KTH Architecture and
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The Business Value of BIM
- Elaborating on Content and Perspective

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Doctoral Thesis

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Abstract

The expectations on digitalization and Building Information Modeling (BIM) in the Architectural, Engineering and Construction (AEC) are high. The high expectations are reflected in an increasing interest in both practice and research for the business value of BIM. A rational and positivistic understanding of the business value of BIM promoted by commercial industry actors characterizes the understanding of its content and perspective. This thesis aims to reflect on, problematize and extend the theoretical understanding of the content and perspective of the business value of BIM. In pursuing the aim, perceptions of the business value of BIM, the associated challenges and costs and the role of the business of BIM in a wider socio-technical context are examined among Swedish AEC industry actors, international AEC industry actors and a large Swedish public infrastructure client.

By combining the rational and process-oriented theories on the business value of IT with the more interpretive and hermeneutic socio-technical systems theory, a social and cognitive dimension can be added to the understanding of the content and perspective of both the business value of BIM and of the business value of IT. The two theories share a common theoretical base in the open systems theory but differences in their conceptualization and perspective of IT. These may complement each other when being combined and allow for a reflection, problematization and extension of content and perspective of business value.

By combining the two research fields and contributing with the socio-technical perspective, this thesis contributes with theory development of the understanding of the content and perspective of both the business value BIM in AEC research and the business value of IT in IS research. The extended understanding of the business value of BIM (´the extended business value of BIM´) consists of adding a social and cognitive dimension to the understanding of the business value that also regards how individuals´ attitudes, beliefs and expectations interplay with technology and with their perceptions of business value. It also consists of a distinction between perceptions of desired outcomes and actual outcomes, an understanding of also the associated challenges and costs and an emphasis on project progress rather than project outcome. The findings have practical implications for project managers, managers and policy makers that implement BIM and show the complex, multi-dimensional and challenging aspects of implementing BIM for business value.

The journey of perspectives in this thesis from optimism towards increased interpretivism also sheds light on the implications of different perspectives exerting power and influence on a research field (hegemony) and wishes to provide a contrast and balance to the rational and positivistic perspectives on BIM in research. This journey of perspectives also wishes to inspire and motivate future BIM research to broaden the theoretical perspectives.

Sammanfattning

Förvätningarna på digitalisering och Byggnadsinformationsmodellering (BIM) är höga inom samhällsbyggnadssektorn. De höga förvätningarna reflekteras i ett ökande intresse för affärsnyttan av BIM ökat bland både praktiker och forskare. Ett rationellt och optimistiskt perspektiv karaktäriserar idag förstålsen av dess innehåll och perspektiv. Denna avhandling syftar till att reflektera över, problematisera och utöka förståelsen av innehåll och perspektiv av affärsnyttan av BIM. Den upplevda affärsnyttan av BIM, de associerade utmaningarna och kostnaderna och rollen av affärsnyttan av BIM i ett bredare socio-tekniskt perspektiv undersöks bland aktörer i den svenska och internationella samhällsbyggandssektorn samt hos en stor svenskt offentlig beställare av infrastruktur.

Genom att kombinera de rationella och process-orienterade teoriner i business value of IT med den mer hermeneutiska socio-technical systems teorin bidrar avhandlingen med en social och kognitiv dimension till förståelsen av innehåll och perspektiv av både affärsnyttan av BIM och affärsnyttan av IT. De två teorierna delar en gemensam teoretisk bas i öppna system, men skiljer sig i sin konceptualisering och perspektiv av IT. Den är just dessa skillnader och den gemensamma grunden i öppna system som när de kombineras kan komplettera varandra och möjliggöra för en reflektion, problematisering och utbyggnad av förståelsen av innehåll och perspektiv av affärsnytta

Genom att kombinera dessa två forskningsfält och bidra med det socio-tekniska perspektivet bidrar denna avhandling med teoriutveckling av den teoretiska förståelsen av innehåll och perspektiv av både affärsnyttan av BIM och affärsnyttan av IT. Den utökade förståelsen av affärnyttan av BIM (´den utökade affärsnyttan av BIM´) består av en adderad social och kognitiv dimension som inkluderar hur individers attityder, inställningar och upplevelser interagerar med teknologin och med deras uppfattning av affärsnyttan av BIM. Den består också av en distinktion mellan önskvärda framtida nyttor och faktiska realiserade nyttor, en förståelse för också de associerade kostnaderna och utmaningarna samt en betoning på affärsnytta i termer av projektstöd snarare än projektresultat. För praktiker såsom projektledare, chefer och beslutsfattare belyser avhandlingen de komplexa, multi-dimensionella och utmananande aspekterna med att implementera BIM för affärsnytta.

Resan i perspektiv från positivism och rationalism mot ökad interpretivism i avhandlingen belyser också implikationerna av hur olika perspektiv får inflytande över ett forskningsfält (hegemoni) och önskar bidra med en kontrast och balans till det rationella och positivistiska perspektivet i BIM forskning. Det är också förhoppningen att avhandlingens resa i perspektiv kan inspirera framtida forskning på BIM att vidga de teoretiska vyerna.

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Appended papers

PAPER 1

Vass, S. and T. Karrbom Gustavsson (2014).The Perceived Business Value of BIM. *eWork and eBusiness in Architecture, Engineering and Construction - Proceedings of the 10th European Conference on Product and Process Modelling (*ECPPM 2014), Vienna, September 17th – 19th , 21-25. Conference proceedings, peer reviewed.

PAPER 2

Vass, S (2014).A Proposed BIM Business Value Model. *Proceeding*s *30th Annual Association of Researchers in Construction Management Conference* (ARCOM 2014), September 1st – 3rd Portsmouth,633-642.Conference proceedings, peer reviewed.

PAPER 3

Vass, S (2017). The Impact of Experiential Knowledge of BIM on the Perceived Business Value of BIM. *Journal of Information Technology in Construction* (Submitted April 2017, in review as of June 2017). Peer reviewed journal.

PAPER 4

Vass, S. and T. Karrbom Gustavsson (2017). Challenges when implementing BIM for industry change. *Construction Management and Economics*, 1-14. Peer reviewed journal.

PAPER 5

Vass, S. and T. Karrbom Gustavsson (2017). BIM research: Common Perspectives and Implications for Future Research. *9thNordic Conference on Construction Economics and Organization (CEO 2017)*, June 13th – 14th Gothenburg. Conference proceedings, peer reviewed.

PAPER 6

Vass, S (2017). The Role of the Public Client in the Social Construction of BIM.*9th Nordic Conference on Construction Economics and Organization (CEO 2017)*, June 13th – 14th Gothenburg. Conference proceedings, peer reviewed.

1. Introduction

1.1 The role of digitalization and Building Information Modelling

The Architectural, Engineering and Construction (AEC) industry plays an important role in economies and societies throughout the world. But the fragmented and project-based industry also creates challenges in productivity (Yang 2012), learning (Hartenberger et al 2013) and innovation and change (Scarbrough et al 2004, Kokkonen and Alin 2016). At the same time, the industry is experiencing an era of digitalization in which Building Information Modelling (BIM) is promoted as a solution to the industry´s challenges (Succar 2009, Crotty 2013). The expectations on BIM for an increased efficiency and innovation in the AEC industry are high in both practice and research and are reflected in strategic innovation programs such as Smart Built Environment (Vinnova 2016).

Consequently, research on BIM has been conducted from mainly technical, rational and process-oriented perspectives including studies on, for example, standardization and classification (Volk et al 2014) and benefits and application areas of BIM (Barlish and Sullivan 2012, Bryde et al. 2013). The organizational perspective has gained increasing attention and includes studies on, for example, BIM implementation barriers related to competence and skills (Mäki and Kerosuo 2015), roles and decision-making power (Gu and London 2010) and attitudes towards new technology (Davies and Harty 2013). Recently, there have also been calls in research for studies that also apply more reflective and critical perspectives to understand BIM and that reflect on the technical and rational perspectives that prevail in the theoretical understanding of BIM in research (Fox 2009, Fox 2014, Dainty et al 2015, Miettinen and Paavola 2014, Yalcinkaya and Singh 2015).

1.2 An increasing interest for the business value of BIM

The high expectations on BIM are also reflected in an increasing interest for the term business value of BIM. Although the term business value is not new and has been extensively researched in Information Systems (IS) research (e.g. Mooney et al 1996, Melville et al 2004, Kohli and Grover 2008), the term was first introduced to the AEC industry context by industry actors with commercial interest in promoting an increased use of BIM (McGraw-Hill in cooperation with funding partners including BIM software suppliers and BIM consultants). In their reports, McGraw-Hill (2009, 2010, 2012) promote the benefits and application areas of BIM based on surveys to their funding partners' BIM users. The term business value of BIM is characterized by a bias towards rationalism and positivism, yet at the same time remains vague and unclear. For example, the business value of BIM is described in terms of a variety of concepts, ranging from overall value, internal benefits, business benefits, business value to player value, and includes a wide range of estimates (see McGraw-Hill 2009, 2010, 2012). Moreover, the circumstances surrounding the business value of BIM, such as enablers and challenges, are overlooked. In the few cases where obstacles to business value are mentioned, they are presented as obstacles that “limit the ability to realize better results” and are later referred to as “top ways to improve BIM, business value, business benefits” etc. The obstacles also relate more to external market conditions (e.g. lack of interoperability between software applications) than to any challenges of the actual BIM implementation itself. There is no further reflection on or problematization of the business value of BIM and the related challenges. Yet, the reports and the business value of BIM have received much attention in both practice (e.g. in BIM Task Group 2012) and research (e.g. in Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013).

1.3 Why develop a theoretical understanding of the business value of BIM?

The lack of a reflection on and problematization of the business value of BIM in McGraw-Hill (2009, 2010, 2012) is not unexpected given that the reports were created with a commercial interest of promoting an increased use of BIM. However, this positively biased understanding of the business value of BIM promoted by commercial industry actors seems to have gained power and influence (hegemony) on AEC research (Bourdieu 1991). The reports (McGraw-Hill 2009, 2010, 2012) have been widely used by and gained large influence on AEC researchers (e.g. Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013). In total, the reports have gained over 400 research citations. The reports have also been used by AEC researchers in a manner that equivalents them with academic research and there has been no consideration or reflection of the origin and purpose of the reports. The researchers that draw on the positively biased understanding of the business value of BIM (e.g Succar 2009, Barlish and Sullivan 2012) have in turn gained large influence on AEC research. Moreover, despite the increasing interest in both practice and research for the business value of BIM and the available body of knowledge on the business value of IT from IS research, there has been no theoretical understanding of the business value of BIM. Thus, there is a need for developing a theoretical understanding of the business value of BIM that not only increases the understanding of the term and its implications for practice and research but that also reflects on, problematizes and extends the current rational and positivistic understanding of its content and perspective. This thesis aims to fill this gap.

IS research has developed a theory of the business value of IT and an understanding of the implications of the business value of IT for business development, organizational strategies, competence development and management practices on multiple levels including the firm, industry and economy level (Mooney et al 1996, Melville et al 2004, Kohli and Grover 2008, Cao 2010). The business value of IT has also been understood as the organizational factors and capabilities that are important for business value creation related to strategizing, developing business processes, competencies and skills and that may have financial, operational and strategic impacts (Melville et al 2004, Kohli and Grover 2008, Cao 2010, Grover and Kohli 2012). The understanding of the business value of IT has been developed from drawing on both rational and business-oriented theories (e.g. microeconomics, the theory of the firm and the resource-based view of the firm) and organizational and process-oriented theories (e.g. contingency theory and organizational behavior theory) (Kohli and Grover 2008, Cao 2010, Grover and Kohli 2012).

Drawing on the theory of business value of IT may thus provide valuable insights for developing both a theoretical understanding of the business value of BIM and an understanding of its practical implications on competence development, strategizing, business models and decision making in the AEC industry. It may also allow for extending the current narrow and positive understanding of the business value of BIM which has been promoted by commercial AEC industry actors. By complementing the theoretical understanding of the business value of IT with a different theoretical perspective, such as the socio-technical perspective, the understanding of the content and perspective of business value of BIM may be further reflected on, problematized and extended.

1.4 Aim and research questions

This thesis aims to reflect on, problematize and extend the theoretical understanding of the content and perspective of the business value of BIM. To fulfil the aim, the thesis combines the theory of the business value of IT, including the IT Business Value Model by Melville et al (2004) with the socio-technical systems theory, including the Extended Technology Acceptance Model (TAM2) by Venkatesh and Davis (2000) and the Social Construction of Technology (SCOT) by Pinch and Bijker(1984).

The theory of the business value of IT (e.g. the IT Business Value Model by Melville et al 2004) is helpful for extending the understanding of the content and perspective of the business value of BIM as it not only understands the business value as the economic impact of IT on organizational performance, but also as the organizational factors and capabilities that enable and challenge the creation of business value related to strategizing, business development, competencies and skills and management practices (Melville et al 2004, Kohli and Grover 2008, Cao 2010). Thus, the following research questions are pursued:

> ***RQ1:*** *How is the business value of BIM perceived in the AEC industry?*
>
> ***RQ2:*** *What factors are perceived as enablers of and challenges to the perceptions of the business value of BIM?*

Drawing on the socio-technical systems theory (TAM2 by Venkatesh and Davis 2000 and SCOT by Pinch and Bijker 1984) supports a further reflection and problematization of the currently positively biased understanding of the content and perspective of the business value of BIM in AEC research. The socio-technical systems theory combines the technical system with the social system and accounts for the impact of individuals, groups and networks. Combining the theory of the business value of IT with a socio-technical systems theory is important as IS research studying the relationship between IT and organizational performance has tended to overlook the socio-technical perspective and socio-technical systems theories (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008). There has also been several calls in AEC research for a need to expand the theories and perspectives used to understand BIM from the rational and technical perspectives to more reflective and critical perspectives (Fox 2009, Fox 2014, Dainty et al 2015, Miettinen and Paavola 2014, Yalcinkaya and Singh 2015) including the socio-technical perspective (Davies and Harty 2013, Sackey et al 2014, Miettinen and Paavola 2014). Thus, there is not only a need for reflecting on the theoretical understanding of the content and perspectives of the business value of BIM, but to also what content and perspectives that dominate the theoretical understanding of BIM in AEC research and how these also impact the understanding of the business value of BIM:

> ***RQ3:*** *How may a dominating technical perspective in current BIM research impact the understanding of the business value of BIM?*

In response to the calls in AEC research for broadening the perspective of BIM from technological determinism (assuming technology shapes human actions and behaviors and drives social structures and cultural values) towards social constructivism (recognizing that human actions and behaviors also shape the use of technology and drive social structures and cultural values) (e.g. Sackey et al 2014, Miettinen and Paavola 2014), a final research question is pursued. In order to reflect on, problematize and extent the theoretical understanding of the content and perspective of the business value of BIM, this thesis will also study the business value of BIM from a wider socio-technical perspective:

> ***RQ4:*** *What is the role of business value of BIM in a wider socio-technological context?*

IS research also emphasizes the co-creation of business value and the need for inter and inter organizational collaboration and change (Melville et al 2004, Kohli and Grover 2008, Grover and Kohli 2012). The fragmented, complex and highly interdependent nature of the AEC industry suggests that there is a need for studying the business value of BIM from a multi-perspective including the perspectives of several actors and disciplines. One important actor in the AEC industry is the public client which is described as a change agent in the industry through its ability to make demands on the AEC industry actors via procurement (Linderoth 2010, Porwal and Hewage 2013, Wong et al 2011, Bosch-Seijtsema et al 2017).Thus, the research questions in this thesis will be explored from a national industry-wide perspective including contractors, consultants and owners in the Swedish AEC industry (Paper 1 and Paper 2), an international industry-wide perspective including architects, contractors, owners, fabricators and educators in the international AEC industry (Paper 3) and from the important client perspective including a large Swedish public infrastructure client (Paper 4 and Paper 6). See Table 1.

Research questions	**Examined in papers**					
RQ1: How is the business value of BIM perceived in the AEC industry?	Paper 1	Paper 2	Paper 3	Paper 4		
RQ2: What factors are perceived as enablers of and challenges to the perceptions of the business value of BIM?		Paper 2	Paper 3	Paper 4		
RQ3: How may a dominating technical perspective in current BIM research impact the understanding of the business value of BIM?					Paper 5	
RQ4: What is the role of business value of BIM in a wider socio-technological context?						Paper 6

Table 1.Research questions

1.5 Relevance and theoretical contribution

In order to extend the theoretical understanding of the content and perspective of the business value of BIM, this thesis combines the theory of the business value of IT (e.g. the IT Business Value Model by Melville et al 2004) with the socio-technical systems theory (e.g. TAM2 by Venkatesh and Davis 2000 and SCOT by Pinch and Bijker 1984). The content and perspective of the business value of BIM is first understood from the theory of the business value of IT including the IT Business Value Model (Papers 1 – 4). The content and perspective of the business value of BIM, and of the business value of IT in IS research, is further reflected on and extended by drawing on the socio-technical systems theory including TAM2 and SCOT (Papers 5 – 6). By combining these two theories and adding the lacking socio-technical perspective (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008, Sackey et al 2014, Miettinen and Paavola 2014) to the understanding of the business value of BIM and the business value of IT, the theoretical understanding of the content and perspective of business value in both AEC research and IS research can be extended to also include a social and cognitive dimension. The theoretical relevance and contribution of this thesis is thus of theory development (Yin 2004, Creswell 2002) (sections 2.3 and 3.1).

By combining the theory of the business value of IT with the socio-technical systems theory, this thesis bridges two theories of different perspective and conceptualization of IT (section 2.3). While the theory of the business value of IT draws on positivism and rational and economic perspectives for understanding IT, the socio-technical systems theory draws on interpretivism and social and cognitive perspectives for understanding IT. However, the two theories share a common theoretical base in the open systems theory (section 2.3). They both take off from the notion that an entity, such as an individual, group or network as in the socio-technical systems theory, or an organization or firm as in the theory of the business value of IT, impacts and is impacted by its external environment. In combining these two theories for extending the theoretical understanding of the content and perspective of the business value of BIM, this thesis undertakes a journey of perspectives from rationalism and positivism towards increased interpretivism and hermeneutics. This journey may motivate and inspire future BIM research to also reflect on the prevailing technical, rational and positivistic perspectives in BIM research and regard interpretive perspectives that account for the interactions between the technical and social systems and individuals, groups and social networks.

1.6 Overview of research questions, methods and theoretical frameworks

An abductive research approach has been undertaken in this thesis whereby the research questions were subsequently developed by a systematic combination of induction and deduction, i.e. alternating between empirics and theory in search for better understanding and sense making (section 3.3 and Figure 1).

RQ1 and RQ2 are pursued in Papers 1 – 4. The theory of business value of IT (e.g. the IT Business Value Model by Melville et al 2004) is used as theoretical lens to interpret the findings. RQ1 and RQ2 were pursued from a mixed methods approach. The qualitative method included semi-structured interviews with Swedish AEC industry actors (Paper 1 and 2) and semi-structured interviews with and participant observations of a large Swedish public infrastructure client (Paper 4). The quantitative method included factor analysis and regression analyses on results from a survey to international AEC industry actors (Paper 3).

RQ3 is pursued in Paper 5. A literature review of the knowledge interests in current BIM research was performed. The analysis is based an examination of technical, practical or emancipatory knowledge interests (Habermas 1971). The implications of knowledge interest are analyzed using the concept of hegemony (Gramsci 1988).

RQ4 is pursued in Paper 6. Socio-technical systems theory (TAM2 by Venkatesh and Davis 2000and SCOT by Pinch and Bijker1984) is used as theoretical lens to interpret the findings and understand the role of the business value of BIM in a wider socio-technical context. The qualitative method included semi-structured interviews and participant observations of a large Swedish public infrastructure client.

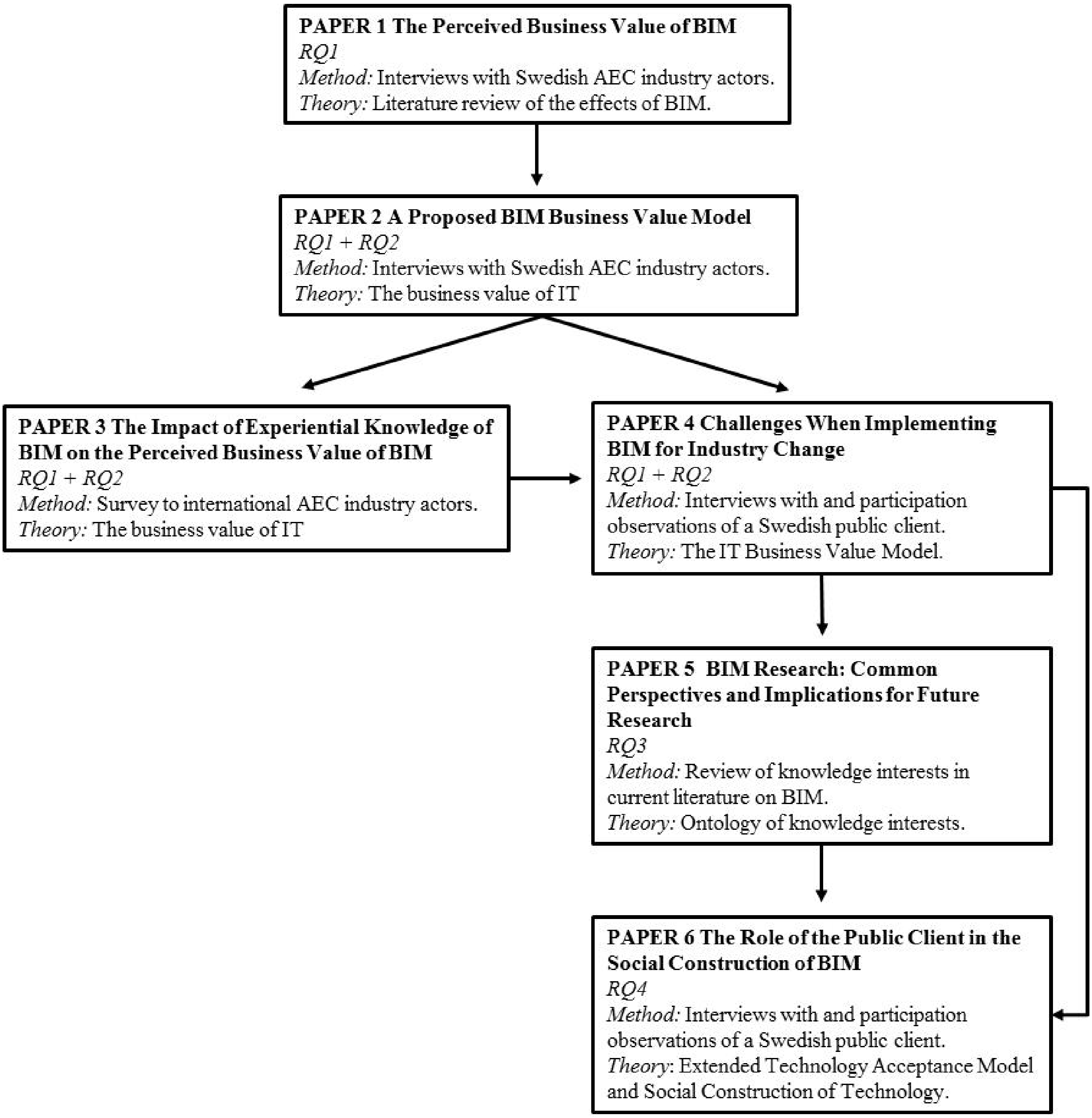

Figure 1. Overview of research questions, methods and theoretical frameworks

2. Theoretical frameworks

2.1 Understanding of theory

In this thesis, theory is understood as the cognitive constructs and lenses constructed by humans for understanding, interpreting and explaining an observed phenomenon in the world. The phenomenon could be the falling of an apple to the ground, the annuals of a tree of the interaction between man and technology. Theory may be developed and applied to a phenomenon so that we may develop knowledge of an observed phenomenon for our own understanding and sense making and so that we may describe and explain the observed phenomenon to others. A theory could thus be a doctrine or principle, a mathematical model, a model of cause and effect or a general explanation. For the author, academic research is the art of being able to understand, explain and predict an observed phenomenon using theory in order to develop new knowledge, enhance our existing knowledge, share our knowledge with each other and to understand our history and predict our future.

2.2 Information Systems theory

IS research intersects knowledge of the properties of physical objects (e.g. technology) with knowledge of human behavior (Gregor 2006). It concerns the design and management of information systems, the evaluation of the systems and their value for IT-supported change processes (Banker and Kauffman 2004). IS research draws on and borrows theories from different fields such as natural sciences (e.g. open systems theory of biology) and social sciences (e.g. sociology) (Gregor 2006, Banker and Kauffman 2004) to build IS theory.

Two theories from which IS research has drawn on to build IS theory include the resource-based view of the firm from strategic management (e.g. in the development of the theory of the business value of IT) and socio-technical systems theory from organizational science and sociology (e.g. in the development of the theory on systems design). While the theory of the business value of IT has drawn the resource-based view of the firm including also microeconomics and industrial organization theory (Kohli and Grover 2008, Cao 2010, Grover and Kohli 2012), it has seldom applied the socio- technical systems theory. In general, IS research studying the relationship between IT and organizational performance has tended to overlook the socio-technical perspective (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008). This thesis combines the theory of the business value of IT with the socio-technical systems theory to extend the theoretical understanding of the business value of BIM and the business value of IT.

2.3 The influence of open systems theory

Theory of the business value of IT and the socio-technical systems theory have both been influenced by the open systems theory from biology (Von Bertalanffy 1950) and they share the common understanding of how an entity, a firm or organization in the theory of business value of IT (section 2.4.2) or an individual, group or social network in the socio-technical systems theory (section 2.5.1), is an open system that impacts and is impacted by its external environment. However, they differ in their conceptualization and perspective of technology, unit of analysis and interpretation of the external environment in their application of the open systems theory. The theory of the business value of IT conceptualize IT as a capability or construct that is taken for granted, has inherent meaning and is assumed to be unproblematic once it has been developed and installed. In contrast, socio-technical systems theory conceptualize IT as an artefact that is socially constructed and shaped by human interests, values and assumptions in a dynamic and a constantly changing social and historical context (Orlikowski and Iacono 2001).The theory of the business value of IT draws on positivism and rational and economic perspectives for understanding IT (Melville et al 2004, Kohli and Grover 2008, Cao 2010), while the socio-technical systems theory draws interpretivism and social and cognitive perspectives for understanding IT (Trist and Bamforth 1951, Trist 1981, Orlikowski and Iacono 2001). In the theory of the business value of IT, the firm and organization is in focus (Melville et al 2004, Kohli and Grover 2008), whereas in socio-technical systems theory the individual, group or network is in focus (Trist and Bamforth 1951, Trist 1981, Orlikowski and Iacono 2001).

It is the differences in the two theories´ conceptualization and perspective of IT, unit of analysis and interpretation of the external environment that may complement and each other when being combined and that may allow for a reflection, problematization and extension of the theoretical understanding of the content and perspective of the business value of BIM and the business value of IT.

The open systems theory originates from biology and Von Bertalanffy´s (1950) study of the organism. It has been embraced in both natural and social sciences and not only influenced the theory of the business value of IT and socio-technical systems theory, but also contingency theory (Scott 1981) and the theory of organizing (Weick 1976). An open system is characterized by a combination of parts whose complex relations make them interdependent (Von Bertalanffy 1950). A system may be organic, mechanical, social, or a combination. In mechanical systems the parts are highly constrained, whereas in social systems the parts are loosely coupled (Von Bertalanffy 1950). Open systems imply that organizations impact and are impacted bytheir external environment such as customers, suppliers and governments (Katz and Kahn 1978). These all exert cultural, economic, technological and political influences. Organizations need to be responsive to and adapt to changes in their external environment to evolve (Katz and Kahn 1978). Public organizations are open systems that influence and are influenced by their external environment such as governments and suppliers (Scott and Davis 2015).

2.4 Theory of the business value of IT

2.4.1 The evolvement of the understanding of the business value of IT

The business value of IT has been studied in a variety of industries including manufacturing, telecommunications, banking and healthcare (Tallon et al 2000, Kohli and Devaraj 2004, Cao 2010). Early studies on the business value of IT focused on the economic impact of IT on firm performance including productivity enhancement, profitability improvement, cost reduction and competitive advantage (Mukhopadhyay 1997, Berghout and Renkama 1997). Later studies extended the focus to also non-economic and intangible impacts including a redesign of organizational strategies and structures (Mooney et al 1996, Kohli and Grover 2008). The business value of IT is commonly defined as “the organizational performance impact of information technology at both the intermediate process level and the organization-wide level, comprising both efficiency impacts and competitive impacts” (Melville et al 2004). It has also been understood as the organizational factors and capabilities than enable the creation of business value related to strategizing, developing business processes, competencies and skills and management practices (Melville et al 2004, Kohli and Grover 2008, Grover and Kohli 2012). The major focus has been on the intermediate business process and organizational level in terms financial, operational and strategic impacts and less on the individual level in terms of perception related impacts (Kohli and Grover 2008).

2.4.2 Open systems theory in the theory of the business value of IT

Open systems theory has influenced the IT Business Value Model and other frameworks that emphasize the co-creation of business value in multi-layered contexts including the firm, industry and macro level (Melville et al 2004, Kohli and Grover 2008) (section 2.3). Firms need to collaborate and pool their resources (goods, services and relationships) across organizational boundaries as a reaction to changes in their external environment (Grover and Kohli 2012). The IT Business Value Model applies the open systems theory at the firm and organization level and interprets the external environment as the competitive environment (e.g. suppliers, competitors) and the macro environment (e.g. governments) (Melville et al 2004). The theory of the business value of IT draws on positivism and has applied the open systems view in a rational and economic perspective (section 2.3).

2.4.3 The IT Business Value Model

The IT Business Value Model (Melville et al 2004) is an example of an open systems model. It departs from the resource-based view of the firm which holds that the organizational capabilities of the firm itself are what primarily create competitive advantage (Wernerfelt 1984). This view of the firm implies a closed system view (Aragón-Correa and Sharma 2003). Melville et al (2004) develop the model by adding the open systems view and describing how the firm may co-create business value by engaging in inter-organizational relationships with the actors in its external environment. The IT Business Value Model has been used to describe how business value creation is dependent on the firm´s ability to implement IT-supported change processes in a multi-layered context (Melville et al 2004, Kohli and Grover 2008). The focus is on the interactions between a firm and the actors in its competitive and macro environment. Implementation of IT-supported change process and the subsequent creation of business value of IT are inter – organizational and depend on that the firm interacts with and is able to co-create intra and inter organizational change with the actors in its competitive and macro environment.

IT-supported change processes take place on three levels: firm level (*focal firm*), industry level (*competitive environment*) and macro level (*macro environment*) (Figure 2). Analysis of such multi-layered contexts is important for understanding the impact of IT on individuals, organizations and society (Walsham 1992, Pettigrew et al 2001).

The *focal firm* makes use of IT resources and human IT resources. The implementation of IT-supported change processes requires the focal firm to manage organizational change (complementary organizational resources). These must be managed both within the focal firm (intra organizational level) and in relation to the actors in the competitive and macro environment (inter-organizational level) (Figure 2).

With the actors in its *competitive environment*, the focal firm co-creates intra and inter organizational change. The competitive environment consists of industry characteristics, such as regulations, competitiveness and technological change and consists of industry actors (trading partners), such as byers and suppliers (Melville et al 2004). By coordinating and integrating their business processes (e.g. order taking, manufacturing, logistics, sales), the focal firm and the actors in its competitive and macro environment co-create intra and inter organizational change to create IT-supported change processes and business value. Examples of intra and inter organizational change include changes in workplace practices, policies, rules, contracts, business models, organizational structures, roles, decision making and culture. These may also pose as challenges and the model thus also support an understanding of the intra and inter organizational challenges associated with implementing IT-supported change processes for business value (Melville et al 2004) (Figure 2).

The *macro environment* also impacts the firms' ability to implement IT-supported change processes. It includes governmental regulations, government initiatives and country specific factors (education system, residents' maturity of IT) (Melville et al 2004) (Figure 2).

Melville et al (2004) developed the IT Business Value Model by combining the closed systems view (the resource-based view of the firm) with the open systems view of an organization. They also drew on microeconomic theory and industrial organization theory (Melville et al 2004). Some IS scholars have argued that such theoretical considerations result in that IT becomes viewed as a black-box and point to a need for shifting the focus towards more socio-technical theories when studying the relationship between IT and organizational performance in order to also account for the impact of individuals, groups and networks (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008).The relationship between IT and organizational performance has also not always been straightforward as suggested by, for example, the debate on the productivity paradox (Brynjolfsson 1993). Some IS scholars also question how much theoretical understanding of business value comes from the rational and economic understanding of the business value of IT (Schryen 2013).

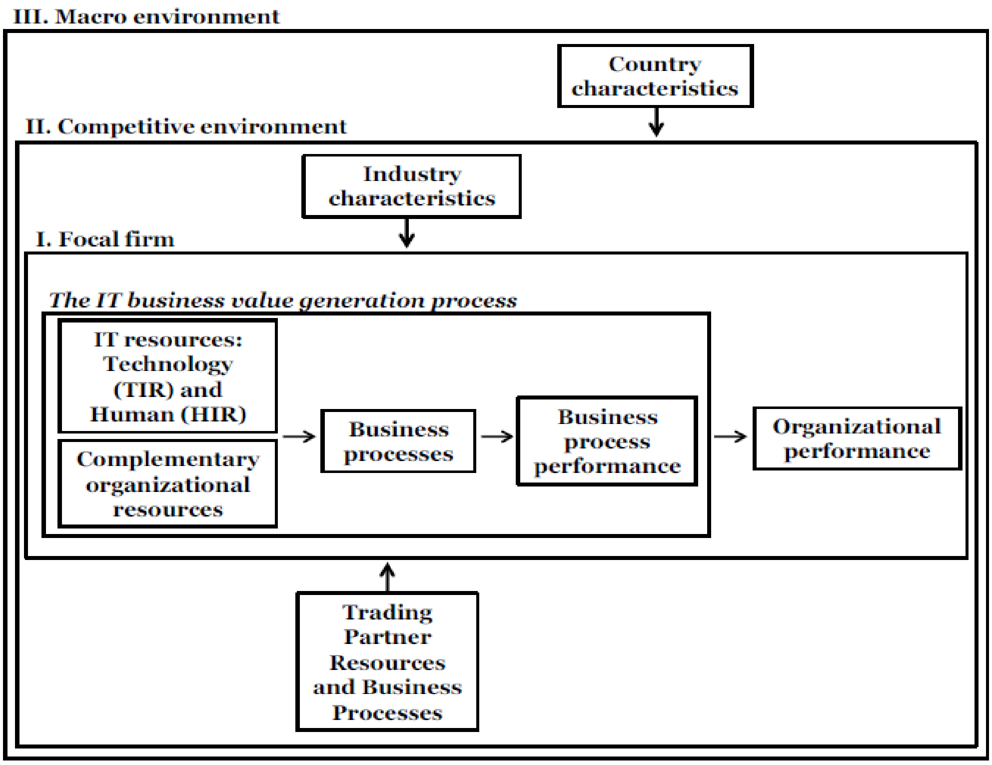

Figure 2. The IT Business Value Model (Melville et al 2004)

2.5 Socio-technical systems theory

2.5.1 Open systems theory in socio-technical systems theory

The socio-technical systems theory was developed from the study of the introduction of mining technology in English coal mines and was influenced by Von Bertalanffy´s (1950) open systems theory (Trist and Bamforth 1951, Trist 1981). Socio-technical systems theory combines the technical subsystems with the social subsystem and recognizes the complex interdependencies between society's infrastructure (e.g. machines, technology) and human behavior in complex organizational work designs. It applies the open systems view from an interpretivist perspective that also regards social and cognitive impacts. The focus is on individuals, groups and social networks and the external environment is interpreted as other individuals, groups and social networks. The open system understanding implies that not only technology but also individuals´, groups´ and networks´ attitudes, beliefs and expectations of a technology shape the design and use the technology and are what drives human actions and behaviors, social structures and norms (Trist and Bamforth 1951, Trist 1981). TAM2, for example, holds that the acceptance of a technology not only depends on technological superiority, but also on the social context and the social and cognitive influences processes that promote an acceptance (Venkatesh and Davis 2000).

2.5.2 The Extended Technology Acceptance Model (TAM2)

In their original technology acceptance model, Davis et al (1989) explain how acceptance and rejection of a technology depends on perceived usefulness of a technology (the degree to which a person believes that using a particular system enhances job performance), perceived ease of use of technology (the degree to which a person believes that using a particular system is effortless) and by individual´s attitudes and behavioral intentions towards using the technology. In their Extended Technology Acceptance Model (TAM2),Venkatesh and Davis (2000) add social influences processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality and result demonstrability) (Figure 3).

Subjective norm is the perception that most people who are important to one think that one should use a technology. Voluntariness is the extent to which this use is perceived to be non-mandatory. Image is the degree to which the use of a technology is perceived to enhance one´s status in a social system. Job relevance is the perception that the technology is applicable for one´s job tasks. Output quality is the degree one perceives that a technology can perform required tasks. Result demonstrability is the perceived tangibility of the results of using the technology. Subjective norm also influences image when an individual‘s work group considers it important to use a technology and elevate one´s image in the group.

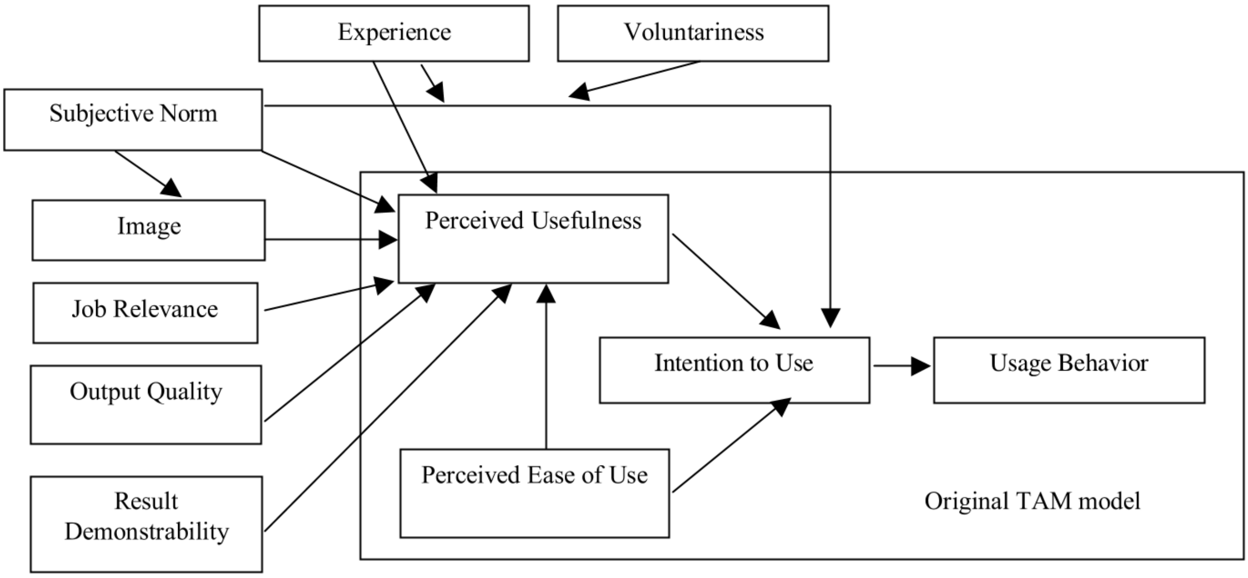

Figure 3. The Extended Technology Acceptance Model (TAM2) by Venkatesh and Davis (2000)

Understanding the acceptance and rejection of a technology among the individuals, groups and networks of an organization (Venkatesh and Davis 2000) is important for understanding how an organization as a whole may impact the use of a technology within an industry, i.e. the social construction of technology (SCOT).

2.5.3 The Social Construction of Technology (SCOT)

SCOT holds that different relevant social groups shape the design, use and impact of a technology based on their sociological explanations; the social contexts in which the arguments for acceptance and rejection of the technology have been promoted and socially supported based on the social group´s different interpretations, beliefs and expectations about the technology, its usefulness and the problems it is expected to solve (Pinch and Bijker 1984). Relevant social groups may be designers such as software developers and the users such as firms, households or consumer groups (Pinch and Bikjer 1984). The sociological explanations of the different social groups form in a process of interpretive flexibility and stabilization. Interpretive flexibility means that the same technology can be seen in different ways and used for different purposes by different social groups. The relations and influences between the different social group's sociological explanations form in the stabilization process where either one social groups´ sociological explanations prevails over others´ or where a compromise is reached (Pinch and Bikjer 1984).

The understanding from TAM2 of how the acceptance and rejection among individuals, groups and networks of an organization are formed by social and cognitive factors (Venkatesh and Davis 2000) provides insights for also understanding the sociological explanations of the organization as a whole and its role in the social construction of technology. SCOT also argues that certain social groups may have larger influence. In the AEC industry context, one such social group may be the public client (Linderoth 2010, Bosch-Seijtsema et al 2017). Understanding the impact of such an influential social group in the social construction of BIM (Pinch and Bijker 1984) is important for understanding IT-supported change processes in the AEC industry. In this context, it is also important to understand what role the of business value of BIM plays for acceptance and rejection of BIM in relation to influence of social and cognitive factors (Venkatesh and Davis 2000).

3. Method

3.1 Theory development

The researcher should ground his/her research questions in theory and consider whether the aim is theory building, theory validation or theory development (Yin 2004, Creswell 2002). This thesis aims to contribute with theory development of the theoretical understanding of business value of BIM in AEC research and of the business value of IT in IS research (section 1.5 and 2.3). By combining the theory of the business value of IT (e.g. IT Business Value Model) with the socio-technical systems theory (e.g. TAM2), a social and cognitive dimension can be added to the currently rational and positivistic dimension characterizing the theoretical understanding of the business value of BIM and the business value of IT.

The two theories have both been developed from the open systems theory that views an entity as an open systems which impacts and is impacted by its external environment (section 2.3) However, it is the differences in the their conceptualization and perspective of IT, unit of analysis and interpretation of the external environment (section 2.3) that may complement and each other when being combined and that may allow for a reflection, problematization and extension of the theoretical understanding of the content and perspective of the business value of BIM and the business value of IT. The interpretive (hermeneutic) and socio-technical conceptualization and perspective of IT of the socio-technical systems theory may contribute with adding a social and cognitive dimension to the current rational and positivistic understanding of the content and perspective of the business value of BIM and business value of IT and may allow for a reflection, problematization and extension of the theoretical understanding of content and perspective. The socio-technical perspective is important and has been lacking in both the theoretical understanding of BIM in AEC research (Sackey et al 2014, Miettinen and Paavola 2014) and in the theoretical understanding of the relationship between IT and organizational performance in IS research (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008).

In a first step, the business value of BIM is understood by drawing on the theory of the business value of IT and the IT Business Value Model (Papers 1 – 4). The content and perspective of the business value of BIM, and of the business value of IT, is then further reflected on, problematized and extended by drawing on socio-technical systems theory (TAM2 and SCOT) (Papers 5 – 6).

3.2 A mixed methods approach

From the development of research questions, the methodological considerations follow (Yin 2004, Creswell 2002). A research method can be qualitative meaning that is seeks to understand, describe and giving meaning to a phenomenon (Merriam 2009, Rudestam and Newton 2007). It can also be quantitative meaning that is aims to test theories by examining relationships and correlations among variables (Creswell 2002). Qualitative and quantitative approaches should not be viewed as rigid polar opposites, but as representing different ends on a continuum where the mixed methods approach resides in the middle (Creswell 2002, Greene 2007). The mixed methods approach allows for a broader and deeper understanding by seeking convergence across qualitative and quantitative data and may increase the validity and reliability of the research (Creswell 2002, Greene 2007).

This thesis applies a mixed methods approach across three informant groups: Swedish AEC industry actors, international AEC industry actors and a Swedish public infrastructure client. The qualitative approach involves interviews with Swedish AEC industry actors and interviews with and participant observation studies of a Swedish public infrastructure client. The quantitative approach involves statistical analyses of a survey to international AEC industry actors and accounts for the international perspective. The design and analysis of the quantitative method built on and complemented the findings from the qualitative approach.

Paper 1 pursued RQ1 and aimed to understand how Swedish AEC industry actors perceived the business value of BIM. The findings from semi structure interviews were interpreted using a literature review of the effects of BIM.

Paper 2 pursued RQ1 and RQ2 and aimed to examine how the Swedish AEC industry actors perceived the business value of BIM and the enablers of and challenges to the business value of BIM. The findings from semi structure interviews were interpreted using the theory of the business value of IT (section 3.4.1).

Paper 3 pursued RQ1 and RQ2 from the international AEC industry perspective. It examined how the business value of BIM was perceived on the individual and project level and how individuals´ experiential knowledge of BIM impacted the perceptions. The findings from a survey were analyzed using factor analysis and regression analyses. The theory of the business value of IT was used to interpret the findings (section 3.5).

Paper 4 pursued RQ1 and RQ2 from the client perspective and examined what intra and inter organizational challenges the public client encountered when implement BIM to create industry change and business value. The IT Business Value Model was applied to the findings from semi-structured interviews (section 3.4.2) and participant observations of (section 3.4.3) the various individuals, groups and networks involved in the BIM implementation.

Paper 5 pursued RQ3 and examined what knowledge interests dominate current BIM research and the implications for the understanding of the business value of BIM. Knowledge interests were examined based on Habermas ontology and social constructivism and technological determinism and were evaluated using the concept of hegemony (section 3.6).

Paper 6 pursued RQ4 from the client perspective and examined the role of the business value of BIM in a wider socio-technical context. The findings from semi-structured interviews with (section 3.4.2) and participant observations of (section 3.4.3) the individuals, groups and networks involved in the BIM implementation were analyzed usingTAM2 and SCOT.

Overview of the mixed methods approach						
Qualitative method						
Perspective	**RQ**	**Paper**	**Method**	**Hours**	**Year**	**Theoretical lens**
Swedish AEC industry actors	1,2	1,2	Semi structured interviews	18	2014	Business value of IT
Swedish public infrastructure client	1,2,4	4,6	Semi structured interviews	40	2014-2017	IT Business Value Model. TAM2. SCOT.
Swedish public infrastructure client	1,2,4	4,6	Participant observations	360	2014-2017	IT Business Value Model. TAM2. SCOT
Quantitative method						
Perspective	**RQ**	**Paper**	**Method**	**Answers**	**Year**	**Theoretical lens**
International AEC industry actors	1,2	3	Statistical analyses	242 (24.5%)	2014	Business value of IT

Table 2. Overview of mixed methods approach

3.3 An abductive research approach

This thesis applies an abductive research approach involving a systematic combination of induction and deduction, i.e. alternating between empirics and theory, in the development of the research questions and in search for better understanding and sense making. Below follows an account of how the abductive research approach was applied to develop and pursue the research questions (see also section 1.4 and section 4).

3.3.1 The abductive reasoning of RQ1

RQ1 aimed to examine how the business value of BIM was perceived in the AEC industry. This interest arose from an observation of how the term business value of BIM had not been academically researched despite the large interest from both industry and research and the extensive research on the business value of IT. The business value of BIM was also characterized by rationalism and positivism (see section 1.3). Together with the lack of a theoretical understanding of the business value of BIM and its theoretical implications (deductive reasoning), the limited and positively biased understanding of the term in industry (inductive reasoning) developed RQ1.

3.3.2 The abductive reasoning of RQ2

RQ2 aimed to understand what factors are perceived as enablers of and challenges to the perceptions of the business value of BIM. Pursuing RQ1 in Papers 1 – 4 showed that the business value of BIM was perceived in terms of future, desirable effects that were not being realized due to the many challenges and costs associated with implementing BIM. This suggested that the challenges associated with the business value of BIM must be better understood formed the inductive reasoning of RQ2. The perceptions also were also impacted by the large interdependencies among the industry actors on multiple levels. This called for theoretical frameworks that consider such interrelations and multi-layered processes and motivated applying the IT Business Value Model (deduction).

3.3.3 The abductive reasoning of RQ3

Using the IT Business Value Model in pursuing RQ1 and RQ2 in Papers 1 – 4 helped for understanding the perceptions of the business value of BIM and for understanding how the intra and inter organizational changes described as enablers of business value creation in the model were rather posing as intra and inter organizational challenges to the business value of BIM. However, there were certain patterns and phenomena in the empirical material that were of social and cognitive nature related to individuals, groups and networks that the model could not explain. This resulted in a search for alternative theories and in an interest for examining what perspectives dominate in BIM research. This formed the abductive reasoning of RQ3 which aimed to examine what knowledge interests and perspectives dominate current BIM research and their impact for the theoretical understanding of the business value of BIM.

3.3.4 The abductive reasoning of RQ4

RQ4 aimed to examine the role of the business value of BIM in a wider socio-technological context. Pursuing RQ3 suggested that the rational and positivistic perspectives used in BIM research would need to be complemented with socio – technical perspectives. This was also supported by how the social and cognitive phenomena of the empirical observations could not be explained by the rational and process-oriented theories of the business value of BIM. This altering between induction and deduction in the search for an understanding of the social and cognitive aspects of the findings formed the abductive reasoning of RQ4. RQ1, RQ2 and RQ4 thus aimed to reflect on, problematize and extend the theoretical understanding of content and perspective of the business value of BIM, while RQ3 aimed to reflect on the content and perspectives of current BIM research.

3.4 The qualitative methods, data collection and analysis

3.4.1 Semi-structured interviews with Swedish AEC industry actors

i) Interview design and data collection

For Papers 1 –2 and RQ1 and RQ2, open ended semi-structured interviews with 9 BIM knowledgeable actors in the Swedish AEC industry were conducted to gain a deeper understanding of how the business value of BIM was perceived and of what factors that were perceived as enablers of and challenges to the perceptions of business value. They represented clients/owners, contractors and consultants (Table 3) The respondents were selected by purposive sampling based on their experience of working in the industry, their experience and knowledge in BIM and their engagement in BIM communities (e.g. BIM Alliance). The interviews were semi structured and prepared in advance (based on the effects of BIM in research) to serve as guidance. The interviews focused on how the respondents interpreted and perceived the term business value of BIM. They took place in 2014, were conducted at the respondent's workplace and lasted 2 hours in average. During the interviews, hand written notes were that were transcribed directly after each interview.

Semi-structured interviews with Swedish AEC industry actors				
Respondent	**Industry actor**	**Current position**	**Year**	**Hours**
A	Consultant	Senior expert	2014	2
B	Contractor	Head of IT	2014	2
C	Client/Owner	Development manager	2014	2
D	Consultant	Head of IT	2014	2
E	Contractor	Head of IT	2014	2
F	Consultant	Project manager	2014	2
G	Client/Owner	Engineering manager	2014	2
H	Client/Owner	Business unit manager	2014	2
I	Contractor	Development manager	2014	2
			Total	**18**

Table 3. Respondent profile of Swedish AEC industry actors

ii) The purpose of conducting interviews

The semi structured approach allowed for some control over the discussions while also allowing the respondents to freely reflect on the business value of BIM (Rudestam and Newton 2007). It also allowed for the respondents to expand their elaborations on the perceived business value of BIM to also discuss the factors they perceived as enablers of and challenges to the business value of BIM. This was important as it laid the empirical foundation for the development of RQ2.

iii) Analysis of the empirical material

The findings in Paper 1 were analyzed by comparing the perceptions of the business value of BIM with the understanding of the effects of BIM in AEC research. In Paper 2, the findings in were analyzed by comparing the perceptions of the business value of BIM with the understanding of the business value of IT in IS research. The perceptions of the business value of BIM in Paper 2 were thematically categorized accordingly to the three levels of the IT Business Value Model (Melville et al 2004). This allowed for also gaining an understanding of what factors the Swedish AEC industry actors perceived as enablers of and challenges to their perceptions of the business value of BIM on the individual and project and the business process and organizational level (RQ2).

Semi-structured interviews with Swedish AEC industry actors					
RQ	**Papers**	**Method**	**Hours**	**Year**	**Theoretical lens**
1, 2	1, 2	Semi-structured open ended interviews	**18**	2014	Business value of IT
		- *Consultants*	*6*	*2014*	
		- *Contractors*	*6*	*2014*	
		- *Clients/owners*	*6*	*2014*	

Table 4. Overview of semi-structured interviews with Swedish AEC industry actors

iv) Limitations

The respondents were chosen based on their experience of BIM and engagement in the BIM community and could be prone to a positive bias towards BIM. An advantage of the purposive sampling was however that the respondents had large experience with BIM and thus could elaborate on both their perceptions of the business value of BIM and the challenges thereof. Also, there were only nine interviews. Yet, they offered new insights into the perceived business value of BIM and the associated challenges. As Patton (1990) puts it, ´the validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information-richness of the cases selected rather than sample size´.

3.4.2 Semi structured interviews at a Swedish public infrastructure client

Paper 4 and Paper 6 consisted of a four year case study of a large Swedish public infrastructure clients´ implementation of BIM from 2014 – 2017. The case study consisted of semi structured interviews (section 3.4.2) and participant observations (section 3.4.3).

The four year case study was being conducted within a collaborative research project with the public client which aimed to evaluate the business value of BIM at the public client. Initially, the focus of the research was on examining the perceptions of the business value of BIM, developing key performance indicators for evaluating these perceptions and following up the key performance indicators in actual projects. By the end of 2014, however, the focus of the research shifted towards understanding the challenges associated with implementing BIM for business value, understanding the social and cognitive factors of the acceptance or rejection of the implementation among the various individuals, groups and social networks of the public client and understanding what role the business value of BIM (i.e. economic factors) played for the acceptance or rejection of BIM. This shift was motivated by both the empirical observations and theoretical frameworks applied (see the abductive research in section 3.3).

i) The case study

The Swedish public infrastructure client is the largest procurer of infrastructure in Sweden. The public client initiated a BIM implementation in 2012 as a response to a government directive which stipulated that the public client ought to implement BIM to encourage increased productivity, innovation and change in the Swedish AEC industry (SOU 2012:39). The case study following the public client's implementation began in in early 2014. It consists of semi-structured interviews with and participant observations of the various individuals, groups and networks involved in the public client´s implementation of BIM. These include a BIM competence group; BIM pilot project managers, BIM implementation managers, BIM coordinators, business unit managers, operation managers and controllers at the department of Major Projects; and BIM pilot project managers, project managers and the BIM implementation manager at the department of Investment Projects. The BIM competence group responsible for developing guidelines and strategies for the implementation at Major Projects and Investment Projects (top-down implementation) was studied mainly through observations. The BIM pilot project managers, BIM implementation managers, project managers, operations managers and business unit managers at Major Projects and Investment Projects conducing the actual implementation of BIM (bottom-up implementation) were studied mainly through interviews. The interactions among the BIM competence group, BIM coordinators, BIM pilot project managers, BIM implementation managers, project managers and business unit managers were studied through observations (section 3.4.3).

The case study consists of approximately 360 hours of observations (Table 6) and40 hours of interviews (Table 5). In addition, it also includes document studies, email correspondence and informal talks. The interpretation of the case study is thus based on a variety of empirical viewpoints and is an example of a qualitative longitudinal case study that aims at contributing to both theory and practice (Yin 1994, Eisenhardt 1989, Merriam 1998).

i) Interview design and data collection

The open ended semi-structured interviews were conducted with ten BIM pilot project managers of Major Projects and Investment Projects, the project manager of the BIM competence group, the BIM implementation manager of Investment Projects, the business unit manager of Major Projects, the business unit manager of Investment Projects and the operations managers of Investment Projects. The interactions among the interviewees were studied through observations (section 3.4.3).

The purpose of the interviews with the ten BIM pilot project managers was to understand how they interpreted and perceived the business value of BIM. However, the focus of the interviews shifted as the respondents only briefly mentioned how they had perceived the business value of BIM and continued to focus on describing the challenges, difficulties and costs they had encountered when trying to implement BIM for business value. They also described how they had reacted to the BIM competence group´s efforts to govern the manner in they were to implement BIM. There were a total of 18 BIM pilot project managers managing the 25 BIM pilot projects. All 18 were contacted and 10 agreed on an interview

(Table 4).The interview lasted 2 hours in average (total of 20 hours). Hand written notes were taken and were transcribed directly after each interview (Table 4).

Semi-structured interviews with ten BIM pilot project managers						
Respondent	**BIM pilot project**	**Department**	**Project phase**	**Years BIM experience**	**Hours**	**Year**
A	Road expansion	Investment Projects	Construction	1 - 2	2	2014
B	Road expansion	Investment Projects	Maintenance	0 - 1	2	2014
C	Railway yard	Investment Projects	Planning	0 - 1	2	2014
D	High speed railway	Major Projects	Planning	5 - 10	2	2014
E	Traffic junction	Major Projects	Construction	0 - 1	2	2014
F	Traffic junction	Investment Projects	Planning	2 - 5	2	2014
G	Road expansion	Major Projects	Construction	5 - 10	2	2014
H	Railway expansion	Investment Projects	Planning	5 - 10	2	2014
I	Railway expansion	Investment Projects	Planning	1 - 2	2	2014
J	Road expansion	Investment Projects	Construction	1 - 2	2	2014

Table 4. Semi structured interviews with BIM pilot project managers

The open ended semi-structured interviews with the project manager of the BIM competence group focused on understanding how the BIM competence group had tried to govern and develop strategies for the implementation of BIM at the public client. The interviews focused on understanding the groups´ work with revising the steering documents governing internal project managers work practices to include BIM-based work practices and the procurement contracts to demand BIM-based work practices from suppliers. The focus was also on understanding how they had tried to communicate the main argument for the BIM implementation of having the public client implement BIM as a means to drive AEC industry change to the individuals, groups and networks of the public client involved in the BIM implementation. The two interviews lasted 2.5 hours in average (total of 5 hours). Handwritten notes were taken and were transcribed directly after the interviews (Table 5).

The open ended semi-structured interviews with the BIM implementation manager overseeing the BIM implementation at Investment Project focused on how the project managers of Investment Projects had been able to implement the revised steering documents and revised procurement contracts, how the implementation manager perceived the business value of BIM and the role it played for the acceptance of BIM at Investment Projects. Three interviews were conducted lasting 3 hours, 2 hours and 1.5 hours (total of 7.5 hours). Hand written notes were taken and were transcribed directly after each interview (Table 5).

The open ended semi structured interviews the business unit manager of Major Projects, the business unit manager of Investment Projects and the operations manager of Investment

Projects focused on understanding what change management initiatives that were taking place at the departments and how they perceived the implementation of BIM as a change initiative in relation to the other ongoing change initiatives. The interviews also focused on what role they perceived that arguments and indicators for the business value of BIM played. The interviews lasted 2.5 hours, 2.5 hours and 2 hours, respectively (total of 7.5 hours). Hand written notes were taken and were transcribed directly after the interviews (Table 5).

ii) The purpose of conducting interviews

The interviews allowed for understanding how the individuals formed their perceptions, beliefs, expectations about the BIM implementation, the business value of BIM and the factors that they perceived as enablers of and challenges to the business value of BIM. The interviews also allowed for a deeper understanding of how the BIM competence groups´ argument of having the public client implement BIM as a means to drive industry change had been diffused to and accepted or rejected by the individuals, social groups and networks of Major Projects and Investment Projects. While the interviews allowed for understanding of the individuals´ interpretations, beliefs and expectations about the implementation of BIM, the observations allowed for understanding how the individuals´ interpretations, beliefs and expectations of BIM were formed in social interactions and social networks (section 3.4.3).

iii) Analysis of the empirical material

In Paper 4, the IT Business Value Model (Melville et al 2004) was applied as lens to interpret the findings. It is an open systems model whose multi-layered analysis accounts for the public client´s large impact on the work practices of the actors in the AEC industry. The model also understands the implementation of IT-supported change processes and the subsequent creation of business value which is useful for interpreting the public client´s aim with the BIM implementation as a means for driving industry change and productivity. The model is also useful as it allows for understanding the challenges associated with implementing such IT-supported change processes (section 2.4.3).

In a first step, the focal firm level of the IT Business Value Model was applied. This allowed for understanding that the intra and inter organizational changes described as enablers of business value (Melville et al 2004) rather posed as challenges in the case of the public client, for example “challenges in changing work practices”. In a second step, the organizational challenges were categorized into nine categories using thematic analysis. In a third step, the competitive and macro environment levels (Melville et al 2004) allowed for distinguishing between intra and inter organizational challenges.

In Paper 6, TAM2 (Venkatesh and Davis 2000) and SCOT (Pinch and Bijker 1984) were used to interpret the findings. TAM2 allowed for understanding to what extent the individuals, groups and networks among Major Projects and Investment Projects had accepted or rejected the BIM competence group's argument of having the public client implement BIM as a means for driving industry change based on social and cognitive influence processes. The findings were analyzed accordingly to the social influences processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality and result demonstrability) of TAM2 (section 2.5.2). Understanding the acceptance for a technology among the individuals, groups and network of an organization is important for understanding how that organization as a whole may shape the use of a technology in the industry. The insights from applying TAM2 could be useful for understanding the role of the public client in the social construction of BIM (SCOT) in the Swedish AEC industry (Pinch and Bijker 1984). SCOT will thus be used as a support for discussing the implications of the findings from applying TAM2 to the public client.

While the method of TAM2 is quantitative, the constructs of the model (i.e. the social and cognitive influence processes), such as social norms and image, originate from experimental studies of human behavior in phycology and sociology. In these studies, the basis for the experiments (e.g. formulations of hypothesis) is often observations of human behavior and has also included interviews and the quantitative data has also been complemented with qualitative data as a means for strengthening the validity and reliability of the research (e.g. in Bagozzi 2007). The descriptions of the social and cognitive influence processes by Venkatesh and Davis (2000) are also that descriptive, explanatory and extensive that they were helpful for interpreting the interviews. Hence, the qualitative application of TAM2 in this thesis is useful and intuitive, but should ideally also be complemented with a quantitative interpretation of TAM2.

Semi-structured interviews with Swedish public infrastructure client					
RQ	**Papers**	**Method**	**Hours**	**Year**	**Theoretical lens**
1,2,4	4,6	Semi-structured open ended interviews	**40**	2014-2017	IT Business Value Model. TAM2. SCOT
		- BIM pilot project managers	*20*	*2014, 2015*	
		- Project manager BIM competence group	*5*	*2014, 2017*	
		- BIM implementation managers	*7.5*	*2016, 2017*	
		- Business unit and operations managers	*7.5*	*2017*	

Table 5.Semi-structured interviews with Swedish public infrastructure client

iv) Limitations

Open ended semi structured interviews may also be prone to bias of the respondents (Boyce and Neale 2006). The BIM implementation represented a major change in work practices, attitudes and culture. BIM enthusiastic project managers of large unique projects may have represented a positive bias towards BIM, whereas project managers of smaller projects may have represented a negative bias towards BIM resulting from a frustration and resistance towards BIM. In a qualitative study, this can be managed by using a variety of viewpoints ranging from interviews, field notes and observations (Yin 2004). Therefore, participant observations were also conducted (section 3.4.3).

3.4.3 Participant observations of a Swedish public infrastructure client

i) The role of the author and data collection

The interactions between the BIM competence group, BIM implementation managers, BIM pilot project managers, project managers and BIM coordinators were studied by an ethnographical field study approach including observations of meetings, conferences, workshops, regular workdays etc. The observations covered approximately 360 hours and took place formally, for example at BIM kick-off conferences, internal and external BIM meetings, regular meetings, workshops, project meetings, phone conferences and various seminars, and informally, for example at lunches and coffee-breaks . The author was partaking mainly as a listener except during brakes and social events when the author also engaged in informal discussions. Interactions between the BIM competence group, BIM coordinators and implementation managers of Major Projects and Investment Projects were observed at, for example, two-day BIM kick-off conferences in 2014, 2015 and 2016. Observations also included internal BIM meetings arranged by the BIM competence group, phone conferences among BIM coordinators and regular meetings of the BIM competence group. Participant observation involves the author taking part in the daily activities, rituals, interactions and events as a means for observing the explicit and tacit aspects of the respondent’s daily routines and working culture (DeWalt and DeWalt 2010). All observations were documented by hand written notes and transcribed directly after each observation.

ii) The purpose of conducting participant observations

While the interviews allowed for understanding the individuals´ interpretations, beliefs and expectations about the BIM implementation (section 3.3.2), the observations allowed for understanding how the individuals´ interpretation, expectations and beliefs were formed in social interactions in groups and social networks. The observations allowed for understanding how the interpretations, beliefs and expectations about the implementation of BIM of the groups and social networks were formed, promoted and upheld collectively. The 360 hours of observations were important for interpreting the social and cognitive phenomena in the empirical material related to perceptions, beliefs and expectations of individuals, groups and social networks using TAM and SCOT. Observations allowed for a deeper understanding of how the social and cognitive processes influencing the perceptions, beliefs and expectations about BIM were developed and upheld in the groups and networks. Important observation included observations of, for example, meetings and conferences among the BIM competence group and BIM pilot project managers where the BIM pilot project managers´ reactions to the governing efforts of the BIM competence group could be studied including both their individual reactions and their collective reactions as a group and network. See Table 6.

iii) Analysis of the empirical material

See analysis of the empirical material (iii) of section 3.4.2.

Participant observations of Swedish public infrastructure client					
RQ	**Papers**	**Method**	**Hours**	**Year**	**Theoretical lens**
1, 2, 4	4, 6	Participant observations	**360**	2014-2017	IT Business Value Model. TAM2. SCOT
		Conferences[1]	*30*	*2014*	
			30	*2015*	
			30	*2016*	
			20	*2017*	
		Total	***110***		
		Workshops[2]	*5*	*2014*	
			10	*2015*	
			10	*2016*	
		Total	***25***		
		Internal meetings[1]	*40*	*2014*	
			50	*2015*	
			50	*2016*	
			30	*2017*	
		Total	***170***		
		External meetings[3]	*15*	*2015*	
			15	*2016*	
		Total	***30***		
		Other	***25***	*2014-2016*	

1) Interactions among the a) the BIM competence group and b) the BIM competence group and the BIM coordinators, BIM pilot project managers, project managers and implementation managers.
2) Interactions the BIM competence group, BIM coordinators, BIM pilot project managers, project managers, implementation managers, business unit managers and operations managers.
3) Interactions among the BIM competence group and the public client´s suppliers (e.g.consultants, contractors).

Table 6. Participant observations of Swedish public infrastructure client

iv) Limitations

Even though participant observation studies can be used to help answer descriptive research questions, they are susceptible to biases (DeWalt and DeWalt 2002), for example by different gender, sexuality and ethnicity. This means that researchers may have different access to information, people, settings and bodies of knowledge (DeWalt and DeWalt 2002). There is also a risk of becoming a participating observer and becoming too engaged. This risk may be handled by having a transparent dialogue about the author´s role in the observation with for example supervisors.

3.5 The quantitative methods, data collection and analysis

i) The purpose of the quantitative method

To examine the international industry perspective, a survey was perceived as most appropriate due to accessibility. Paper 3examined how individuals´ experiential knowledge of BIM impacted their perceptions of business value of BIM. A large international survey was administrated to members of the buildingSMART network (Table 7). Factor analysis examined different categories of perceived business values of BIM and regression analyses examined how individuals´ experiential knowledge of BIM impacted these perceptions.

ii) Survey design and data collection

The survey built on methods from business studies for capturing the impact of experiential knowledge (Eriksson et al 1997, Blomstermo et al 2004). The respondents were asked to choose a specific ongoing BIM project to answer questions about. One examined how the business value of BIM was perceived (see Table 3 of Paper 3). It was developed from the interviews with the Swedish AEC industry actors, a literature review of the effects and business values of BIM and a literature review of the business value of IT. The remaining eleven questions examined to what extent the respondents' experiential knowledge of BIM had been useful for the management of their ongoing BIM project (exploitation of knowledge) (see Table of Paper 3). They were developed from the interviews with Swedish AEC industry actors and a literature review of work practices in BIM implementation. Question related to, for example, the usefulness of having prior experience in using BIM for various application areas and of having prior experiences in managing challenges of BIM implementation.

iii) Analysis of the empirical material

The perceptions of the business value of BIM were analyzed by factor analysis in order to examine whether any types or categories of perceived business value of BIM emerged. The respondents' perceptions of the usefulness of their experiential knowledge of BIM were correlated to the business values of BIM in the factor analysis through regression analyses (multiple, robust and stepwise). This estimated the impact of the respondents´ experiential knowledge of BIM on their perceptions of the business value of BIM.

Factor analysis can reduce larger sets of variables and examine patterns of clustering (e.g. categories) (Stevens 2012, Hair et al 2006). The aim is to find the linear combination of the variables that achieves the maximum amount of variance. The first factor will account for the largest amount of variance; the second factor for the next largest etc. Only those factors will be retained that fulfil the Kaiser criterion (eigenvalue > 1) (Stevens 2012). The Kaiser criterion should also be complemented with sound theoretical and conceptual motivations (Henson and Roberts 2006, Beavers et al 2013).In multiple regression analysis using, two or more independent variables are used to estimate the dependent variable. The best fitting line is estimated based on that the sum of the squared residuals is minimized (Hair et al 2006). The residual is the difference between the observed values and predicted values for the dependent variable. The residuals are used when estimating the models given that they are uncorrelated and have a constant variance. In estimating the best fitting a line, some data points might deviate (outliers) (Li 1985, Fox 1997) and robust regression analysis may be used. Robust regression reweighs the deviating observations. It performs an initial screening of the outliers and then re-weights them (Li 1985, Fox 1997). Stepwise regression analysis can complement regression analyses. It allows for reducing the number of independent variables to a subset of useful predictors while removing those that are less important. It systematically adds the most significant variable or removes the least significant variable during each step.

The findings were analyzed using the theory of the business value of IT. The findings from the factor analysis of the different categories of perceived business values of BIM were compared with the understanding of the business value of IT (e.g. Melville et al 2004). The findings from the regression analyses of the impact of individuals´ experiential knowledge of BIM on perceptions of business value of BIM were compared with the understanding of the factors and capabilities that are described as prerequisites for business value creation in IS research (e.g. Mooney et al 1996, Melville et al 2004, Kohli and Grover 2008) (section 2.2).

Statistical analyses of survey to international AEC industry actors				
RQ	**Paper**	**Method**	**Response rate**	**Theoretical lens**
1, 2	3	*Statistical analyses of survey*	24.5% (242 answers)	Business value of IT
		- Factor analysis		
		- Multiple regression		
		- Robust regression		
		- Stepwise regression		

Table 7. Overview of statistical analysis of survey to international AEC industry actors

iv) *Limitations*

Although the quantitative method aims to measure the views, perspectives and responses of a sample population to generate increased knowledge about a target population, there are limitations (Saunders et al 2009). For example, designing surveys with pre-formulated closed ended questions implies that the survey is only as good as an indicator and representation of the “real world” as perceived by the creator of the survey. Thus, the quantitative methods may be complemented with qualitative methods (Greene 2007, Creswell 2002) (as was also the purpose of the mixed methods approach of this thesis). Selection bias may also be an issue. The members of the buildingSMART network could be described as more enthusiastic in promoting the implementation of BIM and more positively oriented in their perceptions of the business value of BIM. However, as the purpose was to increase the understanding of how experiential knowledge of BIM impact perceptions of the business value of BIM, the BIM knowledgeable and experienced members of the buildingSMART network were chosen.

3.6 Literature review of knowledge interests in current BIM research

i) *The purpose of the literature review*

Paper 5examined what knowledge interests are dominating in current BIM research and their implications for the understanding of the business value of BIM. The aim was to build an argument for broadening the theories and perspectives in research on BIM.

ii) *Analysis of the empirical material*

The knowledge interests of well-cited BIM articles were studied based on whether the knowledge interests were technical, practical or emancipatory (Habermas 1971) or socio-technical (Trist and Bamforth 1951).The technical domain that supports a positivistic knowledge interest (prediction and casual explanation). The practical domain supports a hermeneutic knowledge interest (interpretation and understanding. The emancipatory domain supports critical knowledge interest (criticism, reflection) (Habermas 1971). These were complemented with an examination of whether the knowledge interest were of technological determinism (technology is what influences human actions and behaviors and the success of a technology) (Smith and Marx 1994) or social constructivism (human actions, behaviors and attitudes influence the use and success of a technology) (Trist and Bamforth 1951).

The knowledge interest of the 10 most cited BIM articles from four journals during 2007 – 2017 were analyzed. When categorizing the knowledge interests, keywords and phrases were categorized by the three knowledge domains and by social constructivism or technological determinism. A technical knowledge interest was indicated by keywords and phrases such as ´application areas´ and ´benefits of BIM´, a practical knowledge interest by ´understanding BIM adoption´ and ´understanding the role of cultural change´ and an emancipatory knowledge (which was limited)by ´questioning the governing theories and methodologies´ and´ critical realism´.

iii) *Limitations*

The review was based on a narrow selection of the current BIM literature. The purpose was not to do a comprehensive literature review but to build an argument for broadening the BIM research. Still, there is a need for a more comprehensive review to fully understand how the research on BIM has developed and what the future needs are.

4. Findings

In section 4.1 follows a summary of the appended papers. In section 4.2 the findings to the research questions are presented. In section 5 the contributions of the findings for fulfilling the aim of the thesis are discussed.

4.1 Summary of appended papers

Paper 1 The Perceived Business Value of BIM

Paper 1 explored how the business value of BIM was perceived by Swedish AEC industry actors. The business value of BIM was perceived in terms of desirable future business values (ex-ante) that were currently being hindered by the challenges and associated costs of implementing BIM (ex-post). Perceptions thus included both desirable future outcomes and negative actual outcomes. Also, the factors perceived as enablers of the business value of BIM were posing as challenges and were highly interdependent.

Paper 2 A Proposed BIM Business Value Model

To interpret the perceptions of the business values of BIM in Paper 1, Paper 2 applied the theory of the business value of IT. Comparing the perceptions with the understanding of the business value of IT as mainly the financial and strategic impact of IT on business processes and organizational performance (e.g. Melville et al 2004, Kohli and Grover 2008) showed that the perceptions of the business value of BIM related more to perceptions and expectation of BIM on an individual and project level, rather than a business process and organizational level, and that they were associated with challenges and added costs. It also showed that the challenges associated with the business value of BIM must be better understood from a multi-level perspective, such as from the perspective of the IT Business Value Model (Melville et al 2004). The findings also showed a need for understanding the challenges from a wider industry perspective, including the international perspective (see Paper 3) and client perspective (see Paper 4).

Paper 3 The Impact of Experiential Knowledge of BIM on the Perceived Business Value of BIM

Paper 3 quantitatively explored how international AEC industry actors perceived the business value of BIM in an ongoing BIM project. Two categories of business values of BIM emerged: project progress related (managing project managerial issues) and project outcome related (managing efficiency and optimization).The perceptions were also impacted by the respondents´ experiential knowledge of BIM including having had prior experience in managing various implementation challenges. Comparing the findings with the factors and capabilities that are described as enablers of the business value of IT (e.g. Melville et al 2004, Kohli and Grover 2008) suggested that these were currently being described in terms of challenges rather than enablers. The findings also suggested that the challenges associated with the business value of BIM and of the BIM implementation itself would need to be better understood before paying attention to enablers of the business value of BIM.

Paper 4 Challenges When Implementing BIM for Industry Change

At the public client, the business value of BIM was perceived as both desirable future outcomes (ex-ante) and actual outcomes (ex-post). Project managers perceived actual outcomes in terms of positive effects on project performance (e.g. fewer errors and rework) and negative effects of added costs from implementation challenges. The majority of the perceptions was in terms of challenges and associated added costs. The IT Business Value Model (Melville et al 2004) was used to interpret these challenges. The multi-layered and open systems model accounted for the major impact of the public client on its suppliers. It allowed for understanding the public client´s BIM implementation as an IT-supported change processes and for understanding how the intra and inter organizational changes that are described as enablers of business value in Melville et al (2004) posed as intra and inter organizational challenges in the case of the public client. One challenge related to evaluating the business value of BIM and another to demanding BIM in procurement. There were, however, also social and cognitive aspects in the empirical material which the IT Business Value Model could not explain.

Paper 5 BIM research: Common perspectives and implications for future research

The notion of how the theory of the rational and process-oriented theory of the business value of IT could not help interpret the social and cognitive aspects of the perceptions of the business value of BIM resulted in a search for alternative theories and in an interest in understanding what perspectives and theories dominate in current BIM research. Paper 5 thus aimed to build an argument for broadening the research on BIM. An analysis of the knowledge interest in high impact BIM articles using Habermas (1971) and Trist and (Bamforth 1951) showed that most articles had a technical knowledge interest. Few had a practical knowledge and even fewer had an emancipatory knowledge interest. The findings also discussed the implications of a dominating technical domain exercising power and influence (hegemony) (Gramsci 1988, Bourdieu 1991) in BIM research including the understanding of the business value of BIM. Thus it is important to understand the business value of BIM from other perspectives, such as the socio-technical perspective (Paper 6).

Paper 6 The role of the public client in the social construction of BIM

Paper 6 examined the role of the public client in the social construction of BIM and what role the business value of BIM played in a socio-technical context. Drawing onTAM2 (Venkatesh and Davis 2000) suggested that the acceptance and rejection of BIM was largely impacted by whether the individuals, groups and networks perceived that the implementation of BIM as a means for driving industry change was in line with their interpretation of the public client role (social and cognitive influences) and less by arguments of business value of BIM (economic influences). Other social and cognitive influence processes impacting the perceptions of BIM and the acceptance or rejection of BIM included social norms, job relevance and image. The understanding the acceptance and rejection of BIM among the individuals, groups and networks of the public client also provided insights for understanding the role of the public client as a social group on the social construction of BIM in the industry (SCOT). Using SCOT (Pinch and Bijker 1984) as support for discussing the implications of the findings from TAM2 suggested that the public client´s role in the social construction of BIM was twofold; one promoting an acceptance of the implementation of BIM as a means for driving industry change and one promoting a rejection of it.

4.2 The perceived business value of BIM

The findings show that the perceived business value of BIM (*RQ1*) among the three informant groups was in terms of desirable future outcomes of BIM (ex-ante) (section 4.2.1) and actual outcomes of BIM (ex-ante). The perceptions of the actual outcomes of BIM related both to challenges and added costs (section 4.2.3) and positive outcomes on project progress and project outcome (section 4.2.2). The desirable future business values of BIM were however perceived to currently not be realized due to the challenges and associated costs of the BIM implementation. The challenges also impacted the perceptions of project progress and project outcome related business values of BIM. The perceptions of the business value of BIM related to both an individual and project level (e.g. by project managers) and a business process and organizational level (e.g. by business unit managers).

The findings to RQ1 called for theoretical frameworks that regard the interdependencies among the actors in the AEC industry and the multi-layered context in which the business value of BIM was perceived. Thus, the theory of the business value of IT (e.g. the IT Business Value Model) was used as theoretical lens for interpreting RQ1.

4.2.1 Desired future effects of BIM(ex-ante perspective)

i) Swedish AEC industry actors

Among Swedish AEC industry actors the business value of BIM was perceived in terms of future desirable effects, such as more visual communication and planning, fewer errors and rework, higher quality and more efficient maintenance. However, these were only expected to be realized once the challenges of BIM were managed. The factors that were described as enablers of the desirable business values were described to currently pose as challenges. Comparing the perceptions of the future desirable business values of BIM with the understanding of the business value of IT as also including the capabilities and enablers of business value (e.g. Melville et al 2004, Kohli and Grover 2008) showed a need for further understanding the challenges associated with perceptions of the business value of BIM

ii) Swedish public infrastructure client

Also at the public client, the business value of BIM was perceived as desirable future effects that were hindered by the challenges of BIM implementation. There were however some differences among individuals and departments. For example, the BIM competence group (conducting a top-down implementation) expected positive economic effects of BIM on project performance that could eventually be measurable, including a lower spread in tendering bids, less errors and rework, increased worksite safety, earlier completion times, lower costs of drawings and fewer appeals. These had however been difficult to evaluate as it was difficult to isolate any effects to the implementation of BIM. Among BIM pilot project managers, project managers and implementation managers of Major Projects and Investment Projects (conducting a bottom-up implementation), expectations of future desirable business values related more to an individual and project level such as individual project managers and their management of projects. Among business unit managers and operations managers of Major Projects and Investment Projects, the perceptions also related to a business process and organizational level including expectations on BIM to positively effects and change current business models and strategies, work practices and decision making. A few projects managers of Major Projects had also perceived actual outcomes (ex-post) in terms of perceptions of positive effects on project performance, while the majority of project managers of Investment Projects perceived actual outcomes in terms challenges and added costs.

4.2.2 Project progress and projects outcome related effects (ex-post perspective)

i) International AEC industry actors

The international industry perspective provided perceptions of actual outcomes of BIM (ex-post perspective). Two categories of perceived business values of BIM in ongoing projects had been perceived. The first were project progress related and associated with managing and minimizing project managerial issues such as improved coordination, reduced conflicts, improved communication and increased client satisfaction. The second were project outcome related and associated with managing efficiency and optimization including lower costs, earlier completion times and improved energy performance. The project progress related business values were more statistically significant and there was an overall better understanding of the project progress related business values than the project outcome related.

4.2.3 Challenges and added costs (ex-post perspective)

i) Swedish AEC industry actors

The perceptions of the desired future business vales of BIM were also perceived to be hindered by the current challenges of implementing BIM. These translated into extra costs on both the individual and project level and the business processes and organizational level. These related to high investment costs, costly software updates, additional education, increased complexity and risk. Also, the factors that were perceived to be prerequisites for business value creation were also perceived to currently pose as challenges including a lack of incentives for BIM and a resistance to change. These perceptions provided a contrast to the understanding of the business value of IT (e.g. Melville et al 2004, Kohli and Grover 2008) in that the business value of BIM was also interpreted as costs and challenges, and not only as ´values´ of positive effects on organizational performance (see section 4.3).

ii) International AEC industry actors

Also among the international AEC industry actors, the perceptions of the project progress related and project outcome related business values of BIM were impacted by the respondents´ experiential knowledge of BIM of various implementation challenges including a resistance towards change, high investment costs and costly software upgrades. The respondents´ experiential knowledge of BIM impacted how the project progress and project outcome related categories of the business value of BIM were perceived. Having had prior experience in managing BIM implementation challenges was an important challenge and further supported the need for better understanding the challenges associated with the business value of BIM in order to be able to reflect on and problematize the current rational and normative understanding of the content and perspective of the business value of BIM (see section 4.3).

iii) Swedish public infrastructure client

The need for extending the theoretical understanding of the content and perspective of the business value of BIM was further illustrated when the IT Business Value Model (Melville et al 2004) was used to interpret the perceptions of the business value of BIM at the public client. The model allowed for understanding the public client´s BIM implementation as an IT-supported change processes. However, the intra and inter organizational changes described in the model as enablers of the creation of business value across the firm, industry and macro level, such as changing work practices, policies, business models and roles, emerged in the interviews and observations, but were described and talked about in terms of challenges and difficulties rather than as enablers. These included challenges in changing current work practices, challenges in changing roles etc. One particular challenge related to evaluating the business value of BIM and another to demanding BIM in procurement (see section 4.3).

4.3 The enablers of and challenges to the business value of BIM

When the respondents among the Swedish AEC industry actors and the Swedish public infrastructure client were asked how they interpreted and perceived the term business value of BIM in interviews, the they briefly described their perceptions of the business value of BIM and instead chose to focus on describing the challenges, difficulties and obstacles they had encountered when trying to implement BIM for business value. The factors that were described as enablers to the future desirable business values of BIM were also described to currently pose as challenges (*RQ2*). The challenges related to both an individual and project level and a business process and organizational level. For example, among the Swedish AEC industry actors and the public client, challenges related to individual project managers and their management of projects and to business unit managers and their work with trying to create conditions for the BIM implementation within a unit or department (e.g. changing current business models and work practices).

The common perceptions across the three informant groups of the business value of BIM as the desirable future effects of BIM currently being hindered by BIM implementation challenges and the associated costs illustrated a need for increasing the understanding of the challenges associated with the business value of BIM (*RQ2*). The challenges and the associated costs were often described to pose as barriers to the realization of the respondents´ perceptions of the future desirable business values of BIM. Challenges associated with the business value of BIM were understood when comparing the perceptions of the business value of BIM with the understanding of the business value of IT as also including the factors and capabilities that enable the creation of business value (e.g. developing strategies, business processes, competencies and skills) (Melville et al 2004, Kohli and Grover 2008, Cao 2010, Grover and Kohli 2012) and seeing how these factors and capabilities were described by the respondents, not in terms of ´enablers´, ´conditions´ or ´prerequisites´, but in terms of ´challenges´, ´difficulties´ and ´ obstacles´. That is, the enablers to the future desirable business value of BIM were perceived to currently pose as challenges and barriers to the future desirable business value of BIM.

Among the three informant groups, certain categories of challenges associated the business value of BIM emerged. The IT Business Value Model by Melville et al (2004) and its open systems understanding of the creation of business value as an interdependent and multi-layered process dependent on inter organizational change helped in identifying and categorizing the challenges. The factors and capabilities that were described as enablers of business value of IT in Melville et al (2004), including intra and inter organizational change, emerged in the empirical material but in terms of challenges and not enablers across the three informant groups. Using the IT Business Value Model (Melville et al 2004) (see analysis of empirical material in sections 3.4.1 – 3.4.3), ten categories of challenges associated with trying to implement BIM for business value were identified across the three informant groups. These were interdependent and of both intra and inter organizational nature.

1. Changing work internal practices
2. Education and learning of BIM
3. Developing a common definition of BIM
4. Evaluating the business value of BIM
5. Demanding BIM in procurement
6. Creating incentives for BIM implementation
7. Implementing BIM in maintenance
8. Changing and creating new roles
9. Managing a lack of interoperability
10. Lack of top management support

4.3.1 Changing work internal practices

The Swedish AEC industry actors argued that the major business value of BIM lies in changing of organizational structures and traditional work practices. However, this was also perceived to currently be a major challenge. The business value of BIM was perceived to currently depend on individual BIM enthusiastic project managers changing their own work practices and acting as change agents rather than on any overall industry-wide change initiatives. There were also weak incentives for managers to redesign organizational structures, routines and business models to be aligned with BIM – based work practices. A strong traditional culture and skepticism towards new ways of working also hampered any long-term change. An important factor for business value creation was that BIM would have to be perceived as useful to the current day-to-day work.

Among the international AEC industry actors, having experience in managing resistance towards change also impacted perceptions of business value. Also, at the public client a major challenge of implementing BIM for business value creation was changing the work practices of internal project managers and suppliers. The BIM competence group revised the steering documents governing internal project managers to include BIM – based work practices and the procurement contracts to include demands on BIM to suppliers. However, implementing such IT-supported change process (Melville et al 2004) was challenging. The project managers who were to implement the revised steering documents and procurement contracts found the changes fuzzy, incomplete and confusing and often disregarded them.

4.3.2 Education and learning of BIM

The Swedish AEC industry actors perceived challenges from an increased complexity from BIM and the need to provide additional education and training. The education would need to be relevant to project managers' daily work. An overall competence development of the industry was a prerequisite for business value creation with BIM. It would depend on inter-organizational collaboration and sharing of best practice, knowledge and routines across industry actors. At the public client, a lack of education of BIM was important for implementing BIM for business value. The BIM competence group thus assigned BIM pilot project with BIM coordinators for additional support. As there was an initial lack of BIM competent available in-house staff, some projects were assigned external BIM coordinators (consultants). Later, education in BIM was provided for internal staff and more internal BIM coordinators were assigned. Still, many project managers argued that the public client must develop an internal BIM competence and not rely on consultants to educate them on BIM.

4.3.3 Developing a common definition of BIM

Among the international AEC industry actors, the manner in which BIM was defined and understood impacted the perceptions of the business value of BIM. Having a more holistic understanding of BIM and defining BIM as a process rather than a technology or tool was related to positive perceptions of the project progress related business values of BIM. At the public client, a lack of a common and mutual definition of BIM was a challenge. The BIM competence group aimed to develop a mutual and accepted definition of BIM to communicate internally. BIM pilot project managers argued that a better understanding of the extent to which BIM was used by internal project managers would need to be developed first. At Major Project, there was also often a more holistic definition of BIM than at Investment Projects. Project managers found that the lack of a joint and mutually accepted definition of BIM had contributed to some projects not using BIM and in a subsequent skeptism towards the term business value of BIM. Different definitions and expectations on BIM also created misunderstandings and extra costs both internally and for suppliers. A set of criteria for defining BIM was later developed by the BIM competence group.

4.3.4 Evaluating the business value of BIM

The Swedish AEC industry actors argued that there is a need for a business case for BIM with clear and reliable arguments for the business value of BIM to convince skeptical project managers and offset some of the persistent and strongly rooted traditional misbeliefs towards new technology. Otherwise there is no reason for changing something that already works 'good enough'. The argument was often that the major future potential business value of BIM was in maintenance. However, making such evaluations was difficult as there were few such examples to evaluate. The response from project managers to such economic arguments was also uncertain.

Initially, there was a need for justifying the BIM implementation at the public client by demonstrating the business value of BIM. However, it was difficult to discern any economic effects of BIM on project performance and to isolate any effects to BIM. Together with a lack of time, resources and heavy workload this was used as argument against BIM by skeptical project managers. Project managers also found it difficult to evaluate the effects of BIM on project performance. The evaluations were experience-based and tied to certain key individuals. Some also found BIM to disrupt their daily project management and to add costs. Others perceived that any potential business values of BIM often fell to the contractors who then passed on their internal costs for implementing BIM onto the public client. Implementation managers, business unit managers and operations managers also perceived that the future potential business value of BIM was hindered by challenges and added costs in unclear specifications in procurement contracts and in the different definitions of BIM. The impact of arguments of increased business value of BIM for individual project managers was also questioned by some business unit managers and operations managers.

4.3.5 Demanding BIM in procurement

One major challenge associated with the business value of BIM related to a lack of demand for BIM from clients. Among the Swedish AEC industry actors, a hinder towards the realization of the desired future business value of BIM was a lack of demand for BIM from owners and clients. But it was also challenging for the consultants and contractors to encourage their clients to start making demands on BIM to them it would require the consultants and contractors themselves would have to change their own business models and strategies accordingly. The price pressure and lowest-bid mentality currently driving the procurement process of the Swedish AEC industry was also perceived to hinder making demands on BIM in procurement. Moreover, BIM did not currently have legal status over paper drawings. In the international perspective, a lack of client demand for BIM was also a challenge. However, having had experience in managing challenges arising from a lack of client demand positively correlated with the project progress related business value of BIM.

The aim of the public client´s implementation of BIM was to drive industry change, innovation and productivity by changing the work practices of internal project managers and suppliers. The BIM competence group revised the steering documents governing work practices of internal project managers to include more BIM - based work practices. The procurement contracts were also revised to include more demands on BIM-based work practices from suppliers. However, several challenges emerged. The BIM competence group found it difficult to formulate the requirements to the steering documents and procurement contracts. It was also difficult to follow up that the new requirements were actually followed by project managers and suppliers. Implementation managers and BIM pilot project managers of Investment Projects also indicated difficulties with implementing the revised procurement contracts demanding BIM from suppliers. The requirements were difficult to understand for both the project managers and their suppliers. Project managers would have to put time and effort on directing their suppliers. In other cases, the revised procurement contracts were complemented with additional contracts or simply put aside in favor of earlier contracts versions not demanding BIM. The new procurement contracts provided suppliers with detailed requirements and instructions on how to work with BIM. Among project managers and implementation managers at Investment Projects, this was perceived to clash with the other ongoing change initiative of becoming a more professional client and using less detailed contracts specifications. Some project managers also prioritized the professional client role.

4.3.6 Creating incentives for BIM implementation

An important prerequisite to the business value of BIM among the Swedish AEC industry actors was creating incentives for BIM. This was however challenging due to the low-bid mentality in the industry and tight budgets and schedules. Project managers had no incentives to change their preferred work practices. There were no clear incentives for project managers responsible for project time, cost and quality to work with BIM, increase the risks and uncertainties and thereby jeopardize project fulfilment. For management, there were also weak incentives for changing the current organizational structures and business models. This was also a challenge at the public client. While many BIM pilot project managers perceived the lack of additional resources for BIM from top management a challenge, the BIM competence group did not focus on this challenge. Instead, they tried to create motivation by interacting with the industry and attending BIM networks, conferences and seminars. The incentives for implementing BIM had often came from individual BIM enthusiastic project managers or suppliers. The examples of best practice and business value were also not applicable to Investment Projects as they came from either housing or internal mega projects.

4.3.7 Implementing BIM in maintenance

While the Swedish AEC industry actors perceived the business value of BIM as desirable future positive impacts of BIM on project performance, the major future potential business value of BIM was perceived to lie in use of BIM in maintenance. This would include positive economic impacts from a more efficient management of information during the life cycle. However, BIM was often not perceived as such long-term investment but rather as a short-term investment costs. The public client also perceived the major business value of BIM to be in the long-term contribution to maintenance. However, involving the maintenance department in the implementation had been difficult due to resistance towards BIM and that other ongoing change initiatives were prioritized at maintenance. BIM pilot project managers who had implemented BIM on their own initiatives further argued that the responsibility for including maintenance had fallen to a few engaged project managers.

4.3.8 Changing and creating new roles

The Swedish AEC industry actors also associated the business value of BIM with challenges related to creating and changing current roles. The additional risks and costs associated with experimenting with BIM created a need for developing new expert roles, such as the BIM-coordinator. The BIM coordinator was also perceived to be the future service and product to client of many consultants and the main source from which the business value of BIM would be generated. The project managers' role would also likely extend to ´information managers´. At the public client, the new role of the BIM coordinator was an important role for the implementation of BIM. BIM coordinators not only aided the project managers but also took active part in developing the new procurement contracts. They also supported the BIM competence group with feedback from the BIM pilot projects. This was seen by some project managers as a redistribution of power from project managers to BIM coordinators. Project managers also argued that BIM challenged the traditional the role of the project manager which could create a resistance towards BIM.

4.3.9 Managing a lack of interoperability

A lack of interoperability between software applications was seen as a major challenge to business value of BIM across the three informant groups. The Swedish AEC industry actors argued the creation of business value of BIM not only depended on project actors being able to work together and communicate, but also that the different software applications could do the same. The temporary relationships and the lowest-bid process however implied a loss of crucial information between project phases and actors and resulted in high investment costs and costly software upgrades. Costly BIM installations and upgrades also negatively impacted the perceptions of the business value of BIM among the international AEC actors. A lack of interoperability also caused challenges to business value at the public client. The BIM competence group spent much time, resources and efforts on managing this challenge by participating in BIM networks trying to develop common industry wide standards.

4.3.10 Lack of top management support

The Swedish AEC industry actors also perceived a lack of top management support in terms of a lack of additional funds, education and resources for implementation to challenge the desirable future business value of BIM. A lack of top management support also related to negative perceptions of the business value of BIM among the international industry actors.

4.4 Social and cognitive aspects of the business value of BIM

Using the IT Business Value Model to pursue RQ1 (section 4.2) and RQ2 (section 4.3) helped in developing an understanding the perceptions of the business value of BIM and for understanding how the intra and inter organizational changes that are described as enablers of business value creation were posing as intra and inter organizational challenges to the business value of BIM. However, there were certain patterns and phenomena in the empirical material that were of social and cognitive nature related to individuals, groups and networks that the model could not explain. This resulted in a search for alternative theories and in an interest for examining what perspectives dominate in BIM research (section 4.5).

4.5 The impact of a dominating technical perspectives in BIM research on the understanding of the business value of BIM

In a review of the knowledge interest in current BIM research (*RQ3*), a technical knowledge interest dominated. It was followed by a practical knowledge interest but a lack of a critical knowledge interest (Habermas 1971).The majority were also pursued from technological determinism assuming that technology is what impacts society and humans behaviors. Only a few drew on social constructivism and the socio-technical perspective (Trist and Bamforth 1951) and even fewer drew on reflection and criticism. By limiting research on BIM to a technical knowledge domain and technical and rational theories, these knowledge interest and perspectives gain influence and power over how BIM is theoretically understood and thus exercise hegemony (Gramsci 1988, Bourdieu 1991). They may also reinforce the use of the technical knowledge interests and perspectives. This is important as the research community plays an important role in the understanding and development of BIM by being in a position to decide what is relevant to study and not to study. Thus, it is important to broaden the research on BIM to include more practical and critical knowledge interests and perspectives, such as the socio-technical systems theory. This would not only contribute to better theoretical understanding of BIM, but also challenge the technical and normative tradition that dominates in BIM research and that neglects the social and cultural dimensions of BIM.

The dominating technical knowledge interest and perspective also has power and influence (hegemony) (Gramsci 1988, Bourdieu 1991) on how the business value of BIM is understood. This is illustrated in the how the positively biased understanding of the business value of BIM promoted by commercial industry actors (McGraw-Hill 2009, 2010, 2012) has gained large influence on how the business value of BIM is understood by researchers (e.g. Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013). The business value of BIM has mainly been understood from a dominating technical knowledge supporting rationalism and positivism (Habermas 1971). This further supports the need for reflecting, problematizing and extending the theoretical understanding of the content and perspective of the business value of BIM by a practical knowledge interest and a socio-technical perspective (section 4.6).

4.6 The role of business value of BIM in a socio-technological context

In understanding the perceptions of the business value of BIM, the theory of the business value of IT (e.g. Kohli and Grover 2008, Grover and Kohli 2012) including the IT Business Value Model (Melville et al 2004) helped to understand how the perceptions related to desirable future effects (ex-ante perspective) and current challenges and associated costs (ex-post perspective). The IT Business Value Model (Melville et al 2004) allowed for understanding the intra and inter organizational challenges associated with the business value of BIM. However, there were certain pattern and phenomena in the empirical observations that the IT Business Value Model could not explain. These were of social and cognitive nature and related to attitudes, beliefs, expectations and perceptions about BIM of individuals, groups and social networks. These seemed to be formed, promoted and supported in a social context. For example, the attitudes, beliefs, expectations and perceptions about BIM among project managers of Investment Projects seemed to be collectively formed and be influenced by the attitudes, beliefs, expectations and perceptions about BIM of other fellow project managers, supervisors and other colleagues at Investment Projects. Although the IT Business Value Model (Melville et al 2004) provided important insights into understanding the intra and inter organizational challenges to the business value of BIM among these individual, groups and networks, the rational, economic and process-oriented focus of the model (e.g. on business processes and co-creation of business value) could not explain these social and cognitive dimension of the business value of BIM. This resulted in a search for alternative theories, such as the socio-technical systems theory. The review of the knowledge interest in current BIM research further suggested adding the socio-technical systems theory to extend the theoretical understanding of the business value of BIM and business value of IT. AEC researchers (Sackey et al 2014, Miettinen and Paavola 2014) and IS researchers (Orlikowski and Iacono 2001, Benbasat and Zmud 2003, Lee et al 2008) have also called for the socio-technical systems perspective. To extend the theoretical understanding of the content and perspective of the business value of BIM, the role of the business value of BIM from in a socio-technical context was examined (*RQ4*).

4.6.1 The role of the business value of BIM in the acceptance and rejection of BIM

Drawing on TAM2 (Venkatesh and Davis 2000) to interpret the perceptions of the public client´s implementation of BIM suggested that the business value of BIM (i.e. economic factors) played a small than anticipated role in the diffusion and acceptance of the BIM implementation. Instead, social and cognitive factors related to the individuals´, groups´ and networks´ expectations, beliefs, attitudes and social norms about BIM were of major significance. One such important factor related to the beliefs, expectations and interpretations of the public client role and mission (in Svensk författningssamling 2010:185, 2 § line 10). The main argument for the BIM implementation promoted by the BIM competence group was that the public client should implement BIM in order to drive industry change, innovation and productivity. The acceptance and rejection of this argument and of the BIM implementation among the individuals, groups and social networks of Major Projects and Investment Projects largely depended on their perceptions of whether such an implementation was in line with their interpretations of the public client´s role and mission. The individuals, groups and social networks of Major Projects interpreted the public client´s role included actively *driving* industry change and largely accepted the argument for BIM. In contrast, the individuals, groups and social networks of Investment Projects interpreted the public client role was to *encourage* industry change and not to drive and demand it, and largely rejected the argument for BIM.

Other social and cognitive influence processes (Venkatesh and Davis 2000) impacting the perceptions of BIM and the acceptance or rejection of BIM. Major Projects had been able to implement BIM in a manner that drove industry change due being mega projects and their size, autonomy and resources which created conditions for implementing the revised procurement contracts demanding BIM from suppliers. There was thus a positive social influence of voluntariness and a positive cognitive influence of job relevance and output quality on the perceptions of BIM (Venkatesh and Davis 2000). The head of unit of Major Projects had also endorsed the implementation, further supporting a positive influence of subjective norm on image (Venkatesh and Davis 2000). At Major Projects, the business value of BIM played some role. A few BIM pilot project managers perceived some actual outcomes of BIM on project performance. Fewer errors and rework, faster completion times and lower costs were attributed to the implementation of BIM. The few examples of perceptions of the business value of BIM as actual outcomes were experience-based and depended on perceptions of individual project managers. Still, the examples suggest that the business value of BIM had some positive cognitive influence on result demonstrability and the acceptance of BIM (Venkatesh and Davis 2000).

In contrast, project managers of Investment Projects managed smaller project and had to follow the same work practices, leaving little room for experimentation with BIM. The implementation was taking place top-down manner where project managers were required to use the new procurement contracts demanding BIM, suggesting a negative social influence of involuntariness on perceptions of BIM (Venkatesh and Davis 2000). However, while some project managers interpreted this requirement as a sign that top management prioritized the BIM implementation (suggesting a positive social influence on subjective norms and cognitive influence on job relevance), the majority perceived that top management prioritized the other parallel change initiative of becoming a more professional client (suggesting a negative social influence on social norms and image) (Venkatesh and Davis 2000). At Investment Projects, the business value of BIM played a small role. Project managers often found it difficult to perceive the usefulness of BIM to their daily work and arguments of increased business value from BIM from other mega projects had little impact on their perceptions of BIM, suggesting a negative cognitive influence of job relevance and output demonstrability (Venkatesh and Davis 2000). It had also been difficult for many project managers to use the new procurement contracts that were complex and confusing.

4.6.2 The role of the business value of BIM in the social construction of BIM

Understanding the acceptance for a technology among the individuals, groups and network of such an influential actors in the Swedish AEC industry as the public client is important for understanding how the public client as a social group may shape the design and use of BIM in the industry. The insights from applying TAM2 to the public client can thus be useful for understanding the role of the public client in the social construction of BIM (SCOT) in the Swedish AEC industry (Pinch and Bijker 1984). Using SCOT a support for discussing the implications of the findings from applying TAM2 to the public client suggested that the public client´s role in the social construction of BIM was twofold; one promoting an acceptance of BIM in the industry and on promoting a rejection.

The social and cognitive influence processes of TAM2 (Venkatesh and Davis 2000) suggested that there was both an acceptance and a rejection of the public client implementing BIM as a means to drive industry change. Drawing on the SCOT (Pinch and Bijker 1984), this would suggest that there are two competing sociological explanations (Pinch and Bijker 1984) for BIM at the public client: one accepting the implementation of BIM as a means for the public client to drive industry change (BIM competence group and Major Projects) and one rejecting it (Investment Projects). Public clients have a large influence on the actors in the industry via their ability to make demands on BIM in procurement (Linderoth 2010, Wong et al 2011, Bosch-Seijtsema et al 2017).The public client may thus fill an important role in the social construction of BIM (Pinch and Bijker 1984). The two conflicting sociological explanations for BIM at the public client may have different implications for its role in the social construction of BIM (Pinch and Bijker 1984).

The sociological explanation promoting an acceptance of the BIM as a means for driving industry change at a department that conducts large, unique and complex projects (Major Projects) implies that the public client may have a large impact on the social construction of BIM via its ability to create opportunities for changing work practices, roles, attitudes and behaviors and culture of its suppliers. However, the sociological explanation promoting a rejection of the implementation as a means for driving industry change at a department that conducts the majority of the reinvestment projects and the procurement with industry actors (Investment Projects) may also have a significant impact on the public client´s role in the social construction of BIM. On one hand, project managers of Investment Projects are able to exert an influence on the social construction of BIM in the industry by using the procurement contracts demanding BIM from suppliers. On the other hand, they also exert an “informal” influence in the social construction of BIM through their daily interactions and communications with their suppliers. In this social context, the project managers´ rejection of the BIM implementation may have influence on their suppliers. For example, project managers perceived difficulties with actually using the new procurement contracts which caused confusion and misunderstands among suppliers. In a social context, these perceptions, expectations and beliefs about BIM are communicated together to and with suppliers in social networks and are also important in the social construction of BIM.

5. Extending the theoretical understanding of the content and perspective of the business value of BIM

The expectations on BIM for increased efficiency and innovation in the AEC industry are high in both industry (Vinnova 2016) and practice (Succar 2009, Crotty 2013). These expectations are reflected in the rational, positive and process-oriented theories and perspectives that dominate in BIM research. The high expectations on BIM are also reflected in an increasing for the business value of BIM. The term business value of BIM was introduced to the AEC industry and research by industry actors with a commercial interest in promoting an increased use of BIM (McGraw-Hill in cooperation with BIM consultants and software suppliers). In their reports, McGraw-Hill promote the business value of BIM in a positive and rational manner and the focus is on promises of increased efficiency and productivity. This positively biased understanding of the business value of BIM has been widely used and gained large influence on AEC research (e.g. in Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013). It characterizes the manner in which the business value of BIM is understood by AEC researchers and its origin and purpose is seldom reflected on. The reports promoting the term are also referred to in a manner that equivalents them with academic research. Thus, the positively biased understanding of the business value of BIM promoted by commercial industry actors can be described to exercise hegemony on AEC research meaning that is exerts influence and power on the manner in which the business value of BIM is understood, contextualized and developed by AEC researchers (Gramsci 1988, Bourdieu 1991). Thus, there is a need for reflecting on, problematizing and extending the theoretical understanding of the content and perspective of the business value of BIM. This need is further motivated by the lack of a theoretical understanding of the business value of BIM (despite the increasing interest in research and the body of knowledge on the business value of IT available from IS research).

This thesis aimed to contribute with theory development of the understanding of business value of BIM in AEC research and of the business value of IT in IS research. By combining the theory of the business value of IT (e.g. IT Business Value Model) with socio-technical systems theory (e.g. TAM2), a social and cognitive dimension was added to the understanding of the business value of BIM and the business value of IT. The two theories were both developed from open systems theory and shared the understanding of how an entity, such as an organization or firm in the theory of the business value of IT, or an individual, group or network in the socio-technical systems theory, impacts and is impacted by its external environment. It was however their differences in their perspectives and conceptualization of IT, unit of analysis and interpretation of the external environment that complemented each other when being combined and that allowed for a reflection, problematization and extension of the theoretical understanding of the content and perspective of the business value of BIM and business value of IT (section 3.1).

The theoretical relevance and contribution of extending the understanding of the content and perspective of the business value of BIM is discussed in sections 5 and 6. The practical implications for industry are discussed in section 5.7

5.1 Distinction between desired outcomes and actual outcomes

This thesis has showed a distinction between perceptions of desirable future business values of BIM (desired outcomes) (ex-ante perspective) and current perceptions of challenges and added costs (actual outcomes) (ex-post perspective). This distinction is important as it is a contrast to how the business value of BIM is understood and promoted in AEC practice and research. The business value of BIM has previously been associated with mainly positive economic effects from having implemented BIM in large and unique projects (ex-post), such as an increased on return on investment (McGraw-Hill 2009, 2010, 2012). This understanding of the business value of BIM in McGraw-Hill (2009, 2010, 2012) also characterized how the business value of BIM is described by AEC researchers (e.g. Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013). Thus, the ex-ante perspective of the perceived business value of BIM related to future desired effects and also challenges and costs, provides an important contrast to the current understanding of the business value of BIM in AEC research. This contrast is important as it conveys that the implementation of BIM may not always be straightforward and not always be associated with ´values´.

The distinction between perceptions of future desirable outcomes (ex-ante) and actual outcomes (ex-post) also contributes to the understanding of the business value of IT. The business value of IT has largely been understood from an ex-post perspective as the actual outcomes and impacts of IT on organizational performance including both the economic impacts such as productivity enhancement, profitability improvement, cost reduction and competitive advantage, and the non-economic impacts including redesigned business processes and organizational structures (Mukhopadhyay 1997, Berghout and Renkama 1997, Mooney et al 1996, Melville et al 2004, Kohli and Grover 2008). Thus, the ex-post perspective of the business value of BIM in this thesis also contributes with an extended theoretical understanding of the content of the business value of IT.

5.2 Perceptions of challenges associated with added costs

Both the Swedish AEC industry actors and of the public client mainly perceived the business value of BIM as challenges and associated costs (ex-post). The respondents spent a brief couple of minutes on describing their expectations of future desirable business value of BIM and spent the remaining of the interviews on describing how they currently perceived the business value of BIM in terms of challenges and added costs. Again, this is in contrast to how the business value of BIM is understood where the term is characterized by rationalism and positivism and associated with value-laded words indicating inherent value such as ´overall value´, ´internal benefits´, ´business benefits´, ´business value´ and ´player value´ (McGraw-Hill 2009, 2010, 2012, Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012). Associating the business value of BIM with ´future´, ´desired´, ´challenges´ and ´costs´ has inherent meaning as it suggests that the perceptions of the business value of BIM might not be as rational and positive as has typically been promoted. It also invites to an increased reflection and problematization of the rational and positive content and perspective that has characterized the theoretical understanding of the business value of BIM.

Comparing the perceptions of the business value of BIM as challenges and added costs with the understanding of the business value of IT provides another contrast. The business value of IT is not only understood as the economic and non-economic impacts of IT on organizational performance but also as the organizational factors and capabilities than enable the creation of business value of IT related to strategizing, developing business processes, competencies and skills etc (Melville et al 2004, Kohli and Grover 2008, Grover and Kohli 2012, Cao 2010). What is important in this context is how the business value of IT is contextualized. The focus on the enabling factors and capabilities of the creation of business value reflects that the underlying view of IT is that it is unproblematic once it has been implemented. There is less focus on describing these factors and capabilities in terms of challenges and hinders of business value creation. The understanding of the business value of BIM in this thesis as mainly challenges and the associated problematize the theoretical understand of the business value of IT and the business value of BIM. The numerous and highly interdependent challenges to the business value of BIM that related to both the individual and project level and the business process and organizational level and that were formed in a complex socio-technical context based on the attitudes, beliefs and expectations of individuals and social networks contribute to problematizing the rational and optimistic theoretical understanding of the business value of BIM and business value of IT. The problematization of the understanding of the content and perspective of the business value of BIM and business value of IT began when the factors and capabilities that are described as enablers of business value of IT in the IT Business Value Model (e.g. intra and inter organizational changes) (Melville et al 2004) emerged as challenges (intra and inter organizational challenges) in the AEC context (Swedish AEC industry actors and public client). The challenges associated with the business value of BIM are important to understand as they provide a much needed contrast and balance to the rational and positivistic theoretical understanding of BIM and the business value of IT and support for a reflection and problematization of the theoretical perspectives used for understanding the business value of BIM in AEC research. The reflection, problematization and extension of the theoretical understanding of business value was continued when combining the theory of the business value of IT with the socio-technical theory (section 5.5).

The ten categories of highly interrelated challenges associated with the business value of BIM among the three informant groups also contribute with problematizing not only business value but also the overall implementation of BIM in terms of project governance (e.g. challenges in related to changing steering documents), procurement strategies (e.g. challenges related to making demands on BIM in procurement), business development and reorganization (e.g. challenges related to changing roles and providing incentives), competence development (e.g. challenges in providing education) and in terms of the ability to act change agent.

Thus, this thesis contributes with extending the theoretical understanding of the content and perspective of the business value of BIM and the business value of IT by contributing with a cost dimension related to challenges.

5.3 The individual and project level is equally important

In the theoretical understanding of the business value of IT the focus is on the business process and organizational level and actual outcomes (ex-post) of financial, operational and strategic impacts (Melville et al 2004, Kohli and Grover 2008, Grover and Kohli 2012). There has been less focus on the individual level and project level and perceptions of individuals and groups (Kohli and Grover 2008, Cao 2010). The perceptions of the business value of BIM related mostly to the individual and project level and thus contribute with another dimension to the understanding of the business value of IT. The perceptions of desired future business value of BIM among the Swedish AEC industry actors and the public client related to individual project managers´ perceptions and expectations of the desired effects of BIM on their day-to-day project management, such as an improved communication among actors and less time and effort having to be sent on coordinating work and administration. It had also been difficult for the respondents to discern any business values related to actual outcomes in terms of financial and strategic impacts on the business process and organizational level. The perceptions were experience-based and tied to certain individuals and it had been difficult to evaluate the business value of BIM in terms of actual outcomes on performance.

The individual and project related perceptions of the business value of BIM related to, for example improved communication and visualization, are particularly important in the AEC industry context as the industry is based on the knowledge and experiences of individuals. Thus, for those actually implementing BIM (e.g. project managers), the individual and project related perceptions of the business value of BIM may be easier to relate to and understand than those that are typically promoted in terms of increased return on investment, increased profitability etc (McGraw-Hill 2009, 2010, 2012, Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012).

Thus, this thesis contributes with extending the theoretical understanding of the content and perspective of the business value of BIM and the business value of IT by contributing with the individual and project related dimension.

5.4 Project progress more important than project outcome

Relating to the individual and project related perceptions, project progress related business values of BIM (related to the management of various project managerial issues) were more important than project outcome related business values of BIM (related to managing efficiency and optimization). Again, the project outcome related business values of BIM are those that have been typically promoted in industry and research (McGraw-Hill 2009, 2010, 2012, Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012). The statistical significance of the project progress related perceptions was significantly higher than for the project outcome related perceptions, suggesting that the understanding of the effects of BIM on project progress are larger than project outcome. The major business value of BIM in both the national and international industry perspective seems to lie in the daily management of projects such as improved coordination, reduced conflicts and less errors and mistakes. The perceptions of the project progress related business values of BIM thus contribute with a balance the positively biased understanding of the business value of BIM promoted by commercial industry actors.

5.5 Contributing with the social and cognitive dimension

Most importantly, this thesis contributes with extending the understanding of the content and perspective of the business value of IT in IS research and business value of BIM in AEC by adding the socio-technical perspective and a social and cognitive dimension to the rational and positivistic perspective characterizing the theoretical understanding of the business value of IT and business value of BIM. The theoretical understanding of the business value of IT builds on economic, rational and process- oriented perspectives such as the resource-based view, microeconomics and industrial organization theory (Melville et al 2004, Cao 2010, Kohli and Grover 2008, Grover and Kohli 2012). The theoretical understanding of the content is largely in terms of the impact of IT on the financial, strategic and operational performance of the firm including productivity enhancement, profitability improvement, cost reduction

(Mukhopadhyay 1997, Berghout and Renkama 1997, Mooney et al 1996, Kohli and Grover 2008,Grover and Kohli 2012). In AEC research there is a lack of a theoretical understanding of the business value of BIM. None the less the business value of BIM has still been understood in AEC research in a rational and optimistic perspective which has been prompted by commercial industry actors and its content in terms of economic impact related to overall value´, ´internal benefits´, ´business benefits´, ´business value´ and ´player value´ including an increased return on investment and increased profitability (McGraw-Hill 2009, 2010, 2012,Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012).

In developing a theoretical understanding of the business value of BIM, this thesis started off in the rational and positivistic theory of the business value of IT and moved towards an increased interpreivism and the socio-technical systems theory. The theory of the business value of IT (e.g. Kohli and Grover 2008, Grover and Kohli 2012) including the IT Business Value Model (Melville et al 2004) were important for understanding how the intra and inter organizational changes described as enablers of the business value of IT were posing as challenges in the AEC industry context and for problematizing business value creation. The focus in perspective towards socio-technical systems view shifted as the theory of the business value of IT could not explain some of the pattern and phenomena in the empirical material that were of social and cognitive nature and related to attitudes, beliefs, expectations of individuals, groups and social networks. Adding the socio-technical systems perspective the theoretical understanding of perspective and a social and cognitive dimension to the theoretical understanding of content was important for reflecting on the role of the business value of BIM in a wider context extending the rational and economic context of the focal firm in the theory of the business value of IT. Adding the socio-technical perspective implied that business value was studied in a different setting than in the theory of the business value of IT with focus on individuals, groups and networks in a social context rather than on business processes in an organizational context and with a focus on attitudes, beliefs, expectations and culture rather than financial, strategic and operational outcomes. This setting is particularly important as it studies the role of business value among those who are to actually implement BIM (individuals, groups and networks rather than “firms”) and in a socio-technical context where business value may not be the main impact of an IT-supported change process but rather be one of many aspects, including also social and cognitive influence processes, instead of the main aspect (as it is in the theory of the business value of IT).

In fact, drawing on the socio-technical systems theory showed that the business value of BIM, which was initially perceived to be important for gaining legitimacy and acceptance for the BIM implementation, seemed to play a smaller role in a wider socio-technical context (e.g. in TAM2 and SCOT) than in an economic and process-oriented context (e.g. in the IT Business Value Model). For example, for the acceptance and rejection of the BIM implementation at the public client, arguments of business value of BIM (i.e. economic factors) had little impact on the individuals´, groups´ and networks´ acceptance and rejection of BIM. Instead, the individuals´, groups´ and networks´ expectations, beliefs and attitudes towards BIM which were formed in a social context including social norms and image (i.e. social and cognitive factors) played a large role. The business value of BIM supported the social and cognitive influence processes of an IT-supported change process (e.g. via the construct of result demonstrability in TAM2) rather than being the main influence process in an IT-supported change process (as in the IT Business Value Model). These also were the major factors of the public client´s impact on the social construction of BIM. Thus, when regarding the business value of BIM from a wider socio-technical context, the financial, strategic and operational impacts (economic factors) are not as important as in the theory of the business value of IT. The socio-technical context is thus important for extending the theoretical understanding of the content and perspective of the business value of BIM.

The socio-technical perspective of the business value of BIM is particularly important in the public client context as many public clients worldwide are implementing BM with the specific aim to create increased efficiency and productivity in the AEC industry by implementing BIM. Future studies would need to study public clients´ BIM implementation from a socio-technical perspective as is also supported in a recent study by Bosch-Sijtsema et al (2017) who showed that Swedish contractors were waiting for clients to demand BIM –based work practices in order for them to increase their BIM implementation. They showed contractors´ expectations, interpretations and beliefs about the role of public clients for the industry´s overall implementation of BIM (Bosch-Seijtsema et al 2017). Their study suggests that contractors perceive that there is a need for public clients to make demands on BIM to suppliers in procurement. However, at the public client, making demands on BIM in procurement was the main challenge associated with their BIM implementation and was also challenged by the parallel change initiative of the professional client role which implies sing less detailed contract requirements. In this context, the socio-technical perspective applied in this thesis suggests that it is more important studying the actors´ actual day-to-day work and how they are actually using BIM to change their current work practices rather than studying future promises of BIM, for example studying what they are actually doing when conducting their work with BIM, what decisions they are making on a day-to-day basis with BIM and how their expectations, beliefs and attitudes about BIM are formed. There is a need for shifting the focus of in BIM research from BIM as the phenomenon of interest to work practices, decisions, strategies, knowledge and learning as the phenomena of interest.

5.6 The extended business value of BIM

To conclude, the theoretical understanding of the content of the business value of IT (Melville et al 2004, Cao 2010, Kohli and Grover 2008, Grover and Kohli 2012) and business value of BIM (e.g. McGraw-Hill 2009, 2010, 2012, Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012) has previously been characterized by a financial, operational and strategic dimension. The theoretical understanding of the perspective of the business value of IT and business value of BIM has previously been characterized by a rational and positivistic perspective. By adding a social and cognitive dimension to the theoretical understanding of content and a socio-technical perspective (increased interpretivism) to the theoretical understanding of perspective, this thesis contributes with a more holistic and extended understanding of business value. This way, this thesis contribute with theory development of the theoretical understanding of business value in both IS research and in AEC research. This understanding may be reflected in the alternative terms:

> ´The *Extended* Business Value of BIM´ (contributing with theory development of the understanding of business value in AEC research)
>
> ´The *Extended* Business Value of IT´ (contributing with theory development of the understanding of business value in IS research)

The ´extended business value of BIM´ and ´the extended business value of IT´ not only consists of adding and contributing with a social and cognitive dimension to the financial, operational and strategic dimension characterizing the previous understanding of content and a socio-technical systems theory to the rational and positivistic theories characterizing the previous understanding of perspective (section 5.5), but also of a distinction between desired outcomes (ex-ante) and actual outcomes (ex-post) (section 5.1), an understanding of business value as not only the benefits but also as costs and challenges (section 5.2), an emphasis on project progress rather than project outcome (section 5.4) and a recognition of perception of also the individuals who are actually managing the BIM implementation in their day-to-day projects, i.e. the individual and project level (section 5.3).

5.7 Practical implications

The understanding of the business value of BIM as not only the positive effects and values on project of firm performance assumed to be a result from merely implementing BIM (as promoted in McGraw-Hill 2009, 2010, 2012, Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012, Eadie et al 2013), but also as the desired future outcomes and the current added costs arising from various challenges also provide an important balance to practitioners´ understanding of the business value of BIM. The ´extended business value of BIM´ may contribute with balancing the expectations on BIM among practitioners while also increasing the understanding of the potential effects of BIM for individual project managers actually conducting the implementation of BIM that are more in line with their daily work (primary impacts on project progress and secondary impacts on project outcome). A greater understanding of the challenges associated with the business value of BIM may also provide useful insights for practitioners implementing BIM. The challenges had implications for project management practices and skills, business development, decision making and procurement. Also, the numerous challenges encountered by such a large and influential actor as the public client, who has been described to act as a change agents, when trying to implement BIM for creating business value and driving industry change suggests to practitioners that the implementation of BIM for business value may be more complex than what has been promoted. In particular, this thesis suggests that arguments of the business value of BIM with an aim of justifying BIM to skeptical individuals, groups and social networks may in fact not play such a large part in reaching an acceptance for BIM implementation. Instead, what seems to matter more are the individuals´, groups´ and social networks attitudes, beliefs, expectations about BIM. Practitioners must pay attention to how these are formed and upheld in complex social contexts where social and cognitive influence processes, such as social norms and image, play significant roles.

6. Reflections on the knowledge interests of this thesis

6.1 A journey of knowledge interest and theoretical perspectives

When reflecting on the knowledge interests of the business value of BIM in this thesis, the initial knowledge interests in Papers 1 – 3 and RQ1 – RQ2 could be described as a technical knowledge domain (Habermas 1971). The focus was on how the business value of BIM was perceived in the AEC industry and the author´s point of departure was influenced by the rational and positivistic understanding of business value of IT. The subsequent focus on the enablers of and challenges to the perceptions of the business value of BIM also reflect a technical knowledge interest of providing casual explanation and prediction (Habermas 1971).

A shift in knowledge towards a practical (hermeneutic) knowledge interest of providing increased understanding and explanation (Habermas 1971) began with an empirical observation of how the respondents briefly described the desired future business values of BIM and instead chose to focus on describing the associate challenges and added cost. Using the theory of the business value of IT including the IT Business Value Model as theoretical lens had been important for understanding how the factors that were described as enablers of business value of IT (intra and inter organizational changes) were in fact posing as challenges to the perceptions of the business value of BIM (intra and inter organizational challenges). The model had supported a reflection and problematization of the business value of BIM in Paper 4 where the knowledge interest shifted from a technical domain to a practical domain focused on understanding how and why the challenges were perceived. The main shift in knowledge interest however occurred when the rational and positivistic perspective of the business value of IT focused on describing the enabling factors and capabilities of the business value of IT (i.e. a technical knowledge domain focused on casual explanation and prediction) would not suffice as theoretical lens for interpreting and understanding the empirical observations. There were pattern and phenomena in the empirical material of social and cognitive nature that were formed and upheld in complex social context based on the attitudes, beliefs and interpretations of individuals, groups and social networks. These could not be understood from the rational, positivistic and process-oriented perspective of the theory of the business value of IT and led to a search for alternative theories. The practical (hermeneutic) knowledge interest focused on understanding and explanation was pursued by drawing on the socio-technical systems theory. The knowledge interest was focused on understanding how the individuals´, groups´ and networks´ involved in the public client´s BIM implementation formed their acceptance or rejection of BIM based on social and cognitive influences and on understanding how these impacted the public client´s role in the social construction of BIM. It was also in this context that the understanding was formed of how the business value of BIM only played a smaller role in a wider socio-technical context. This finding further strengthened the interest in the practical (hermeneutic) knowledge domain. This process illustrates the journey in knowledge interests and perspectives undertaken in this from a technical knowledge interest focused on developing casual explanation towards a practical (hermeneutic) knowledge interest focused on developing understanding and sense making. A journey was undertaken in theoretical perspectives from rationalism and positivism towards increased interpretivism and hermeneutics.

The knowledge interests and perspectives characterizing theoretical understanding of the business value of IT in IS and the business value of BIM in AEC research have been of a rational and positivistic perspective and a technical knowledge interest focused on providing casual explanation and predation of how to create business value. By illustrating how a journey in knowledge interests and perspectives from rationalism and positivism towards increased interpretivism and hermeneutics contributed with an increased understanding of business value and provided new insights into the social and cognitive dimensions of business value, this thesis wishes to encourage research on BIM to make a similar journey in hopes of encouraging a more practical, reflective and critical discussion of BIM. This thesis wishes to inspire current BIM research to extend the dominating rational, technical and positivistic perspectives (technological determinism) to also include socio-technical perspectives that combine the technical system with the social system with an emphasis on the social and cogitative processes (social constructivism).

6.2 The importance of extending knowledge interest and perspectives in BIM research

Extending the theoretical understanding of the content and perspective of the business value of BIM and business value of IT with a socio-technical perspective was important for contributing with theory development of the rational and positivistic understanding of business value in AEC research and IS research. The understanding of the business value of BIM in AEC research has previously been characterized by a rational and positive content and perspective promoted by commercial industry actors. The positively biased understanding of the business value of BIM in promises of increased efficiency and productivity (McGraw-Hill 2009, 2010, 2012) has also been widely used and gained large influence on the understanding of the business value of BIM in AEC research (e.g. in Succar 2009, Becerik-Gerber and Rice 2010, Barlish and Sullivan 2012). It characterizes the manner in which the business value of BIM has been understood, conceptualized and discussed by AEC researchers and could be described to exercise hegemony on the understanding of BIM in AEC research (Gramsci 1988, Bourdieu 1991). The hegemony motivates the need for reflecting on, problematizing and extending the theoretical understanding of the content and perspective of the business value of BIM. This is crucial as researchers fill important roles in forming the understanding and development of BIM in both research, by for example determining what aspects of BIM to study and what perspectives and theories to apply, and in practice, by for example educating future actors and determining what skills and competencies they should have.

In addition to contributing with theory development of the understanding of business value in AEC research and IS research and drawing attention to the issue of hegemony, extending the theoretical understanding of the content and perspective of the business value of BIM and business value of IT with a socio-technical perspective may challenge the technical, rational and optimistic perspectives that dominate the overall understanding of BIM in research and practice. Not only the understanding of the business value of BIM has been characterized by rationalism and positivism. The overall theoretical understanding of BIM and its implications for practice and research has been characterized by a rational and positive perspective that has drawn on technical, rational and process-oriented theories. Several AEC researchers have recently pointed to a hype of optimism towards BIM in AEC research and for a need of more reflective and critical perspectives. Miettinen and Paavola (2014), for example, argue that BIM needs to be studied as a multidimensional, historically evolving and complex phenomenon. Sackey et al (2014) argue for shifting the focus from technological determinism towards an increased socio-technical understanding of BIM. Dainty et al (2015) reject the “technocratic optimism” (BIM hype) which dominates the current BIM research and raise important questions on the implications of such a trajectory on the development on research. By this thesis arguing for a need for extending the theoretical understanding of the content and perspective of the business value of BIM with a socio-technical perspective and illustrating the knowledge and insights that can be gained from such an understanding, this thesis wishes to contribute to the ongoing debate pointing to a need for reflection and questioning of the perspectives and theories that dominate in BIM research. This includes shedding light on how business value may also be interpreted as challenges and added costs, the challenges associated with individuals´ day-to-day interaction with BIM and the illustrating how the business value of BIM plays a minor role in reaching an acceptance for BIM implementation. The socio-technical perspective suggests that it is more important to study individuals´ actual day-to-day work such as what they are actually doing when working with BIM, what decisions they are making based on BIM and how their attitudes, beliefs and expectations are formed and upheld in the social context rather than focusing on studying the future promises of BIM.

At the same time, this thesis has also shown the difficulties, time and effort needed for reaching to a point of reconsidering and questioning one´s prevailing conceptions, perspectives and theoretical frameworks. In three of six papers, the theory of the business value of IT was used as theoretical lens. The discussion of the enablers of the business value of IT from IS research had an influence on the interpretation of the empirical material from Paper 1 to Paper 4. It was after having observed that certain phenomena of social and cognitive nature in the empirical material could not be sufficiently explained and understood by drawing on the theory of the business value of IT that a search for alternative theories began. This search was not easy and is still ongoing. Still, this thesis wishes to motivate and inspire future BIM research to make a similar journey and also reflect on the dominant technical, rational and positivistic perspectives. This would mean an increased focus on an interpretive perspectives that regard the interactions between the technical and social systems and account for the social and cognitive factors of individuals, groups and social networks.

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