current research on BIM where it is argued that in order to achieve successful implementation of BIM and make use of its potential benefits, there is a need to understand how the implementation is dependent upon conducting the necessary changes in the organisation (Succar, 2010). One major benefit of BIM is the ability to address the fragmentation of the industry by improving collaboration and communication of the stakeholders (Mihindu & Arayici, 2008, Froese, 2010). In order for BIM to achieve its full potential and gain the predicted outcomes, Froese (2010) argues that changes in the organisations work practices and changes in the skills of the project participants are required.

Altogether, when implementing BIM the greatest benefits will be gained at the higher maturity stages of BIM-use. At these stages the change of work practices plays a vital role changing project participants from fragmented actors delivering work results to each other in sequence to an inter-organisational and integrated collaborative team working together with the project. All project stakeholders are argued to benefit from this development. In order to correctly account for the benefit from the investments of BIM a shift from the focus of individual actors to the project is needed (Dehlin & Olofsson, 2008). It is at the project level rather than at individual stakeholders the influence of BIM can be seen. As it is argued that it is the client that is the greatest benefactor of BIM evaluations of the results of BIM-use should be done on the project level (Olofsson et al., 2008).

2.3.2. Public client's role in BIM implementation

As described earlier Client organisations are argued to be the actors both with the greatest potential benefits from BIM implementation and also the actor in a position able to influence other project participants. Supporting these conclusions, research has argued that national leadership and coordination are the most critical factors for successful BIM implementation (Smith, 2014). Smith (2014) further states that this leadership is needed to coordinate the actors in the industry and to avoid many problems with disjointed BIM implementation approaches.

Many researchers focus on the need for government entities to provide this leadership and how these entities need the support of other major players in the industry (Smith, 2014; Khosrowshahi & Arayici, 2012; Wong et al., 2011). Further a consultancy report has shown

that client driven BIM implementation has the most chance of success and that government mandated seems most effective as a driver (McGraw Hill, 2014). In detail these mandates constitute demands on all firms linked to projects with government clients to become BIM capable otherwise they will not be able secure any future projects. These types of mandates can be found in the US, UK and Singapore and have there been argued to be successful in providing a catalyst for the industry to adopt BIM.

Further, public clients have been argued to have to take an active part in the implementation and use of BIM in construction projects. Porwal & Hewage (2013) present a BIM partnering framework which is argued to support the development of BIM in construction projects. They argue that as clients are bound to procedural and legal frameworks in public procurement settings, there is a need for a different approach for collaborative BIM developments in this setting. This procurement framework is argued to be able to address legal, procedural and cultural challenges with the implementation and use of BIM. Further, the study showed that the following issues were of importance in the implementation of BIM (Porwal & Hewage, 2013):

- The need for guidance, where to start, what tools to use and how to address legal procedural and cultural challenges with the implemented technology.
- BIM capabilities of the project participants.
- Potential for project participants to gain the required BIM capabilities if currently not obtained.
- Training and support implication of key project stakeholders
- Lack of availability of required tools in the specific project.
- Conflicts and risks with changing work practices by the implementation of BIM.

These conclusions are well in line with the majority of studies arguing for the client's role in implementing BIM. These studies argue for the client organisation's role to be twofold: First to initiate interest for BIM by demanding it in all projects and secondly to actively take part and develop the use of BIM in the projects.

2.4. Actor-network Theory

In Actor-network Theory (ANT) society is viewed as an interwoven socio-technical web (Hanseth & Monteiro, 1997). This web is built up of a highly heterogeneous network of actors, institutional arrangements, textual descriptions, work practices and technical artefacts (Hanseth & Monteiro, 1997). This makes ANT concerned with studying the social and the technical together. Instead of studying the social and technological elements as relatively separate, ANT treats them as inseparable and makes an argument for analysing people and artefacts with the same conceptual apparatus (Walsham, 1997). Within these networks one or more of these actors try to make themselves representatives and spokespersons for other actors by translating their interests to others and making these interests generally accepted (Linderoth, 2000).

ANT was first developed by Michel Callon (1986) and Bruno Latour (1987) in the late 80: s. This theory has later become much criticised. Even though the harsh criticism, the theory has its strengths and has often been related to the IS research field (Tatnall & Gilding, 2005; Walsham, 1997). Relating to this research field (Walsham, 1997) presented a list of key concepts relevant in the theory:

- **Actor (or Actant)** – Both human and non-human entities
- **Actor-network** – Heterogeneous network of actors with aligned interest, these include people, organisations and standards
- **Enrolment and Translation** - Creation of bodies of allies, both human and non-human, by translating their interests aligning them with the actor-network
- **Delegates and Inscriptions** – Delegates, actors who "stand in and speak for" particular viewpoints which have been inscribed in them.
- **Irreversibility** – The degree to which it is subsequently impossible to go back to an earlier point where possible alternatives exist.
- **Black box** – A frozen network element, often with properties of irreversibility
- **Immutable mobile** – Network element with strong properties of irreversibility, and effects which transcend time and place

All these concepts are linked to the translation process where one actor tries to influence others in the network. In order to reach successful translation, the leading actor and its arguments have to go through a number of 'tests' where other actors have to be enrolled and convinced of the value of accepting the translation (Latour, 1987).

2.4.1. Sociology of translation

Callon (1984) identifies four moments of translation in the process of a driving actor to impose themselves and their definition of the situation on others, these steps are: problematisation, interessement, enrolment and mobilisation of allies. These moments represents different phases of the general process of translation. During this process the identity of the involved actors, the possibility of their interaction and the space for them to manoeuvre are negotiated and delimited (Callon, 1984).

- *Problematisation* - The first moment in this process is the problematisation, or becoming indispensable. In this stage one or some of the actors present a new idea, this can be a problem or a new opportunity. In this stage it becomes relevant to identify the actors who are indispensable to address the problem or reap the benefits of the opportunity. It also becomes relevant to specify which roles and relationships these actors should have. All the identified actors will have different interest and goals in this stage. It becomes relevant to find one question, an obligatory passage point (OPP), which can benefit all the indispensable actors. The involved actors should be convinced that their alliance around the question will benefit them all. The process of problematisation also possesses dynamic properties for the network: It indicates which actions that must be accepted and also which alliances that must be forged. It "fetters" the linked actors together; they cannot attain what they want by themselves (Callon,

1984). The obligatory passage point represents the question which answer can benefit all the actors in the network, regardless of their motivations, and which is dependent on the involvement of all the identified actors.

- *Interessement* - The second stage in the translation process is how the actors take their places in the network. Callon, (1984) describes this phase as follows:

  "…the group of actions by which an entity attempts to impose and stabilize the identity of other actors it defines through its problematisation."

  In this stage steps to isolate the identified actors have to be taken. The actors identified in the problematisation are linked to the problematisation of other actors. Consequently their identities are also defined in relation to these competitive ways. To interest actors is to construct devices between them and other entities who want to define their identities in other ways. The leading actor interests the actor identified in the problematisation by isolating it from other actors who may want to link themselves to it.

- *Enrolment* - In this phase the actor's roles are stabilised in the network. As the interessement does not necessarily lead to the desired alliances the roles of actors are further defined and coordinated. This enrolment does not imply or exclude pre-defined roles, rather it sets a frame by which a set of interrelated roles is defined and given to actors who accept them. Callon (1984) further describes enrolment as follows: "To describe enrolment is thus to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessement and enable them to succeed". In this stage the issue is to transform the question stated earlier into a series of more certain statements. The enrolment is generally simplified if the questions stated in the obligatory passage point have generated a favourable outcome.

- *Mobilisation of allies* - If the three earlier stages of the translation process have been successful, an actor-network has now been formed. However, in this network only a few individuals are involved. An issue now arises of how representative these spokespersons are for the actor they represent in the network. Callon (1986) describes this issue as "will the mases follow their representatives?". The actors involved in the network must mobilise the group they are representing, their allies.

  The actor-network developed in the process is however not stable. Through the different stages betrayals and controversies will arise. Callon (1986) describes this as: "Not only does the state of beliefs fluctuate with controversy but the identity and characteristics of the implicated actors change as well". To minimise the risk for this and to stabilise the network it becomes important to reach closure. Closure arises when the spokespersons are deemed to be beyond question. This is a process that is generally not obtained until a series of different negotiations have has taken place and this could take long time. Relating to the stabilisation of the network is also the creation of black boxes.

2.4.2. Black boxes and Inscriptions

There are several concepts linked to ANT that plays a large role in the translation process. As described earlier the process of translation is the process of one actor to impose themselves and their interpretation of a problem on other actors essential for the problems solution. How large and stable this network then becomes is dependent on how much the actors can place in their black boxes Linderoth (2000). Callon & Latour (1981) describes this process as follows:

"An actor grows with the number of relations he or she can put, as we say, in black boxes. A black box contains that which no longer need to be reconsidered, those things whose contents has become a matter of indifference. The more elements one can place in black boxes – modes of thought, habits, forces and objects – the broader the construction one can raise."

The black boxes often have properties of irreversibility, that is to say, a large degree of difficulties to go back to a point where alternatives where possible (Walsham, 1997). The black boxes can also remain even when the network is no longer dependent on the interactions that created it (Callon & Latour, 1981). With this follows that actors can be changed without redefinitions of the network itself (Linderoth, 2000).

Inscriptions are also an ANT related concept. Inscriptions refer to how actions following the desired program of actions are inscribed in an artefact, guiding and restricting the use of said artefact towards the desired program. In terms of technical artefacts the developer tries to define their potential user, their competence and the context where the artefact will be used (Linderoth & Pellegrino, 2005).

These inscriptions can have different levels of power and flexibility (Linderoth, 2000). Inscriptions with high levels of flexibility do not guide the artefact's program of use as much an inflexible inscriptions. However, the power and flexibility of inscriptions can change through a series of translations. Latour (1990) exemplifies this by describing how a hotel manager tries to makes his guests to follow a desired program: to return the room keys when leaving the hotel every day. In a series of translations the hotel manager start with a sign asking the guests to return their keys, a not very powerful inscription as many of the guests do not understand the language and later attaching a metal weight to each key thereby inscribing the desired behaviour more powerfully. This later inscription was powerful enough that most guests followed the desired program, leaving the keys, rather than the anti-program of keeping them. How powerful inscriptions are depends upon the irreversibility of the actor-network in which they are inscribed (Hanseth & Monteiro, 1997). You can never in beforehand know if the inscriptions will be powerful enough, but by studying the sequence of attempted inscriptions we learn more about the specific inscriptions needed to make the actors follow the desired program (Hanseth & Monteiro, 1997). As in the case of the hotel manager, the first inscription was to put up signs and later attaching the weighs to the keys. The inscriptions are also linked and thereby accumulating more power.

2.4.3. Applying ANT

Actor-network theory, in spite of its name, is not only a theory, rather it is theory and methodology combined (Walsham, 1997). ANT provides theoretical concepts by which the world can be viewed; it also suggests that it is these concepts that should be followed in empirical work. Thereby ANT leads the researcher to investigate and document network elements, both human and non-human, the translation process and inscriptions, how black boxes are created as well as the stability and irreversibility of the network and the elements that construct it (Walsham, 1997). This is an extensive task which is one major critique of this theory (Walsham, 1997).

During the progression of my PhD studies, I have on several occasions in different settings and by many different researchers got the advice not to go too deep into ANT. The reason for this has varied, but many due to the complexity of such a study and the time constraints in the PhD studies. However, most of these warnings of ANT in its entirety have ended with the suggestion of taking inspiration from the theory to explain the processes currently underway with the introduction of BIM in the Swedish infrastructure sector.

The concepts presented in this theory chapter are very applicable when explaining the current workings towards BIM-use in this organisation. More on how I have taken inspiration from ANT when interpreting my empirical material in the method chapter.

3. Method

In this chapter the research study this licentiate thesis is based upon is in focus. How the study was initiated and conduced, which methods that were used and how the empirical material was analysed are also elaborated upon.

3.1. The research study

This research study has been financed by the STA, with the expressed purpose of analysing the applied use of BIM in the infrastructure sector. When the study was initialised it was part of two parallel studies focusing on different aspects of the use of BIM. The first had the purpose of analysing technical aspects of BIM while the second, this one, would focus on how BIM implementation influences changes to the project management role. However, the first of the studies was never started and instead this study became a standalone project. The research project was started in the end of 2013 and has continuously been in contact with STA as the main source of empirical material.

At the outset, the purpose of the research study was to analyse how the implementation of BIM influenced and changed the project management role. The main questions were: How new tools could be used, how new problems were needed to be addressed by project managers and how a new BIM-centric project process would change the overall role and work practices of project managers from the client perspective. Generally studies of BIM tend to focus on construction of buildings rather than infrastructure. As there are differences between these two areas a focus on infrastructure could address a gap in knowledge. This study was initially aimed at helping the STA to develop their BIM-use and give insight into how BIM can be used to support project manager's work.

The scope of the research project was later changed into two stages: first to study the BIM implementation process and later focus on how this process influenced the project management role. At the start of this research project, at the end of 2013, there were some projects at the STA using BIM, but these projects used BIM at varying degrees with widely different results. In order to get reliable results of the influence of BIM, there was a need to understand the BIM concept and how it was interpreted at this implementing organisation. Therefore the BIM implementation process has been in focus in this licentiate thesis. This process presents an empirical example for a technology driven change process which in turn influences the organisation in which it is implemented. By understanding this technology driven change process, insight in how actors are influenced by large implementation initiatives like BIM can be gained. In the continuation of this research project it will be supplemented with a study focusing on how the implementation process has influenced the project management role.

3.2. The Swedish Transport Administration (STA)

The STA is the Swedish authority responsible for the construction and maintenance of a majority of the infrastructure installations in Sweden. In this capacity it is the largest client of infrastructure projects on the Swedish market. In the regulations of this organisation is states

that this organisation in their role as client should work towards increasing productivity, innovation and efficiency on the markets of investments and management of infrastructure (SFS 2010:185).

In 2012 a Swedish government official report presented suggestions that this organisation, in its capacity of a large client, should evaluate the use if BIM and work towards BIM usage in the infrastructure sector of the AEC-industry (SOU 2012:39). Following this this report in February of 2013 the general director for STA made a formal decision to implement BIM in the whole STA. Several BIM related initiatives have been initiated related to this decision and these have been covered in this study.

The STA is organised with several sub department with different responsibilities. In this study the most prominent departments have been: Investment, large projects and maintenance. Of these two, investment and large projects are the two departments preforming construction projects. The investment department collects the main bulk of projects, everything from small improvement projects to larger road or railway construction. This department works relatively standardised with projects managers conducting multiple projects simultaneously. Large projects collect the largest and most complicated of the STA's projects. These projects are driven more independently from each other and have larger internal support structures. These two departments do not have extensive collaboration and addresses the project process very differently. This difference is a very important aspect in how they link to the network around BIM.

3.3. Research design

In this study a hermeneutic perspective has been taken from outset. The development of the knowledge of technology driven change processes has been the main objective throughout the research project. In order to fulfil this objective, qualitative research methods have been used. Qualitative research aims to analyse the subjective meaning or social production of issues, events or practices (Flick, 2009). Thereby qualitative research tries to understand, describe and give meaning to the studied phenomenon. A case study of the BIM implementation at the STA has been conducted and supplemented with interviews and document analysis. The studied implementation process of BIM at the STA was proceeding in parallel with the study. By applying a qualitative approach, the network in which BIM was discussed could be mapped. The different actor's subjective understanding and opinions regarding the change process could continually be studied.

In this study an inductive perspective has been used in which the results have been analysed trying to find generalizable conclusions. In order to interpret the results an actor-network Theory (ANT) inspired approach has been applied. ANT related concepts and processes have been used to categorize and interpret the findings of the study. However, ANT in itself does not constitute a complete theory explaining the change process in question (Walsham, 1997). Rather ANT has served as a framework by which the empirical findings have been structured in order to enable analysis from further theoretical perspectives.

3.4. Case study approach

When studying organisational change processes related to the implementation of new IT the use of interpretive case studies are recommended (e.g. Markus & Robey, 1988; Orlikowski, 1992; Linderoth & Jacobsson, 2008). A single-case study (Yin, 2013) has been conducted of the BIM implementation process at the STA. However, when the BIM issue was initiated at the STA, several initiatives relating to BIM-use was conducted simultaneously. Therefore, the research case-study started with a formative stage trying to understand and limit the scope of the case. The first task in the case study was to identify the parameters relating to the technology driven change process which the research study was aimed to understand.

3.4.1. Start of the project - the formative stage

The study started in late 2013. At this time the general director at STA had taken formal decision to implement BIM in the organisation. As a consequence of this decision a project to introduce BIM into the organisation was initiated, "the BIM initiation project". In parallel with this project, two other initiatives were conducted, both relating to some degrees to BIM: Virtual Construction for Roads (V-Con), Anläggningsdata (AnDa). Even though all these initiatives addressed management of information in some ways, the issues was addressed very differently and very limited cooperation can conducted between them. Therefore the first task was to identify the actors relating to the BIM implementation process at this organisation and delimit the case which to study.

- **V-Con - Virtual Construction for Roads** - This was a BIM related collaboration taking place between the STA, the Dutch agency Rijkswaterstaat and the two scientific institutes TNO from the Netherlands and CSTB from France. The STA was connected to this project and therefore had a thorough insight in the V-Con project. Several semi-structured interviews provided an understanding of this project. Additionally a pre-commercial procurement process linked to this project was observed where software developers were involved in this project. However, early results showed that this project focused on the standardisation and classifications related to the development of BIM. The project was aimed to have an impact on a European Union level, and have an impact on the development of BIM related solutions applicable in various countries. Early results also indicated that this project (V-Con) worked with the development of BIM as a technology and not directly with how this technology would be applied in organisations.
- **AnDa – Anläggningsdata (facility data)** – This was a project started to develop the use of digitalised information for maintenance of roads and railways at the STA. This project was studied early in the research project by document analysis. AnDa was led from the maintenance side of STA and mostly associated itself with the management of information. This project did not have any direct influence on how projects were to be conducted, but rather developed the how information should be managed in the maintenance side of this organisation. It also did not use the phrase "BIM" explicitly and therefore was suitable as the main focus in the research study.

- **The BIM initiation project** – This project was early categorised as a major source of empirical material for the research study. It was started as a direct response to the general director's decision to implement BIM at the STA. The BIM imitation project was the centre-point for the BIM work at this organisation. One of the early "BIM-days" at the STA was studied and there a first impression of the BIM implementation process at this organisation was obtained. The study also was able get extensive insight in guidance documents of this project as well as the results this project produced. Linked to the BIM initiation projects were a total of 28 BIM pilot projects in which BIM usage was tried and evaluated. These pilot projects provided a great start for analysing BIM usage at this organisation.

Based on this analysis the BIM initiation project was categorised as the main focus in the case study. However, the case study did not limit itself to the specific BIM initiation project; instead the surroundings and actors linked to this project were mapped and included in the case study.

3.4.2. Continued work, the explorative stage

In order map the circumstances of the case the project manager for the BIM initiation project was interviewed in depth to get her perception of BIM at this organisation. The person responsible for the development of the technical aspects of BIM was also interviewed. These two interviews were supplemented with a document analysis of several documents produced in this project, such as the project specification, official BIM strategy, several BIM presentations and later the guidance documents this project resulted in.

Several pilot projects were connected to the BIM initiating project, trying out the use of BIM in a construction projects. The BIM pilot projects were often referred to in the early BIM implementation process. The project managers of these projects were contacted, but it was revealed that the situation was more complex than initially thought. As described in paper 2, these projects were of three different categories, projects using BIM even before the BIM initiation project, project using BIM to a limited degree as a consequence of the project or project not using BIM at all. Most of the pilot project managers were unwilling or sceptical to participate in interviews as they did not believe that they could contribute to the research project. The project managers willing to contribute were mostly connected to the projects in the first category. Based on the results in this stage of the research project it was concluded that there was not one way BIM was being used at this organisation and therefore no way to gain generalizable conclusions of how BIM implementation influences the project management role. However, much empirical data of how this organisation was developing their BIM implementation had been gathered. Therefore a change in the purpose of this research study had to be done. Instead of directly study how BIM implementation influenced the project management role, the BIM implementation process was studied first. Later, when the implementation process had come further the project management perspective was added to fulfil the initial aim of the research study.

This perspective of understanding the BIM implementation process at this public client organisation is prominent in appended paper 1 and 2 of this licentiate thesis. These papers served as a stepping stone in my development as a researcher and paved the way forward to the use of ANT.

3.4.3. ANT as a way of understanding the implementation process

In order to understand and interpret the process in which the BIM issue was initiated and developed an ANT inspired approach was applied. Sociology of translation, as described by Callon (1984), identifies four stages in which an actor tries to impose themselves and their understanding of a problem onto others. Sociology of translation serves well to model the process in which the BIM issue was managed. The group of the BIM initiation project act as the main driving actor. Their understanding of BIM is the solution which they try to enrol other actors into accepting.

By mapping the actor-network which the BIM initiation project is trying to establish, both actors included and excluded can be identified. Ways of enrolling actors into this network can be identified by the actions of this actor. Triangulating findings from interviews, document analysis and observations presents a diverse picture of this network (Silverman, 2013). As the BIM issue is presented to have an impact of several actors this actor-network approach is suitable to cover this process.

When studying an implementation process from an actor-network perspective the role of technology is not subordinate to human entities. This aspect of ANT is also well suited to studying a technology driven change process. In the implementation of BIM at the STA, the benefits and difficulties linked to the technology was given a superior priority. Therefore, how the technology influenced the discussions and negotiations are very relevant when studying the implementation of BIM.

In order to map the actor-network surrounding the BIM issue a longitudinal perspective is needed. The translation is a process and continues and changes throughout the process. Therefore it became important to thoroughly analyse how the BIM initiative started and how the process continued. As a public client public organisation, most documents produced by the STA are publicly available. Access to documents and different versions of the same documents enabled insight in both earlier stages of the translation process and also its progression. When supplemented with interviews, exploring the subjective experiences of the individuals involved enabled triangulation of the results. Together this case study gathered a coherent view of the translation process.

The task of completely map an actor-network is a daunting task. Simply the scope of this task is presented as a major critique of ANT (Walsham, 1997). In this study, the ambition to map the entire actor-network has not been taken. Instead, the scope has been limited to focus only on the actors whom the BIM initiative has addressed in the translation process. By the framework of ANT many of the actions of an actor can be explained and help develop the understanding of the client's role in a technology driven change process.

3.4.4. In depth semi-standardised interviews

When studying a vaguely defined concept like BIM it is difficult to develop interview question that are interpreted in similar ways by different interview persons. BIM have many different meanings for different people, and to understand the interview question the interviewee tend to fill in the gaps by applying their knowledge of the concept. Flick (2009) describes this phenomenon with the term subjective theory. This subjective theory of a subject presents the interviewees own and subjective interpretation of the interview topic. This knowledge includes both explicit and implicit assumptions. The explicit assumptions can generally be express spontaneously by the interviewee in answering open questions. The implicit assumptions are harder to access and the interviewee needs methodological aids to access these. These tools are used to reconstruct the interviewee's subjective theory of the studied issue. Interviews based on this method strive to reconstruct the subjective theory of the interviewee. The topics of the interview are introduced by an open question and ended by a confrontational question. These confrontational questions relate to the theories and relations the interviewee has described in the open question, critically re-examining this theory by competing alternatives. (Flick, 2009)

Early in the study it became clear that all interviewees had very different relationship to BIM. With these differences comes varying understandings of the BIM concept. That is to say, the interviewees had varying subjective theories of BIM. In order to understand different actor's roles in the BIM implementation process and their place in the actor-network, is was important to understand their relationship to BIM. By using the method of semi-standardised interviews as described by Flick (2009) it became easier to reconstruct these subjective theories. The subjective theories represented not only BIM but also the role of BIM in relation to the interviewee.

Interviews following this method generally start with very open questions about the interviewee, their role and what BIM is for them. The interviewee then was asked to continue describing their ideas by open and short follow-up questions. To support the interviewee's description of their perceived role in relation to the BIM initiative short comments are given. The interviewee is encouraged to present their narrative of the translation process.

When the interviewee reached the end of the narrative and was finished in presenting their view of the interview topic the interview was continued by several confrontational questions. The questions are generally linked to the subjective view of the subject expressed by the interviewee and relates to information found in documents or in earlier interviews. The confrontational questions tries to question the narrative of the interviewee and encourage them uncover their subjective theory of the subject. For the general structure of the interviews and examples of confrontational questions see Appendix 1.

By this interview process it became possible to reconstruct the different actor's views of BIM. It is also possible to link the different views together by the confronting questions. By this method understanding of different actor's position in the BIM related actor-network can be

gained. Also, how the interviewee relates to actions taken to enrol them into the actor-network can also be found.

As each interviewee has different roles and are located on different locations in the actor-network each interview was prepared differently. Different questions, both leading and confrontational, were prepared depending on the interviewee. Also questions were frequently added and excluded depending on the narrative expressed by the interviewee. Therefore a standardised question template has not been used in the interviews. In case of interviewees with similar roles, for example project managers the questions from earlier interviews were used to devise guidelines for possible question. The follow-up confrontational questions was always linked to the narrative of the interviewee and therefore had to be adjusted to the specific interview.

The interviews were documented by taking thorough notes throughout the interview. The choice of taking notes made the interview flexible in its execution. The ease by which earlier answers could be accessed during the interview enabled a simple creation of the confrontational follow-up questions. Directly after the interview the notes were rewritten to catch the narrative of the interviewee. The transcribed interviews also cover the impressions from the specific interview. The documented interview, the initial notes, the transcriptions and any documents the interviewee referred to during the interview were stored together for easy access.

The choice of taking notes over other means of documenting the interviews was also made to make the interviewee feel confident with the interview situation. In the translation process of BIM many conflicts have arisen and these were often presented in the interviews. To be able to discuss what information is recorded the interviewee can feel more comfortable that their interests are not violated. These issues are discussed more in the research ethics section.

Here follows a list of all interviews linked to the case study:

Interview no.	**Respondent**	**Interviewee's role**	**Date**	**Duration**
1	A	BIM coordinator, Hallandås project	2014-04-28	1,5h
2	B	Project manager, BIM initiation project	2014-04-29	1h
3	C	Technical manager, Förbifart Stockholm	2015-01-23	1,5h
4	D	Member in "BIM area of experience"	2015-10-13	1h
5	E	Project manager, Förbifart Stockholm	2016-01-27	1,5h
6	F	Assistant Subproject manager, Ostlänken	2016-01-28	1h (telephone)
7	G	Specialist Data coordination	2016-01-29	1h
8	H	Co-founder in the initial BIM network at the STA	2016-02-25	2h

9	I	Project manager, BIM implementation project, “Investering”	2016-02-23	2,5h
10	I	Project manager, BIM implementation project, “Investering”	2016-03-11	0,5h (telephone)
11	H	Member in “BIM area of experience” and supervisor	2016-04-06	2h
12	H+I	Member in “BIM area of experience” and supervisor + Project manager, BIM implementation project, Investering	2016-05-26	2h
13	D	Member in “BIM area of experience”	2016-06-10	1,5h
14	I	Project manager, BIM implementation project, “Investering”	2016-09-14	2h
15	I	Project manager, BIM implementation project, “Investering”	2016-10-05	2h
16	A	Manager “BIM area of experience”	2016-10-06	1,5h
17	J	Project manager, BIM implementation project, “Stora projekt”	2016-10-11	1h
18	A	Manager “BIM area of experience”	2016-12-05	1,5h

3.4.5. Document analysis

In the frame of this research study many documents relating to the BIM translation process have been analysed. As a public actor, most of the documents linked to the BIM implementation process have been open for me as a researcher. The documents present the main way of information within the organisation, presenting directions and strategy, presenting guidelines and setting up demands on external actors. By studying the documents it was possible to get an understanding of the official description of the BIM implementation process that is presented to the whole organisation. The main deliverables of the BIM initiation project was also several documents: A BIM strategy and new guidance documents. By studying the documents the ways in which actors are enrolled into the BIM issue were analysed. The documents also went through several iterations and are constantly developed. To be able to follow their development a longitudinal aspect of the translation process can be gained. Additionally the analysis of the documents has served two major purposes in the case study:

- To understand the official method by which this client organisation translates BIM to actors linked to construction projects conducted by the STA.

- To serve as the foundation for the how the subjective theories can be reconstructed.

The subjective theories of BIM found in the interviews relate to the view presented in the documents. Most often the subjective theory differs from this view, and the differences are very relevant when understanding how different ideas of BIM are present at this organisation.

In addition to the official documents, several referral processes have been studied. These processes are relating to the development of official guidance documents. By studying the referral responses it has also been possible to get an insight in the wide difference of subjective theories relating to BIM. This information has been used to interpret the responses to the open questions in the semi-standardised interviews as well as devising the follow-up confrontational questions.

3.5. Research ethics

As BIM is an issue with several different often conflicting views, it soon became clear that research ethics would be major concern in this research study. During interviews the topic of not taking notes on sensitive information came up on several occasions. Therefore it has been important for me as a researcher to establish a safe interview situation where the interviewee can feel comfortable with the information they share. It has been important for me to distance myself from the organisation and always present myself as being a researcher from a university rather than a participant in the implementation process, stressing my impartially. Often the interviewee was able to elaborate on the sensitive information and thereby felt comfortable with me taking notes and using them in my study.

Often the conflicts occurring in relation to the translation process are of great interest in order to understand said translation. Therefore the discussion around sensitive topics has stressed what aspects of the conflicts are of interest for the study. The opportunity for the interviewee to further develop their narrative has always been given to ensure that the documented interview rightfully portrait the interviewee's picture. The choice of taking notes over recording the interviews have also been taken to establish a more trustworthy environment for the interviewee. This way the interviewee can be sure that anything they are not comfortable with is not recorded.

3.6. Limitations

There are limitations linked to the method used in this research study. As presented by Flick (2009), the semi-standardised interview can cause irritations with the confrontational questions as the interviewer might have problems in making the method clear. To mediate for these problems, the confrontational questions have been phrased in the form of ignorance from the interviewer's part rather than questioning the competence interviewee.

As discussed earlier, the mapping of an actor-network is an extensive task requiring numerous sources of empirical material. The somewhat limited amount of interviews can be considered a limitation in terms of reliability of the study. In order to mediate for this the interviews has

been made in depth and often with follow up interviews to be sure that the subjective theory of the interviewees has been reconstructed in a reliable manner.

In the research study, I as a researcher have had contacts with some individuals at the STA more than others. With this situation follows a risk that other individuals link the research study to the individuals with which most contact is given. To address this issue, actions to establish the research study as being conducted by representatives for an outside actor have been taken. Communication with individuals of interest for the study has always been taken from KTH channels, using mainly the KTH e-mail service.

In addition to these limitations the ANT inspired approach also suffers from several limitations. Mainly these stem from the fact that it has not been possible to map the entire actor-network relating to the translation of BIM. However, this has not been my ambition, rather the goal has been to use ANT inspired concepts to develop the knowledge of the translation process. It is also problematic that this translation process is currently ongoing, continuously developing. Generally, ANT studies analyses a past event trying to explore the reasons behind the outcome. As this translation process is ongoing, the research study can have an influence on the studied translation process thereby changing it. The situation has further highlighted the importance to distance the research study from the studied organisation in order not to contaminate the empirical material.

4. Findings

In this chapter the findings of the research study is presented. The results of the three appended research papers present the main bulk of the findings. This chapter links these three publications together as well as in greater detail presenting the translation process in which the BIM issue was initiated, developed and implemented in the STA.

4.1. Translating BIM

The story of BIM at the STA is the story of translation. It is the story of how a small group of project managers, early adopters of BIM, tried out the new technology in their construction projects. Later the project managers tried to impose themselves on the rest of the organisation in order to influence it towards the use of the technology. This technology driven change process was however not only influencing single components in construction projects, instead it was early understood that BIM would have an impact on a multitude of actors. In order for the project managers to influence these actors, there was a need to understand the network in which this this implementation process was taking place. In order to describe this process the four stages from sociology of translation (Callon, 1984) is used. In this way it is presented how the network surrounding the BIM implementation process was developed and how various actors were linked to the translation process. The process of translating BIM at the STA is presented in appended paper 3 and further developed here.

4.1.1. Problematizing BIM

The BIM interest at the STA was initialised by individual construction project managers around 2010. At the time, the STA went through a lot of turmoil. It had just been established in 2010 and was the result of a combination of two predeceasing organisations: the Swedish Road Administration and the Swedish Railway administration. During this reorganisation the leadership was unclear. According to one of the more influential project managers in an early BIM project, this lack of guidance enabled the BIM developments. Resourceful project managers had a large degree of freedom to take action and start new initiatives. Several project managers got inspired by the buzz around the BIM concept and tested it to various degrees in their projects. To support one another and share experiences these project managers grouped themselves in a BIM network. The network was not managed centrally but was an unstructured forum where BIM interested individuals could exchange knowledge and experiences. The network linked individuals from several of the at the time largest infrastructure projects in Sweden. Many of the individuals linked to the network also had contacts in the BIM organisation BIM alliance Sweden which influenced their interpretation of the technology.

The Swedish government authorised a committee to analyse the public client organisations measures to increase productivity and innovation in the infrastructure sector of the construction industry. This committee started their work in 2009 and resulted in a Swedish Government Official Report in 2012 (SOU, 2012:39). The report suggests that the STA should take the initiative and initiate the implementation of BIM in the infrastructure sector of

the construction industry. According to interview 8, some of the project managers linked to to the BIM network were directly involved in the writing of this report and thereby had a large impact on it. Following this report the General Director for the STA decided upon: "a coordinated and controlled implementation of BIM, Building information modelling/model in the whole STA". This decision was made in February 2013 and thereby the BIM issue received some degree of legitimacy in the organisation. Following this decision, the first BIM implementation project was started: the BIM initiation project. Many of the individuals linked to the BIM network was included in this project and thereby continued their work towards BIM. The BIM initiation project was subjected to be the first structured in the implementation process and to pave the way for future BIM-use.

The BIM initiation project was started in late 2013.One of the first tasks undertaken in this project was the development of a BIM strategy for the STA. This strategy document describes BIM as: "the use of information models in a continuous flow through the main processes connected with a constructed facility". Further it is expressed that object oriented information could be used for multiple purposes, such as: clash control, analysis of different design alternatives, cost calculations and time scheduling. The combination of these benefits was expected to result in a more efficient project process. This BIM strategy relates to the BIM maturity model developed in the UK which describes four BIM levels, 0 to 3. It is stated that the STA should develop the prerequisites to demand BIM level 2 from 2015 and onwards.

In order to achieve the benefits presented in the BIM strategy the BIM Initiation project formulated questions in relation to how BIM should be implemented. These questions related to implementation barriers like interoperability and other technical aspects of adoption. Additionally the main question was how to influence projects to use BIM, thereby enabling change and make them to adopt to the new possibilities. How BIM implementation is linked to benefits and changes are further presented in appended paper 1.

Identification of actors

During the problematisation several actors were identified as essential for the use of BIM at the STA. These actors are discussed and addressed in the BIM strategy document and in the questions and difficulties identified as barriers to BIM adoption. As these actors were identified as essential, their involvement and enrolment became the centre point in the continuation of the BIM implementation process. These actors were: The project-conducting departments of the STA, Third party users and the BIM technology.

- *The project- conducting departments of the STA* – For the STA to take part and use the new possibilities with BIM, their own organisation was identified as an actor that needed to change. In order to influence change towards BIM supported work practices throughout the life cycle of projects, the construction projects conducted by the STA was identified as an essential actor to drive implementation. By ensuring that STA representatives work with BIM in projects, influence on other actors is predicted. As better information management were expected with BIM-use, the rest of the STA organisation is expected to follow and use the improved information created in the

projects. In this way the construction projects at the STA serves as a proxy for the rest of the organisation.

The projects are however not a perfectly homogenous group. Most prominent is the difference between projects conducted in the different departments of the STA, investment and large projects. The projects all have their own possibilities with different project goals. The projects and their project managers are still addressed as a united group in the BIM adoption process and identified as the first essential actor in the BIM network.

- *Third party users* –The contractors, designers and consultants linked to the construction projects conducted by the STA. In order to adopt BIM, it is these actors that need to deliver project related information in new ways. Higher levels of BIM maturity require changing work practices with more cooperation and exchange of model based information. In order to support the use of BIM in the project-networks, third party actors need to be influenced to work collaboratively through the use of BIM.
- *The BIM technology* –BIM as a concept was tested in several projects linked to the initial BIM network. From these projects it was shown that it could be used to varying degrees and with different outcomes. Depending on how it is used it has different requirements. More advanced collaborative uses of BIM requires more advanced models and higher levels of interoperability. The level to which BIM should be used in projects will have to be addressed in the implementation process. Infrastructure, unlike house construction, has not been in focus in the development of BIM tools. As indicated in interview 9, there are currently problems in expressing drawn out objects, like roads and railways. This situation hinders the use of BIM in infrastructure projects. Interview 11 revealed that standardisation is also an issue not as developed in infrastructure as in in house construction and especially the issue of road alignment has been identified as a problem when developing models based on open formats. Therefore the BIM technology will have a great impact on how BIM can be used both in construction projects and by the STA as a whole.

It should be noted that other actors were needed to be enrolled earlier to get the BIM implementation process started. These actors, such as the general director were needed to be enrolled to enable the creation of the BIM initiation project but were not addressed in the development of the BIM usage of the STA.

Definition of an obligatory passage point

In addition to identifying the actors deemed indispensable for BIM implementation, the early work of in BIM initiation project argued for how these actors had a common interest in accepting the proposed program, to adopt BIM. The argument for the value in BIM usage was constantly repeated, both in documents and presentations held to promote the program. The long term goal, presented in the BIM strategy document, are that "facility information should, with the help of BIM methods be managed in a life cycle perspective, to ensure that the

information can be managed and used efficiently". As described in appended paper 1, the gains from implementation of new technology are mainly linked to the change in work practices. Therefore an obligatory passage point was devised, presenting how all essential actors would benefit from joining the network and how they should work with BIM. Together with these goals it is presented that all actors in construction projects would gain benefits with a change towards BIM usage. In this way the BIM initiation project had to enrol the actors around these issues:

- To know the extent to which BIM should be used. In other words know how the technology should be used in the projects and thereby how it should influence work practices.
- Ensure that the actors are convinced and they realise the benefits with allying around the BIM implementation process.

4.1.2. Gathering interest and legitimacy

The various construction projects previously connected to the BIM network were after the start of the BIM Initiation project used as pilot projects. Many of these projects were still being conducted and experiences and results from these projects were delivered to the initiation project. In addition to these BIM projects several new pilot projects were started. The pilot projects did however only use BIM to a very limited degree, if at all. The levels to which BIM was used in the different pilot projects and their impact on the BIM translation process is further discussed in appended paper 2.

As the different pilot projects had very different experiences with BIM and used the technology very differently their impact on the initiation project varied widely. Mainly one of the pilot projects, currently the largest infrastructure project in Sweden, had a major influence on the outcomes of the initiation project. In this project the first draft of the demands on BIM were produced. This document was later to be further developed in the BIM initiation project and brought forward to all projects.

In this process the understanding of BIM as initially presented by the BIM network was formalised and accepted as the general BIM view by the BIM Initiation project. In this way the BIM issue was not only relevant for a small group in the BIM network but rather something relevant for the whole organisation. The BIM issue was presented to the different departments at the organisation on several so called 'BIM days'. In addition to these presentations, much informational material was developed and distributed to co-workers at the STA. In this material BIM was presented as something with great benefits and which does not need much change of current work practices.

4.1.3. Enrolling key actors

At its conclusion, in late 2014, the BIM Initiation project delivered a total of 32 documents. These documents contained proposed changes to guidance documents and a few new documents setting up guidelines and demands for BIM usage in projects. The documents went through a thorough referral procedure gaining feedback from many parties, either influenced

by the documents or knowledgeable about BIM. In this referral process numerous comment were gathered. In order to address the comments a document categorising the comments and expressing how they would be addressed were created. In this document a total of 314 comments are collected of which around 220 were addressed directly or referred to the continued work of the BIM implementation process. After major reworks all the 32 documents had been implemented in some form the mid-2015. Among the 32 documents were three new documents describing the use of BIM in the organisation. These three documents describe demands and guidelines on the use of Object Oriented Information Model (OIM). These documents details the demands on how object oriented information should be produced and shared within projects. Further these documents also contain guidance for how project participants from the STA, such as project managers, should work with BIM. How the new documents relates to changes in work practices are more described in appended paper 2.

The new demand document, the OIM, was implemented in 2015-06-01. This document is in turn referred to by guidance documents describing how projects should be procured and became active when the procurement template was updated in 2015-09-09. As the main deliverable, the 32 documents make up the central part in the enrolment of the actors identified in the problematisation stage. The documents address all the actors and their relation to the BIM issue. Through these documents the actors are enrolled into using BIM the following ways:

- *The project conducting departments of the STA* – By making changes to guidance documents and procurement templates, object oriented models (BIM models) are introduced as a preferred alternative to traditional drawings for managing project related information. When accepted, the documents demands that the deliverables from contractors and consultants in projects should be done in coordinated models. The coordinated models should contain all project related information in one or a few models, thereby combining information created by many professions into a single or a few models. The new guidance documents also describe how the models should be produced and managed in the projects. The majority of the changes to existing documents contained the change from "drawing" to "model".

  Further the documents present a ‘base level of BIM-use’. A level that is supposed to the lowest level of BIM maturity used in construction projects conducted by the STA. The documents also stress the responsibility of project managers as change agents and their role to initiate change in their particular projects. It is presented that it is the project manager’s responsibility to ensure that the project team has the right competence to use BIM. The documents do however not describe how the internal project organisations at the STA should make use of the models and change their work practices.

- *Third party users* – The BIM introduction project did not address this actor directly in the translation process. Instead this actor is enrolled by the new demands for BIM described in the procurement templates. As it is described that project information should be delivered to the STA in coordinated models, new demands are put on the

main contractor to create these models. This contractor is in this way incentivised to influence other project participants to collaborate trough BIM. By this collaboration the creation of the collaborative models are simplified as they can be created continuously trough the project process. To work with BIM supported work practices from the outset are assumed to make the creation of the coordinated models easier, thus giving the main contractor the incentive to promote BIM to all project participants.

In this way the work practices in the project coalition are only addressed very limitedly in the demand documents. There are no explicit demands on collaborative BIM-use, only the delivery of coordinated models. The reason behind the choice, not to influence work practices in detail, was due to conflicts with other initiatives at the STA described later. However, some guidelines and demands on use of the models are still presented in the demand documents. It is specified that models should be the basis for the creation of bills of quantities. Additionally there are demands that are aimed to support the use of models as the basis for machine guidance and other construction site related issues. The demands relating to work practices were included in the demand documents and became problematic later in when the documents was implemented.

- *The BIM technology* – How the models should be produced and managed was identified as a major issue in the implementation process. Problems with interoperability and software were identified as problematic in the pilot projects. To address this problem the guidance documents mostly specifies .dwg/.dgn file formats. This choice of file formats is far from the open and object oriented information initially aimed for; however it was found that it could not currently be done in the infrastructure sector.

  The majority of the material in the demand document relates to the technical aspects of models. Classification of the information is presented as an important issue and relates to the Swedish standard BSAB.

4.1.4. Mobilising the organisation to accept BIM

During the concluding phases of the BIM initiation project two BIM implementation projects were started. These projects were initiated in both of the two project conducting departments of STA, Investment and Large Projects. These two implementation projects were started to interpret the deliverables from the BIM initiation project and implement them in their respective part of the STA. Thereby the implementation projects acts as spokespersons for the construction projects conducted by the STA. By the nature of how the BIM issue was translated by the BIM initiation project, the construction projects managers at the STA were given a large role as change agents. The construction projects and their managers are directly influenced by the work in the BIM implementation projects as these projects are linked to their respective department of the organisation.

Guidance documents influencing projects are managed by many different departments of the STA. Thereby the BIM initiation project could not directly change the documents at will, but had to enrol these actors into accepting their vision for BIM at the STA. In this translation several difficulties arouse in the interpretation of the BIM concept and how it related to other directives given from competing initiatives such as the professional client initiative.

Professional client initiative

Simultaneous to the development and implementation of BIM, the Swedish Transport Administration worked with another development process, a change towards a professional client organisation. This initiative strives to establish the STA as a professional client organisation, procuring contractors and consultants to conduct the design and construction of projects. This initiative tries to promote innovation and productivity of contractors and consultants by not actively demanding specific solutions. Instead this initiative limits the way in which the STA demands particular work practices and instead focuses on the function of the installation. In this way the STA is supposed to take a step back from projects and not be as participating as have been customary earlier.

The work with professional client and the BIM implementation is somewhat contradictory. BIM-usage is generally relating to new work practices, focusing on collaboration around the joint development and use of models. With the professional client initiative the participating role of the STA to influence these new work practices were limited. Due to this possible contradiction, the general director's decision to adopt BIM specifically states that the BIM implementation should be in line with the professional client concept. As a result the BIM initiation project could not demand BIM centred work practices. Instead, incentives for BIM supported collaboration was presented in the demands for coordinated models.

How this initiative was interpreted in the two different BIM implementation projects varied. Investment which more closely follows directives from the main organisation interpreted this initiative as demands on their role in projects they conducted. Large projects and the BIM initiation project however viewed this initiative as guidelines not limiting their involvement in projects to the same extent.

BIM at investment

According to interview 9 and 10, the activities in the BIM initiation project sparked concern from individuals in the investment department at the STA. There was a worry that the BIM implementation would influence the work practices at the department in ways which were not in line with other directives, such as professional client. This prompted the creation of a BIM implementation project at this department. This project was responsible for interpreting and translating the results from the BIM initiation project into the investment department. One of the early activities in the project was to collect opinions on the new documents in the referral process. In this referral many very critical voices from investment were presented with harsh criticism against the new documents.

Following the extensive rework of the documents presented by the BIM initiation project several other relating templates and guidance documents were changed. The mission statements template was changed in 2015-09-09. This document refers to the BIM demand document, the OIM document, which specifies how project information should be produced, exchanged and delivered within projects. Thereby the demands on object oriented information became active in all projects following the implementation of the new template in September 2015. The impacts the changes have on projects are however limited. Several limitations were included, and the BIM demand document is only referred to in parts and not as a whole. Additionally interview 9 and 10 indicated that the implementation process was given many other limitations, for example no extra cost on projects was allowed. That is to say, no new roles are allowed to be added to increase the internal project organisation and thereby increasing costs of projects. Altogether, the BIM initiation project's influence on projects at the investment department was channelled through the BIM implementation project at this department. In the process the many of the changes was limited to better fit with other directives such as professional clients.

BIM at large projects

The BIM implementation project at large projects are different from the implementation project at investment. It was started to mirror the activities at investment. However, this project has closer connection to the BIM initiation project and was also subjected to continue the collaboration between the BIM pilot projects and the continuing development of BIM at the STA. The largest and most influential pilot projects were projects conducted at large projects. Generally construction projects at this department are managed more independently with larger support structures compared to the investment department. This makes the BIM-use in the projects more diverse. As projects at this department have larger autonomy and project organisations, many of the developments and suggestions for new roles in projects were implemented in construction projects here. According to interview 17, the new demands for object oriented information model developed in the BIM initiation project were fully implemented in this department. However, this department did not have to relate to the same restrictions as at investment and issues were addressed mostly at the specific project.

BIM area of experience

To support the continuing BIM implementation the BIM initiation project was reorganised into a BIM area of experience. This change was done due to the need for an actor to continue the development of BIM at the STA. The responsibilities for this group, the BIM area of experience, are also to manage the documents earlier produced in the BIM initiation project. The documents are the three OIM documents as well as the BIM strategy.

In this group several of the individuals working in the BIM initiation project continued and thereby form a link from the original group of project managers in the BIM network. Within this group, the development of the documents continued. This group also works as the mediator for BIM to the two project conducting departments at STA. Thus the BIM area of experience manages the BIM issue and continues the contact with the two implementation

projects. According to interview 13, the connection between the BIM area of expertise and the two implementation projects varied. From the manager of the implementation project at large project there was a desire for more involvement from the area of experience while the opposite was true at the investment department.

Divergent translations

The BIM network, the group of project managers first trying out BIM in their project even before the formal decision was made, has been the actor initiating the BIM initiative at this organisation. This group has thereby been the actor taking the initiative for the BIM translation process; more discussed in paper 3. In the translation process this actor's main way of enrolling the other actors in the actor-network is by implementing new guidance documents demanding BIM-use in projects. The documents were aimed to be implemented in their entirety in all projects conducted by this organisation. By the implementation all projects would be enrolled into the use of BIM. However, this translation process encountered an anti-program, a competing understanding of BIM. At investment, the department of the STA conducting the main bulk of new construction projects, the work of the BIM initiation project was criticised. The implementation project at investment has developed a competing interpretation of BIM. This interpretation has a closer connection other directives this actor is given from the top management. The two competing interpretations of BIM at the STA are not compatible.

The critique and non-acceptance of the BIM translation resulted in a divergence between the implementation project at investment and the BIM area of experience. In represents a gap between the understanding and vision for BIM at the STA. Resulting from this divergence, two different and competing translation processes arouse. The main difference between these two interpretations of BIM refers to how the translation process should enrol third party actors. Investment has been enrolled in the program of professional client organisation developed by the board level management at the STA. This initiative aims to change this client organisation's role towards a less involved actor during the project process. By this directive it is prohibited to demand certain work practices from third party project participants. The interpretation of BIM translated by the BIM area of experience instead includes several demands on how information should be produced, shared and managed in projects to increase the use of BIM. This translation process argues for the need to help third party actors towards the use of BIM. These two translation processes are contradictory and act as counteracting programs to each other.

5. Discussion

5.1. BIM, a technology driven change?

The BIM concept in construction presents many of the characteristics of a system innovation as described by Slaughter (1998). Use of BIM, especially on the higher maturity stages described by Succar (2009), is expected to influence many if not all actors linked to construction projects. By this extensive influence, BIM is presented as a new paradigm (e.g. Azhar, 2011), a collaborative and inter-organisational use of information with models. However it should be noted that new paradigms only can be observed after a paradigm change. As it has been shown that the use of ICT, when applied to an organisational context, often drifts away from the intentions of the developers (Ciborra, 1997; Holmström & Stalder, 2001), there are large uncertainties when predicting the future of BIM in the construction industry. Simultaneously, many benefits have been shown with the use of BIM. With the use of models, information can be managed more efficiently and sharing of project information can enable more integration and collaboration in the fragmented AEC-industry (Eastman et al., 2011; Azhar, 2011; Steel et al.,2012). The collaborative use of BIM is dependent upon the involvement of a multitude of interlinked actors. If some actors are not enrolled into the use of BIM the value of models decrease as vital information may be lacking.

The system and collaborative aspects of BIM argue for studying the implementation process from an actor-network perspective. This perspective enables analysis of actors' roles and relationships and gives insight into their motives for accepting or rejecting their assigned roles in the network (Linderoth, 2010). As several studies have argued for the importance of client organisations to initiate and drive the implementation of BIM (Wong et al., 2010; Wong et al., 2011; Porwal & Hewage, 2013), the client organisation's role in initiating the creation of the actor-network comes of interest.

The early stages of the BIM implementation process at STA show how the BIM issue was brought forward and which actor that initiated the process. Early adaptors of BIM, construction project managers at this organisation, tried out the technology on their own initiative in their projects, somewhat influenced by BIM organisations such as BIM alliance Sweden. Later these individuals, following their own understanding of the technology, were given the responsibility to manage the BIM implementation process. The way in which the BIM issue was initiated and managed has many similarities to what have been found relating to other technology driven change processes. Currie (1989) and Whyte (2002) describe how middle management and technology experts often are given responsible for achieving sought after results from the implementation of technology. Even when the decision is made by the CEO, Whyte (2002) found a lack of direct involvement by board level representatives after this decision.

It can be argued that the situation in which middle management and experts are given responsibility for the change process are linked to the nature of implementation of advanced technology. The individuals with best insight in the potential and difficulties of the technology are given responsibility for the change process as no other actors have the needed

expertise. The individuals are highly enrolled in the use of the technology and convinced of its utility. Therefore the actor with best understanding of the technology will act as its spokesperson representing the technology during the change process. When this is the case the technology heavily influences the implementation as the leader of said implementation is in effect a proxy for the technology itself. Thus the understanding of the change process as well as the problems linked to the change mainly takes a technological perspective. In effect, the technology itself drives the change process and guides it forward.

5.2. Strategies for translating BIM

BIM technology is widely discussed, both in academia and in the construction industry. There are several predictions and assumed trajectories for how BIM is expected to be developed. The maturity stages presented by Succar (2010) and other similar models express this assumed development. In future use, with higher maturity stages of the technology, numerous assumptions are made, assumptions of the successful way of using BIM. Thereby BIM can be considered a technology with many programs of use inscribed (Linderoth, 2010). However the programs vary depending on what is included in the BIM concept. With higher maturity stages of BIM follows many procedures that need to be followed in order to achieve successful BIM-usage. The opposite is true if BIM is only adopted at lower maturity levels. If for example BIM is mainly used locally, actors do need tools for inter-organisational collaboration connected with higher maturity stages of BIM. This reflection clearly describes how the use of the BIM technology impacts and shapes the network in which it is used.

At the STA, the BIM network followed by the BIM initiation project initiated and led the translation process. It is their interpretation of the problem, low productivity and large possibilities with new technology, that have directed the change process. This actor's understanding of the technology has also influenced which actors that have been identified as indispensable for the solution of the problem, the implementation of BIM. It is also this actor that identified the programs inscribed in the use of BIM relevant for the BIM implementation at the STA. Likewise, the interpretation of how the inscribed programs influence the actor-network around BIM is made by this actor.

The strategy by which the BIM initiation project enrols actors into using BIM is clearly influenced by the interpretation of the programs inscribed into the technology. Mainly two actors are addressed in the translation process, the technology itself and the construction projects conducted by the STA. The actual users of the technology, actors in projects, are addressed only indirectly through changes to demand documents.

The BIM technology and its inscribed programs have a large impact on both the enrolling of actors and the goal of the translation process. In the translation process technological requirements are precisely specified. For example, file formats and classification systems are identified as essential issues which the other actors have to accept. Also some specific programs of use are addressed in the translation process. The use of models as the bases for machine guidance and quantity take off are specified. The specifications are not developed

from suggestions from actors in the network but rather primarily as a possible benefit deemed beneficial by the translating actor.

The main way in which the construction projects are enrolled into using BIM is by the development of new guidance documents presenting requirements on BIM deliveries in projects. By the definition of a base level of BIM and demands in the guidance documents, the issue of how the technology should be applied in projects are resolved. The translation process tries to establish the issue of BIM-use as a black box, a locked network element (Walsham, 1997). As BIM has a several possible programs linked to it, the BIM initiation project tries to limit the actor-network to accept their interpretation. This black box, the guidance documents, defines the requirements the STA should put on third party actors in construction projects. The issue whether or not to use BIM in projects are resolved, it should be used in all projects to the base level or higher. However, this base level of BIM use does not in detail describe how the new requirements are going to influence work practices in projects, that is to say the program of use linked to BIM. Some uses are specified, as described above, but more advanced programs are not prohibited. By the creation of BIM as a black box the traditionally large independence of project managers are limited. The black box with its inscribed demands is developed to influence project managers at the STA towards the desired program, the use of BIM. The project managers are in turn subjected to influence third party users by the programs inscribed in the black box.

The strategy by which the BIM initiation project translates BIM shows many resemblances to the technological imperative as described by Markus& Robey (1988). The technology of BIM is viewed as having potential to influence the behaviour of individuals and organisations. As long as the technology is in place, the black box is accepted, change will be achieved. With this perspective, the influence of individuals on the development of the use of the technology is disregarded (Orlikowski, 1992). With the black box containing inscriptions, the BIM network tries to limit the ability for individuals to influence the BIM issue. However, for this translation to be successful the black box must be accepted and the inscriptions need to be strong enough.

5.3. Conflicting views of BIM

As described in the Building Information Modelling chapter, the BIM concept contains different aspects depending on the actors that try to define it. This is true both in academia and the industry. Depending on the view of the technology varying programs are inscribed into its use. At the STA there is currently no single view of BIM. According to the results of this research study, almost all individuals have their own interpretation of what BIM is. This difference in understanding of BIM has resulted in a division of the translation process of BIM.

As described in the findings chapter, the mobilisation of construction projects has been problematic. The two BIM implementation projects at the project conducting departments at the STA have been enrolled in the BIM translation in varying degrees. It has resulted in a situation where there are two conflicting views of BIM, two incompatible interpretations of

how BIM should be used by the STA. These two translation processes have large differences in terms of how actors are interested and enrolled in the actor-network. The main difference is how much the STA should influence the work practices of third part actors. Notably these two translation processes do not differ substantially in their relation to the BIM technology and its role as an actant in these actor-networks.

It can be noted that the actors relating to the translation process of BIM is also connected to other superordinate translation processes. For example, one of the early adopters initiating the BIM work presents an idea of BIM as a way of developing the project management role, devising a standardised process and phase out traditional project managers in standard projects. In the BIM strategy document the management presents BIM as a tool in the digitalisation work at this organisation. In the BIM implementation project at Investment, BIM is viewed as a supplement to the professional client organisation initiative. Altogether, these are just a few of the various visions of BIM and how it relates to other ideas and other translation processes.

The story of BIM at The STA is one where a group of early adopters of BIM established their idea of BIM. This group did not have a homogenous idea, but rather included different aspects of BIM that corresponded to their personal wants and needs. This diverse idea of BIM was later translated to the rest of the organisation. The translation focused on interesting the actors by showing the potential benefits with BIM and how it relates to the general goals of this organisation. In this translation the idea of BIM spread in the network, with every actor developing their own idea of the technology, relating it to their own agenda.

From this translation process it can be shown that BIM is not an isolated change process. The implementation of BIM is linked to many different aspects of the organisation and not all of them were identified as the start of the translation. One actor was identified as representative for the infrastructure industry, the projects conducted by the STA. By enrolling the projects managers to demanding BIM-use in their projects the industry is expected to follow. By establishing BIM as a black box with inscriptions in the form of new guidance documents the projects were supposedly enrolled.

But enrolling of these actors was problematic. The large projects department the black box was accepted. However, projects conducted by this department are large degrees autonomous and therefore tend to view inscriptions as having a large degree of flexibility. At the investment department, on the other hand, inscriptions in the form of guidance documents generally have far more power. At this department, the black box was not accepted and only a fraction of the inscriptions in the documents were applied to the project process. How projects have actually made use of BIM have in large parts been the responsibility of the respective project manager. The project managers are given the role of delegates for the BIM initiative, representing it to third party actors in their project. As the inscriptions in the guidance documents are either seen as flexible or mostly removed, a large degree of freedom has been given to the project manager in specific construction project. This has resulted in a situation where project managers, in the role delegates, have significant impact on how BIM is used in

their projects. As the inscriptions are either disregarded or seen as flexible, the project manager's individual idea of BIM are a major factor in its application in the project.

5.4. Client's role in the BIM translation

In literature on innovation, the client is often presented as a needed driver for change by establishing demanding for the new technology (Barlow, 2000; Blayse & Manley, 2004). When implementing technology into complex systems, like in construction, the need for system integrators have been stressed (Winch, 1998). In order for innovation not to be slow, these actors must be convinced of the innovation and have the right skills to utilize it for system innovation to be incorporated within the whole system (Nam & Tatum, 1997). In the BIM implementation process at the STA this role of system integrators is given to project managers in the specific construction project. With the black box established in the translation process, these individuals are assumed to be enrolled intro the understanding of BIM presented by the BIM initiation project. However, as the acceptance or strength of the black box has been problematic, both the inscribed programs of BIM-use and the conviction of BIM benefits are unsure.

It has been argued that clients with a large degree of both technical competence and involvement in projects have a positive impact on change towards the use of new technology (Nam & Tatum, 1997). The same results have been found in studies analysing BIM implementation initiatives (Porwal & Hewage, 2013). When client organisations are able to support the use of the technology and adapt to mirror the circumstances the implementation are more likely to be successful. In terms of the STA the use of BIM is locked into the black box. This limits the ability for projects to adapt to their specific circumstances. The development of the use of BIM is also delegated to the main contractor. The STA does in essence only establish a demand for models, how this demand is fulfilled and what implications it has are almost wholly up to the main contractor.

The construction industry is complex, and it has been found that it often presents characteristics of relative unboundedness (Harty, 2008). With this understanding is applied on the circumstances in which BIM is being implemented, the importance of negotiations can be emphasised. In the implementation of BIM, the supposed users of the technology, actors in construction projects, are not included in the development of the demand documents. Instead these actors are assumed to be enrolled into the use of BIM solely by the new demands.

6. Conclusions

In this thesis, the client organisation's role in relation to a technology driven change process have been studied. With the purpose of increasing the understanding of technology driven change processes at public client organisations, the current BIM implementation at the STA has been in focus. In the study both possibilities and difficulties in initiation change in a diverse and fragmented industry have been described. By mapping of the actor-networks around the translation in this change process, greater understanding has been gained. The main actors have been identified and how they relate to each other. Which actors are included and excluded in the translation has been discussed. Lastly the results have been related to earlier research on innovation and organisational change in fragmented and diverse industries.

6.1. Implications

As an example of a technology driven change process, the current implementation of BIM in the construction industry can tell us of how client organisations try to initiate and manage change. When related to earlier research, the findings in this thesis have several implications both for theory and practice:

6.1.1. Theoretical implications

Innovation comes in many different forms, from modular innovations changing singular components to system innovation with an impact on a multitude of actors and components in an interconnected network. How new technology drives change in an organisational setting is heavily influenced by the scope of said technology. The more components the technology impacts the more actors are involved in its implementation and thus widens the network to which the innovation has to be translated. With a wider network, the number of individual variables influencing the translation is increased.

How the implementation of new technology is linked with organisational change depends on the degree to which actors can influence the technology. If actors have limited influence, the technology itself has been shown to have large potential to initiate change. Instead organisational aspects become more relevant when actors have the ability to influence the implementation process.

In research on BIM, a development trajectory had been established to describe the future of BIM-use. Many researchers assume that this development trajectory will be followed, and that BIM maturity will increase by this expected trajectory. Similar assumptions can also be found in many of the current implementation initiatives of this technology. The predetermined development of the technology expresses prominent characteristics of a technological imperative view of this technology driven change process. This view dictates the proposed actions promoting the change process. Focus on technical factors such as interoperability and software development are the main ways in which actors are enrolled into using the technology. The organisational aspects are only addressed indirectly with suggestions that non-enrolled actors have to be convinced of the benefits of joining the network.

The findings in this thesis argue for a complex network of actors interacting in the development and application of the BIM technology. In a fragmented and diverse field, such as the AEC-industry, several characteristics of relative unboundedness can be found. In such environments the influence of client organisations are not absolute and many different actors will be involved with the development and use of new technology. Therefore, to mostly describe client organisations as needed initiators, developing demand for this inter-organisational change can be argued to be too simplistic. With a system innovation such as BIM, most if not all actors linked to construction projects needs to be enrolled in the actor-network. Addressing technological difficulties and creation of demand, even though essential, might not be enough to truly enrol these actors into joining the inter-organisational actor-network.

This thesis argues for a more complicated role of client organisations in relation to system innovation. In order to facilitate change by the implementation of technology in an inter-organisational context, the role of client organisations becomes one of negotiation. The importance of enrolling actors by addressing difficulties and ensuring mutual benefits from accepting the translation process becomes central issues. Factors like technical competence and involvements by actors like system integrators also become more prominent. A technological focus is however not enough to ensure its use in an inter-organisational setting.

6.1.2. Practical Implications

With the goal of increasing productivity and achieving higher quality, BIM is being promoted in both academia and practice. In this development client organisations are both described as the actors with the largest potential benefits and the greatest ability to influence change. The most common strategy for increasing BIM implementation and change towards BIM-centric work practices is client stablished demand for BIM.

The use of black boxes in the enrolment of actors, found in the findings of this thesis, has a limiting effect on the creation of an actor-network around BIM. The success of enrolling construction project managers, subjected to act as system integrators, can be questioned. The inscriptions in the black box have either not been accepted or are viewed as having a large degree of flexibility. Instead of enrolling these actors into the desired program, the specific use of BIM, there is a risk that other program is followed instead. Also, it has been shown that technical experience and conviction of the value in the technology are important assets of system integrators. If these actors are not fully enrolled by flexible or weak inscriptions, these qualities might be missing.

As a technology driven change process, the current implementation is guided by the perceived possibilities and difficulties expressed by the initiating group, the BIM initiation project. The link between this group and the general management of the STA is somewhat limited. As shown in the findings in this thesis it has resulted in several programs acting as counterprograms to each other. The situations in which middle management and experts in the particular field are leading technology focused change processes are common. However,

coordination between the BIM initiative and other change processes would be beneficial for the overall development of the STA and its influence on the AEC-industry.

Overall, the goals of the BIM implementation process are unclear as the change process is led by this subordinate implementation project. How the benefits of BIM are linked to the operation of the STA is not the main reason for the implementation process. BIM is brought forward as a way of increase digitalisation and productivity. The facilities management aspect of BIM, the aspect most linked to the operation of this client organisation are not included in the change process. These issues are managed by other development projects with limited connection to the BIM development.

6.2. Continuation of the study

In this licentiate thesis, the BIM implementation process has been studied. How actor-networks surrounding the BIM issue have been developed and which actions have been taken to enrol actors into this network has been in focus. In this process the role of project managers have been emphasised. These project managers are subjected to act as system integrators, enrolling project participants to accept the view of BIM expressed by the BIM implementation at the STA.

In the continuation of the research project, construction project managers will be the main focus. These actors are relating to several, sometimes conflicting, programs of actions and have several different inscriptions to relate to. How project managers are influenced by the implementation of BIM was also the initial purpose of the research study and therefore a suitable continuation.

In this thesis, the scope has only included the client organisation. In the continuation this scope will be widened to also include project participants in the projects initiated by this client organisation. How these actors are influenced by the changes to demand documents and how they change as a result thereof will be an important continuation of this licentiate thesis.

6.3. Limitations

The main limitation of this thesis is the change in scope from the original purpose. Initially the relationship between BIM and the project management role should be in focus. Based on the abductive research method it became clear that the early pilot project using BIM was not representative for the general BIM-use at this organisation as their ideas of BIM did not correspond to the idea of BIM present in the BIM imitation project. Therefore the scope was changed towards studying the implementation process as it was during this process the circumstances for the project managers were developed.

Further one limitation is how representative the STA is in relation to other public client organisations implementing BIM. The issues isolated by the BIM implementation initiative at the STA might not be the same as in other countries with similar initiatives. Still, the BIM implementation at the STA is heavily influenced by international BIM initiatives, especially

in the UK. Therefore, findings from the STA should bare similarities to other countries taking similar steps.

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8. Appendix

8.1. Appendix 1 - Example of interview template

Background information
Name interviewee:

Professional role:

Department at the STA (if relevant):

Time and date:

Location:

Duration of interview:

Presentation of the research project
Presentation of me as a researcher

Short presentation of the area of interest for the interview

Examples of questions to guide the interview
These are examples of questions aimed at getting the interviewee to narrate their individual perception of the BIM developments at the STA. The questions are only suggestions to guide the interview towards the right subject.

- Please describe your role at the STA
- How do you view BIM?
- What is your view of the BIM implementation process?
- How are you in your professional role linked to other actors at this organization?
- How does the implementation of BIM influence you in your role at the STA?

For project managers:

- What is the difference now from a couple of years ago?
- How do you use BIM in your project?
- Is BIM an important issue to you?
- How do other project participants express their view of BIM?

For interviewees partaking in the BIM implementation:

- What actions are taken in the BIM implementation process?
- What are the latest developments in the BIM implementation process?
- How do you perceive the relation to other BIM related projects?
- What is going well?
- Are there any difficulties in the BIM implementation?

Example of confrontational questions

The confrontational questions are related to answers given earlier in the interview in order to deepen the insight in the interviewee's perception of the subject. These questions are always tailored to the specific interview but often relate to common themes, for example:

- But, is there not a conflict between the demands specified in the guidance documents and the professional client initiative?
- But, is this really BIM? The guidance documents only specify file formats with very limited capability.
- Why should the STA drive the BIM implementation when it is other project participants that gain the benefits in the current BIM use described?
- Why is the BIM issue isolated and not managed together with other business development initiatives at the STA?