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ADVANTAGES AND DISADVANTAGES OF VERTICAL INTEGRATION IN THE IMPLEMENTATION OF SYSTEMIC PROCESS INNOVATIONS:

Case studies on implementing building information modeling (BIM) in the Finnish construction industry

Master's Thesis
Espoo, May 8th 2010

Supervisor: Professor Riitta Smeds, D.Sc. (Tech.)
Instructor: Antero Hirvensalo, M.Sc. (Tech.)

Aalto University School of Science and Technology

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Abstract:

Vertical integration refers to a combination of several or all functions in the value chain under a single firm. Many researchers have suggested that vertical integration facilitates the development and implementation of systemic innovations. As opposed to autonomous innovations that can be introduced as such without any major changes or modifications to the rest of the business system, systemic innovations require significant adjustments in other parts of the business system in order to be implemented successfully. However, systemic innovations are often too complex and large to manage and coordinate under a single integrated firm.

Building information modeling (BIM) is an example of a systemic process innovation in the construction industry. BIM is a set of interacting policies, processes, and technologies generating a methodology to manage the essential building design and project data in digital format throughout the life-cycle of a building. BIM has been expected to bring significant improvements in productivity in the construction industry since the 1980's but the implementation and diffusion of BIM have been proved to be slower and more difficult than expected, largely due to its interorganizational and systemic nature. At the same time, there has been a trend of vertical integration in the construction industry in recent years. This study aims to shed more light on the connection between BIM implementation and the organizational structure, and examines the advantages and disadvantages of vertical integration in the implementation of BIM as an example of a systemic process innovation.

The empirical research is based on two opposite case studies from the Finnish construction industry; a vertically disintegrated project network and a vertically integrated project network. Both case studies included a single construction project where BIM was being implemented. The qualitative data consists of project documentation, interviews, and observations. A theoretical model of the advantages and disadvantages of vertical integration is first constructed based on the literature review. The model is later tested with the empirical data and refined into an improved model based on the analysis.

The findings of the study propose that there are seven structurally relevant factors in BIM implementation; (1) management support, (2) coordination and control, (3) learning and experience, (4) technology management, (5) communication, (6) motivation, and (7) defining roles. There are both advantages and disadvantages of vertical integration related to each of these implementation factors. Thus, in order to achieve as smooth implementation as possible, managers should understand the impact of the organizational structure in BIM implementation and plan the implementation projects accordingly.

Keywords: vertical integration, technology implementation, systemic process innovation, building information modeling (BIM), construction industry

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Tiivistelmä:

Vertikaalinen integraatio tarkoittaa usean tai kaikkien arvoketjun toimintojen yhdistymistä samaan yritykseen. Monet tutkijat ovat olleet sitä mieltä, että vertikaalinen integraatio edistää systeemisten innovaatioiden synnyttämistä ja käyttöönottoa. Kun tavalliset innovaatiot voidaan ottaa käyttöön sellaisenaan ilman sen suurempia muutoksia laajempaan toimintaympäristöön, systeemisten innovaatioiden menestyksekäs käyttöönotto vaatii merkittäviä muutoksia koko toimintaympäristössä. Usein systeemiset innovaatiot ovat kuitenkin liian monimutkaisia ja laajoja yhden yrityksen hallittavaksi.

Rakennusten tietomallinnus (BIM) on esimerkki systeemisestä prosessi-innovaatiosta rakennusalalla. Tietomallinnus tarkoittaa laajaa kokonaisuutta, joka koostuu yhteisistä käytännöistä, prosesseista ja teknologioista. Tietomallinnuksen tarkoituksena on hallita rakennukseen liittyvää tietoa digitaalisessa muodossa rakennuksen koko elinkaaren ajan aina suunnittelusta toteutukseen ja käyttöön. Tietomallinnuksen on odotettu tuovan merkittäviä parannuksia rakennusalan tuottavuuteen jo 80-luvulta lähtien, mutta sen käyttöönotto ja leviäminen on osoittautunut ennakoitua hitaammaksi ja vaikeammaksi. Keskeisenä syynä tähän on ollut tietomallinnuksen systeeminen ja organisaatioiden rajat ylittävä luonne. Samalla kuitenkin, myös kiinnostus vertikaaliseen integraation on lisääntynyt rakennusalalla. Tämä tutkimus pyrkiikin valottamaan tietomallinnuksen käyttöönoton ja organisaatiorakenteiden välistä yhteyttä tutkimalla vertikaalisen integraation hyötyjä ja haittoja tietomallinnuksen käyttöönotossa.

Tutkimuksen empiirinen osa perustuu kahteen vastakkaiseen tapaustutkimukseen Suomen rakennusteollisuudessa. Toisessa tapauksessa projektiverkosto koostui erillisistä yrityksistä, kun taas toisessa tapauksessa projektiverkosto oli vertikaalisti integroitunut. Molemmissa tapauksissa tarkasteltiin yksittäistä rakennushanketta, jossa testattiin tietomallinnusta. Laadullinen tutkimusaineisto koostuu projektidokumentaatiosta, haastatteluista sekä osapuolien havainnoinnista. Tutkimuksessa luodaan ensin teoreettinen malli vertikaalisen integraation hyödyistä ja haitoista perustuen kirjallisuuskatsaukseen. Tämän jälkeen mallia testataan tutkimusaineistolla ja parannellaan analyysin perusteella.

Tutkimuksen tulosten perusteella tietomallinnuksen käyttöönottoon liittyy seitsemän organisaatiorakenteen kannalta merkittävää tekijää. Nämä tekijät ovat (1) johdon tuki, (2) koordinointi ja hallinta, (3) oppiminen ja kokemus, (4) teknologian hallinta, (5) viestintä, (6) motivaatio sekä (7) roolien määrittely. Kaikkiin näihin tekijöihin liittyy vertikaalisen integraation tuomia hyötyjä ja haittoja. Tämän vuoksi yritysjohdon pitäisikin ymmärtää organisaatiorakenteen mahdolliset vaikutukset tietomallinnuksen käyttöönotossa, jotta käyttöönottoprojektit osattaisiin suunnitella ja toteuttaa mahdollisimman sujuvasti.

Asiasanat: vertikaalinen integraatio, teknologian käyttöönotto, systeeminen prosessi-innovaatio, rakennusten tietomallinnus (BIM), rakennusteollisuus

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The ECPIP Finland project has given me an extraordinary chance to dive into the fascinating world of research in the complex context of the construction industry. The project has taken me to Stanford University in California and to GSA in Washington DC. I have met an incredible amount of researchers and construction industry professionals both in Finland and abroad. In fact, I have personally met 18 authors from the reference list of this thesis during the project. That's amazing! I really want to thank Tekes, VTT, and all the participating firms for making this project possible.

SimLab has provided an excellent environment to find out what academic research is all about. I want to thank professor Riitta Smeds, the supervisor of my thesis, for all the opportunities and of course the guidance and support in writing this thesis. I am also deeply grateful to my instructor, Antero Hirvensalo, for great advice and comments when I needed them the most. Working at SimLab wouldn't have been the same without all the great co-workers. Special thanks to my teammates in ECPIP Finland: Hanna Björkstrand, Kaarina Kaste, Juha Kujala, Antti Maunula, and Sami Ruotsalainen. And all the rest SimLabbers, present and past, thanks for making it so much fun!

Finally, I want to thank my family for all the love and support during my studies and throughout my whole life. And all my friends, thanks for understanding my busy schedule and stressful state of mind. Hopefully now, I got some more time for you again! And last but definitely not least, I want to thank my beautiful wife, Jessica, for never-ending love and support. Without you, all of this would have been meaningless.

Let the next journey begin!

Teemu Lehtinen
Espoo, May 8th 2010

Table of Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms

2-D CAD	2-Dimensional Computer Aided Design
3-D CAD	3-Dimensional Computer Aided Design
4-D CAD	4-Dimensional Computer Aided Design (3-D + time)
5-D CAD	5-Dimensional Computer Aided Design (3-D + time and cost)
AECO	Architecture, Engineering, Construction and Operations
BIM	Building Information Modeling
BU	Business Unit
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CIFE	Center for Integrated Facility Engineering
ECPIP	Engineering and Construction Project Information Platform
FM	Facilities Management
GDP	Gross Domestic Product
GSA	U.S. General Services Administration
IAI	International Alliance for Interoperability
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
IT	Information Technology
MEP	Mechanical, Electrical, and Plumbing
Mgmt	Management
NIBS	The National Institute of Building Sciences
NVD	New Venture Development
OECD	Organisation for Economic Co-operation and Development
TCE	Transaction Cost Economics
Tekes	The Finnish Funding Agency for Technology and Innovation
TKK	Helsinki University of Technology
VDC	Virtual Design and Construction
VTT	Technical Research Centre of Finland

I INTRODUCTION

千 里 之 行 始 于 足 下

"A long march starts from the very first step."

– Ancient Chinese proverb

This introductory part presents the point of departure and the content of this Master's Thesis. The part consists of five chapters; background and motivation (Chapter 1), focal concepts and the context of the study (Chapter 2), research problem, objectives and scope (Chapter 3), research approach (Chapter 4), and structure of the study (Chapter 5). Overall, the purpose of this part is to describe the starting point of this thesis before submerging into the literature review in Part II.

1 Background and motivation

Many organizations struggle with their make-or-buy decisions as there is usually more in it than just economic profitability considerations. The concept of *vertical integration* is fundamentally based on these decisions, and thus, it determines where the organizational boundaries are drawn in a given situation. Traditionally, the term vertical integration has been understood as the degree of ownership of different functions along the value chain of a product or a service (Fergusson 1993, 28). Improved coordination, increased control, and various advantages from synergies are often cited as the main benefits of being a vertically integrated organization (e.g. Harrigan 1984, 639). Historically, vertical integration has played an especially important role during the creation of new industries where the existing market has not necessarily been capable of satisfying the demands of an emerging industry (e.g. Afuah 2001). However, as an industry matures and competition evolves, the incentives for vertical integration usually decrease as it may be more cost-efficient to buy needed products or services from the market rather than to produce them in-house.

The development of information and communication technology (ICT) has, however, had its effect on the concept of vertical integration. With ICT it is possible to achieve at least some of the benefits of vertical integration without the actual ownership of different business units along the value chain. Some researchers have even started to talk about *digital vertical integration* meaning that interorganizational ICT systems could enable separate organizations to collaborate together in a similar way as internal business units do in a traditional vertically integrated firm (e.g. Davies et al. 2009, 112). Accordingly, many researchers have predicted – especially before the burst of the dot-com bubble in 2001 – the fall of traditional vertically integrated organizations and the rise of networked, vertically disintegrated firms that would concentrate solely on their core competence and outsource everything else (e.g. Brynjolfsson et al. 1994; Evans & Wurster 2000). As this prediction still lives on, it has not been fully realized yet as firms will still want to keep strict control of the flow of their information and physical goods. In addition, the complex ICT systems and the collaboration between firms are after all created and managed by people, which means that there is always some inherent friction present such as development and implementation difficulties or risk and reward sharing issues (Singh 2005). In fact, there even seems to be newly arisen interest towards traditional vertical integration within many industries recently (Worthen et al. 2009).

In recent years, researchers have started to call complex interorganizational ICT systems of this kind as *systemic innovations* (e.g. Lee & Chang 2007; Maula et al. 2006; Taylor & Levitt 2004). As opposed to autonomous innovations that can be introduced as such without any major changes or modifications to the rest of the business system, systemic innovations require significant adjustments in other parts of the business system in order to be implemented successfully (e.g. De Laat 1999, 159-160; Maula et al. 2006, 241-242; Teece 1996, 205). In addition to the complex ICT systems, other examples of systemic innovations from the literature include instant photography, front-wheel drive, a jet airliner, and audio CD (Teece 1996).

Since systemic innovations impact multiple actors in the business system, special attention needs to be given to the coordination between different actors (Teece 1996, 219). As the organizational structure has its influence on the coordination, researchers have suggested that certain organizational structures facilitate the development and implementation of certain types of innovations (e.g. Chesbrough & Teece 2002; Cooper 1998; Teece 1996). More specifically, vertical integration has been said to facilitate systemic innovations by removing the institutional barriers, and thus, facilitating the overall coordination (Armour & Teece 1980; Chesbrough & Teece 2002; Langlois 1992; Taylor & Levitt 2004; Teece 1996). Therefore, somewhat paradoxically, an interorganizational ICT system which is an example of a systemic innovation and enables digital vertical integration, in fact, requires traditional vertical integration in order to be successfully implemented and diffused. The empirical evidence supporting this view is, however, quite limited and some researchers have even come up with contradictory arguments. The main opposing argument seems to be the fact that most systemic innovations are too complex and large for any vertically integrated company to manage alone anyway (De Laat 1999; Maula et al. 2006). Nevertheless, more research is needed in this area to find out if some degree of vertical integration is indeed a facilitating factor.

This Master's Thesis aims to shed more light on the dynamics between vertical integration and systemic innovations. The motivation for this study emerged from ECPIP Finland (Engineering and Construction Project Information Platform) research project where the implementation of *building information modeling (BIM)* was studied in the contexts of both vertically disintegrated and vertically integrated project networks in the Finnish construction industry. BIM is a textbook example of a systemic process innovation and refers to different technologies and processes that enable different actors of a construction project network to collaborate and develop a virtual model of the planned building (Taylor & Bernstein 2009, 69; Taylor 2007, 995). Vision after vision, BIM has been expected to bring significant improvements in productivity in the construction industry. In fact, tools and processes for BIM have been developed since the 1980's (Penttilä 2006, 403) but the actual implementation and diffusion have been proved to be slower and more difficult than expected, largely due to its interorganizational and systemic nature (e.g. Fischer & Kam 2002; Fox & Hietanen 2007; Taylor & Levitt 2004; Taylor & Levitt 2007; Taylor 2007). Interestingly now, when BIM is gaining momentum again, there seems to be a trend of vertical re-integration within the construction industry (e.g. Cacciatori & Jacobides 2005; Lukkari 2008). Coincidence or not, it supports the objective of this thesis to examine closer the impact of vertical integration in the implementation of BIM. Furthermore, most of the systemic innovation literature actually deals with systemic product innovations, and therefore, this study will contribute to the largely ignored area of systemic process innovations of which BIM is a prime example.

Finally, as ICT has been a major driver for innovation and increasing productivity in many industries, the construction industry has been slow in adopting and utilizing new technologies (e.g. Mitropoulos & Tatum 1999, 330; Kadefors 1995, 406). The development of the construction industry is an important issue for general economic growth worldwide. In most OECD countries, the construction industry contributes around 7 % of GDP (Gann & Salter 2000, 956). In Finland, the built environment constitutes 70 % of the Finnish national assets and the construction industry employs more than 20 % of the Finnish work force (Kiviniemi 2006, 2). Bearing all this in mind, this study also aims to contribute to the positive development of the construction industry by increasing the understanding about the impact of organizational structure (i.e. vertical integration) in the implementation of BIM, and thus, fostering BIM implementation and diffusion within the industry.

2 Focal concepts and the context of the study

This chapter introduces the focal concepts and the context of this thesis in more detail before introducing the research problem and objectives. The concepts of vertical integration (Section 2.1) and systemic process innovation (Section 2.2) will be explained and defined. In addition, the industrial context of the construction industry has some special characteristics that need to be taken into account in this study (Section 2.3). Similarly, building information modeling (BIM), as an example of a systemic process innovation in this study, is a complex concept with multiple dimensions. Therefore, the concept of BIM will be reviewed in order to gain more understanding about the topic (Section 2.4).

2.1 Vertical integration

Vertical integration can be understood in various ways and the definition has evolved in the literature during the past several decades. The term first emerged in the economics literature as early as 1930's (e.g. Coase 1937). Coase (1937, 388-389) described vertical integration in his famous article, *the Nature of the Firm*, as being the "*coordination of the various factors of production*" which is "*carried out without the intervention of the price mechanism*". Few decades later, in the 1970's, Blois (1972, 253) defined vertical integration as being "*the organization of production under which a single business unit carries on successive stages in the processing or distribution of a product which is sold by other firms without further processing*". Blois's definition, however, included only the production and distribution functions and left out, for example, the selling function for other firms to carry out.

Later on, Porter (1980, 300) provided a more thorough definition in the 1980's in which vertical integration was defined as *"the combination of technologically distinct production, distribution, selling, and/or other economic processes within the confines of a single firm. As such, it represents a decision by the firm to utilize internal or administrative transactions rather than market transactions to accomplish its economic purposes.*" In other words, according to Porter (1980), vertical integration describes an organization's ownership and control of more than one of the functions in the value chain, and thus, relates to organization's make-or-buy decisions. Porter (1980, 315-318) also defined the more specific concepts of forward and backward integration. By forward integration, Porter (1980, 315-317) means integrating vertically downstream toward the market to be served. And conversely, by backward integration, Porter (1980, 317-318) means integrating vertically upstream toward the supporting businesses such as suppliers.

In this original *control by ownership* sense of the term, a vertically integrated organization can be defined as a single legal entity which performs several or all functions in the value chain internally (Fergusson 1993, 28). Based on this definition, the degree of vertical integration is, thus, determined by the number of these sequential functions performed internally (Balakrishnan & Wernerfelt 1986, 347). The overall concept of vertical integration, based on Porter's (1980) definition, is illustrated in Figure 1 below.

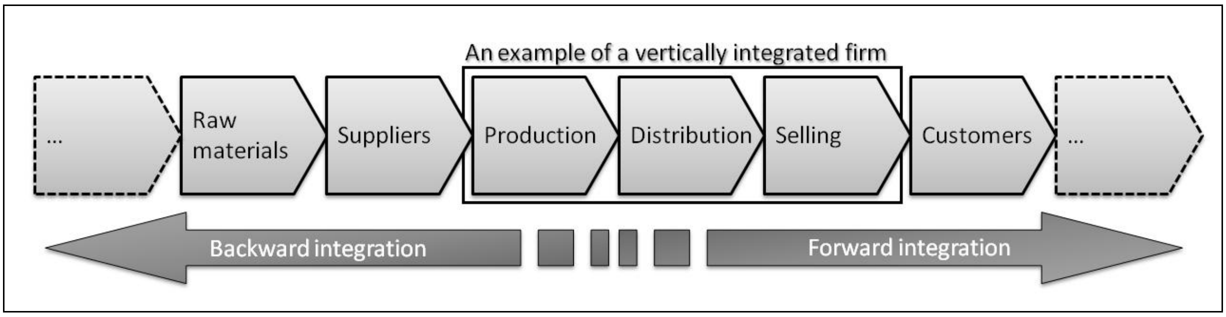

Figure 1: The concept of vertical integration (adapted from Porter 1980)

The theoretical framework that focuses on vertical integration and make-or-buy decisions is transaction cost economics (TCE) (Cacciatori & Jacobides 2005, 1852). Arrow (1969, 1) has defined transaction costs broadly as the "*costs of running the economic system*". Coase (1937) was, however, the first author who brought out the concept of transaction costs using the term "*costs of using the price mechanism*". According to Coase (1937, 390-391), these costs are related to finding out prices and searching for suppliers from the market, as well as negotiating and making contracts with them. Furthermore, Coase (1937) argues that these transaction costs determine the dynamics of a firm getting larger or smaller, and thus, the degree of vertical integration at a certain time and circumstances.

Continuing Coase's (1937) work in TCE, Williamson (1975) later defined that firms integrate vertically to minimize transaction costs that arise from (1) *the opportunism and bounded rationality of firms and their suppliers*, (2) *the uncertainty and frequency of transactions*, and (3) *asset specificity in supplier-firm or firm-customer relationships* (Coase 1937; Williamson 1975 cited in Afuah 2001, 1211). *Opportunism* means that a firm can take advantage of information that other firm does not have to lie, conceal information, misrepresent facts, or mislead the other firm in pursuing its own ends (Williamson 1975, 1985 cited in Afuah 2001, 1212). *Bounded rationality*, which enables opportunism, means that a firm cannot foresee all the possible contingencies in a transaction, making it extremely costly to write, monitor, and enforce complete contracts (Grossman & Hart 1986 cited in Afuah 2001, 1212). Similarly, the more *uncertainty* there is in the relationship and less *frequent* the transactions are, the more difficult it is to draw the complete contract which leads to opportunism. And finally, the relationship is *asset-specific* if the assets of the firm cannot be profitably deployed for any other application. (Afuah 2001, 1212) According to Williamson (1981), these factors determine *the efficient boundary of a firm*, and thus, the degree of vertical integration.

As an extension to vertical integration by ownership, Harrigan (1984; 1985a) introduced a new concept of vertical integration where a firm can control vertical relationships through contracts without owning the different functions in the value chain. According to Harrigan (1984, 641), "*the concept of vertical integration should be expanded to encompass a variety of arrangements by which the firm can use outsiders (as well as its own business units) to forge an optimal vertical system for supplying goods, services, and capabilities"*. Similarly, Blair (1983 cited in Fergusson 1993, 25) emphasized that "*ownership of functions is not a prerequisite for successful vertical integration, and that the distinction between integration through ownership versus integration through voluntary or contractual control is not important in assessing the benefits that might accrue to customers of the integrated process's products.* Mahoney (1992, 559) also argued that "*the vertical integration strategy may be implemented by a continuum of governance structures which include spot markets, short-term contracts, long-term contracts, franchising, joint ventures, and vertical financial ownership (hierarchy)*". Thus, vertical integration does not always mean vertical financial ownership and at least part of it can be achieved with different governance structures.

With these different governance structures, firms may adjust to different degrees of vertical integration depending on competitive environment and strategy. Harrigan (1984) defines four degrees of vertical integration which are (1) *non-integration*, (2) *quasi-integration*, (3) *taper integration*, and (4) *full integration*. *Non-integration* means incorporating only one function in the value chain and buying everything from the market. *Quasi-integration* means that different functions in the value chain are integrated through joint ventures, franchises, minority equity investments, loan guarantees etc. *Taper integration* means the situation where some of the inputs and outputs are bought and sold outside of the firm and the rest in-house. Finally, *full integration* means that everything is transferred in-house. (Harrigan 1984, 642-646) Mahoney (1992) calls full integration vertical financial ownership.

The evolution of the definition of vertical integration has continued even further with the development of ICT. Davies et al. (2009, 112) introduced a term *digital vertical integration* which enables separate organizations to achieve vertical integration through interorganizational ICT systems. Similarly, Fergusson (1993, 22) has defined integration to be "*the flow of information and knowledge between industry functions (vertically), between disciplines (horizontally), and through time (longitudinally). This flow of information and knowledge is accomplished by organizational (human ware) and technical (hardware and software) means of coordination*".

In this study, however, vertical integration is studied from the financial ownership structure point of view, and thus, is defined in the following way:

> ***Vertical integration*** *is a combination of several or all functions in the value chain under a single firm. Forward integration means expanding towards customers and backward integration towards suppliers. The number of sequential functions under a vertically integrated firm defines the degree of vertical integration.*

2.2 Systemic process innovation

Innovations are usually defined as successfully commercialized inventions or ideas (e.g. Smith 2006). According to Smith (2006, 22), innovations can be grouped in three different forms based on the idea of application; (1) *product innovations*, (2) *service innovations*, and (3) *process innovations*. *Product innovations* come in the form of a product and are probably the most visible form of all innovations, whereas *service innovations* are service applications that are either entirely new services or already established services provided in a new way. As product and service innovations are something that individuals and organizations can directly buy and sell, *process innovations*, on the other hand, are innovations related to working practices and operations behind the products and services. Although not as visible as product or even service innovations, process innovations have the largest impact on the society as a whole. (Smith 2006, 22-26)

Processes, as such, can be defined as "*a set of logically related tasks performed to achieve a defined outcome".* According to this definition, basically all operations can be considered as processes or sub-processes of a broader process. Davenport and Short (1990, 12) identify two important characteristics for processes. First, all processes have customers who receive the defined outcome of a process. These customers may lie either internal or external to the firm. Second, processes cross organizational boundaries meaning that they are independent of formal organizational structure. (Davenport & Short 1990, 12)

Process innovations, thus, relate closely to how firms manage their knowledge, capabilities, and resources. According to Dodgson et al. (2008, 259), process innovations often require firms to reorganize the deployment of these capabilities and resources in order to optimize the way they serve their customers. Some examples of common types of process innovations are the introduction of new machinery and equipment, changes in production processes (such as JIT, Kaizen, or BPR), and use of ICT in design (such as CAD, or 3-D modeling). (Dodgson et al. 2008, 259-260)

As process innovations usually require individual firms to reorganize their operations, systemic process innovations, on the other hand, require whole networks of firms to reorganize in a coordinated way. Teece (1986) makes a distinction between two types of innovations; (1) *autonomous innovation*, and (2) *systemic innovation*. Teece (1996, 205) further explains that whereas an *autonomous innovation* can be introduced without modifying any other components or items of equipment, a *systemic innovation* requires significant readjustment to other parts of the system. As Chesbrough and Teece (2002, 128) put it, systemic innovations need simultaneously multiple complementary innovations in order to be realized successfully. Thus, the major distinction between autonomous and systemic innovations relates to the amount of coordination needed in the development and commercialization of the innovation. Some examples of systemic innovations, according to Teece (1996, 205), are electronic funds transfer, instant photography, front-wheel drive, a jet airliner, and audio CD. Figure 2 illustrates the difference between autonomous and systemic innovation.

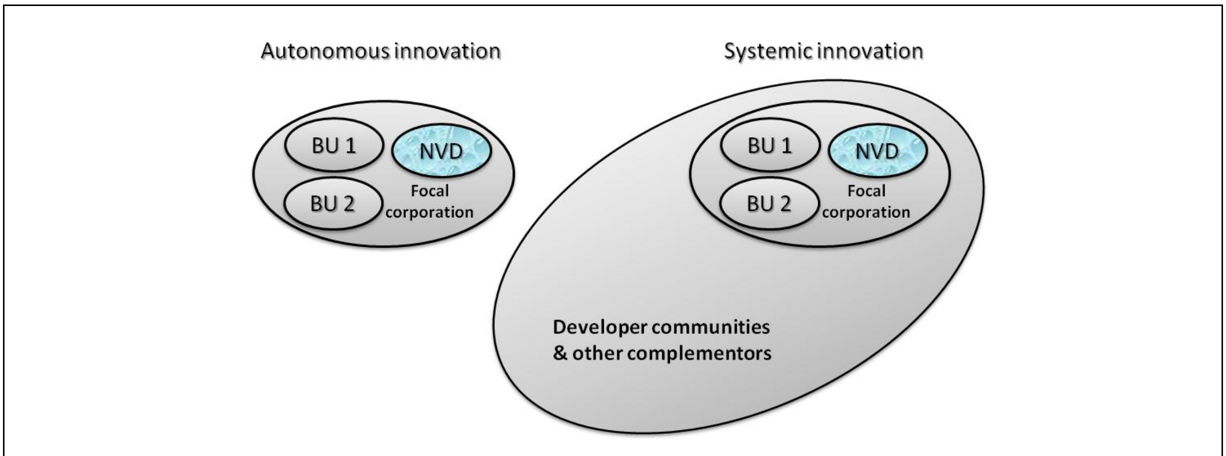

Figure 2: The difference between autonomous and systemic innovation (Maula et al. 2006, 247)

However, Teece's (1996) definition above – as almost all references on systemic innovations in the literature – refers to systemic product innovations. In fact, the references on systemic process innovations are almost nonexistent in the literature. For example, Chesbrough and Teece (2002) examined the IBM PC as an example of a systemic innovation, and only briefly mentioned lean manufacturing as an example of systemic process innovation as it requires interrelated changes in product design, supplier management, and information technology. Similarly, De Laat (1999) examined the development of DVD as an example of systemic product innovation and mentioned nothing about systemic process innovations. Furthermore, Maula et al. (2006) mention the internet, 3G mobile telephony, and different operating systems as the examples of systemic innovations, which in fact can be seen as process innovations from the users' point of view. Langlois (1992, 117), on the other hand, lists the factory mode of production, the moving assembly line, refrigerated meat-packing, and containerized shipping as the examples of systemic process innovations. In the context of the construction industry, Taylor and Levitt (2004) investigated the diffusion of prefabricated subcomponent walls as an example of a systemic product innovation. Additionally, Harty (2005) examined the implementation of 3-D CAD in the UK, but instead of calling it a systemic process innovation, he introduced the term unbounded innovation.

Taylor and Levitt (2004, 6) define systemic innovations as innovations that reinforce the existing product but require multiple companies in a network to change practices in a coordinated way. When achieving this coordinated change, systemic innovations will typically create significant increases in overall productivity over the long run. As a drawback, however, adopting a systemic innovation may induce switching or start-up costs for some participants and reduce or eliminate the role of others. (Taylor & Levitt 2004, 6)

Harty (2005) adds even another dimension to the definition systemic innovations with his bounded and unbounded modes of innovation. According to Harty (2005, 515), a systemic innovation can be either bounded or unbounded, and similarly, a bounded innovation can be either autonomous or systemic. By boundedness, Harty (2005, 515) distinguishes between innovations that can be contained within an implementer's control and those that cannot. Interestingly related to the topic of this thesis, by Harty's (2005, 515) definition, systemic innovations that are being implemented within a vertically integrated network could be considered as bounded innovations, and similarly, systemic innovations that are being implemented within a vertically disintegrated network could be considered as unbounded innovations.

Finally, the forms and types of innovations depend on from which perspective they are being examined. BIM, for example, can be considered as a product innovation for the software providers offering the BIM tools, but at the same time it can be seen as a process innovation for the users, such as designers and contractors who are using the tools in a construction project. Furthermore, BIM has been said to be a systemic innovation because its implementation and utilization require changes in the operations of several actors in a construction project network (e.g. Taylor & Levitt 2004). In this thesis, BIM is examined from the users' point of view, thus being a systemic process innovation.

Summarizing the above, a systemic process innovation is defined in this study in the following way:

> ***A systemic process innovation*** *is a collection of interconnected innovations related to the boundary spanning working practices of the whole business system, and require all the actors in the business system to change accordingly in a coordinated way when being implemented.*

2.3 Construction industry

According to Eccles (1981, 450), the construction industry covers the erection, maintenance and repair of immobile structures, the demolition of existing structures, and land development. These immobile structures include all the buildings and infrastructure that constitute the built environment. This thesis focuses, however, on the buildings, and more specifically on architecture, engineering, construction and operations (AECO) industry because it is the context where BIM is being developed and implemented.

AECO industry has some special characteristics that affect the two focal concepts of this study, vertical integration and innovation management. First of all, AECO industry is one of the most fragmented industries (Krippaehne et al. 1992, 156) which means that it is a large industry of small firms. Only a small fraction of these firms are large and no single firm or group of firms has a monopoly (Fellows et al. 2002, 3). Furthermore, AECO industry is a project-based industry and these projects are considered as being amongst the most complex of all production undertakings (Winch 1987, 970). The complexity arises from different technical, financial, political, and social factors being involved in construction projects (Sandhu & Helo 2006, 601). Considering the facts above, it is impossible for any firm in the industry to be vertically integrated in a full degree. However, some degree of vertical integration exists, for example between design and construction or construction and manufacturing. Figure 3 illustrates the typical organizational boundaries between the numerous participants in a construction project.

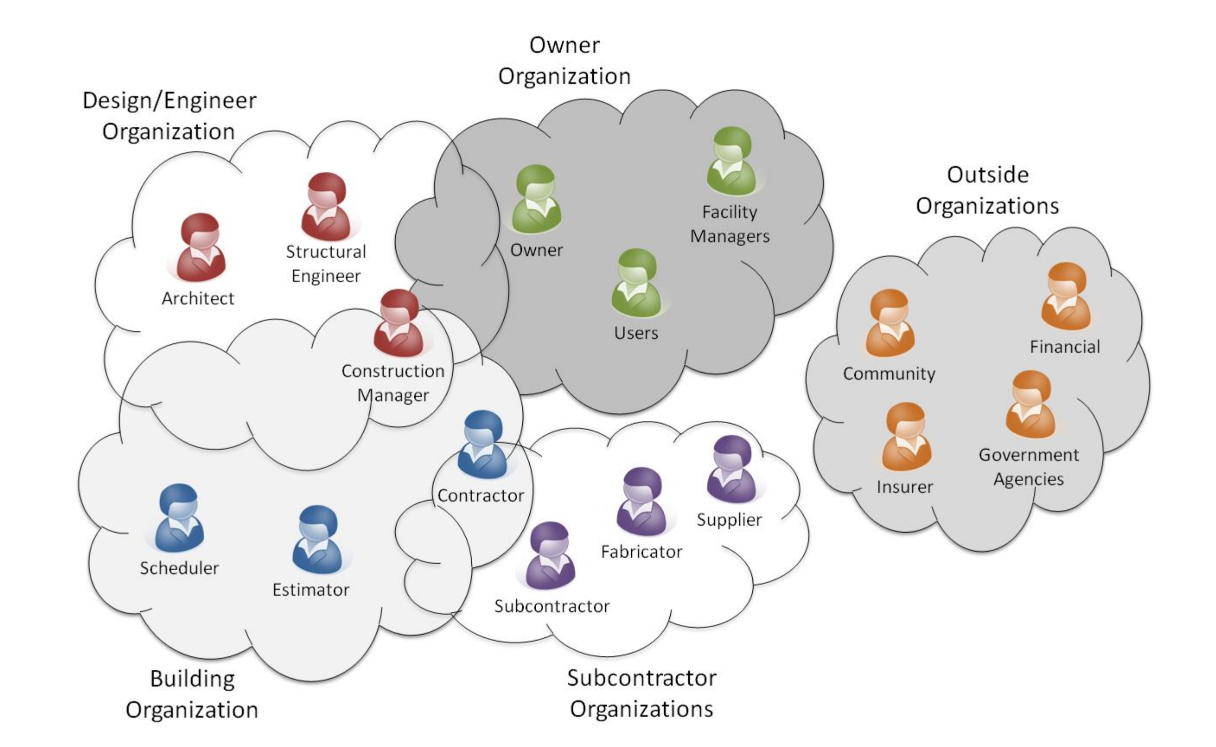

Figure 3: Typical organizational boundaries between the participants in a construction project (modified from Eastman et al. 2008, 3)

The special characteristics of AECO industry have an influence on the innovation management as well. According to Allmon et al. (2000, 98), introducing new technology can be more difficult in the construction industry than in other industries because of various innovation barriers such as existing diverse standards, industry fragmentation, business cycles, and risk aversion. Additionally, Harty (2005, 513) highlights the following five features of the AECO industry that need to be acknowledged when innovations such as BIM are being introduced: (1) *need for extensive collaboration*, (2) *project-based work*, (3) *the centrality of communication*, (4) *importance of interorganizational relations*, and (5) *the distribution of power and control*.

First, according to Harty (2005), the construction work is a collection of efforts where *extensive collaboration* is required from a large number of different organizations, each with their own objectives, practices, and resources. This variety of different objectives and actors brings additional challenge to innovation management, especially with the systemic process innovations such as BIM. Second, the construction work is *based on projects* where this extensive collaboration of a diverse range of firms needs to be coordinated. The learning and development related to innovations such as BIM occurs in individual projects where practical problems are encountered and solved. These experiences, however, need to be captured and translated into reusable organizational resources at the firm-level also in order to utilize innovations in a broader scale. (Harty 2005, 513-514)

Third, construction projects rely on *communication* and effective information transfer. Design details, work schedules, materials purchasing, and supply and resource allocation need to be coordinated across a project within and between firms. As innovations such as BIM can make communication and information transfer more effective and accurate, it is important to acknowledge the centrality of communication in construction projects when implementing such innovations. Fourth, Harty (2005) mentions the *importance of interorganizational relations*. As already mentioned earlier, construction projects always span across multiple organizational boundaries, and these interorganizational relations need to be taken into account in innovation management as well, especially with systemic innovations. (Harty 2005, 514)

Finally fifth, probably the most important feature of AECO industry is the *distribution of power and control*. Even though construction projects may be coordinated by one main contractor, still each organization involved has its own control over a project and brings its own expectations and working methods. Thus, the implementation of innovations located at this interorganizational and project-wide level, such as BIM, is placed beyond the control of a single firm. Overall, the industrial context where an innovation such as BIM is introduced is characterized by multiple interorganizational relations, complex interdependencies between firms, and the lack of a single authoritative driving force that can see through implementation across a whole project. (Harty 2005, 514-515)

In this study, the industrial context of the construction industry is defined in the following way:

> ***The construction industry****, where vertically integrated firms in a full degree cannot exist, is characterized by multiple interorganizational relations, complex interdependencies between firms, and the lack of a single authoritative driving force to lead the innovation implementation in project-based environment.*

2.4 Building information modeling (BIM)

Building information modeling (BIM) is a comprehensive concept that has been defined in various ways in the literature. First of all, the acronym BIM can be used to refer to a product (*building information model*, meaning a structured dataset describing a building), an activity (*building information modeling*, meaning the act of creating a building information model), or a system (*building information management*, meaning the business structures of work and communication that increase quality and efficiency) (NIBS 2007, 1). In this study, BIM is used to refer to the activity, building information modeling, as it is most commonly used in the literature and it includes both technologies and processes used in creating the actual building information models.

Over the years, other terms for BIM have also been used, such as *building product modeling* or *product data modeling*, to name a few (e.g. Penttilä 2006, 403). Additionally, CIFE (Center for Integrated Facility Engineering) from Stanford University has been using the term *virtual design and construction* (VDC) in a wider sense (Kunz & Fischer 2009). Nevertheless, the term BIM seems to be gaining popularity in both industrial and academic circles (Succar 2009, 357).

Basically, BIM is an emerging technological and procedural paradigm within the AECO industry after paper-based drafting and computer aided design (CAD) (Succar 2009, 357). As CAD has developed from 2-D to 3-D, 4-D and even 5-D including not only the 3-dimensional geometry but also time in 4-D and cost in 5-D (Kraus et al. 2007, 1), BIM includes all this and in addition more specific information on different building elements and systems associated with a building, such as wall types, spaces, air handling units, geospatial information, and circulation zones (GSA 2007, 3).

A major difference in the actual work processes is that with both paper-based drafting and 2-D CAD, information was typically exchanged between project participants in the form of a printed set of plans, whereas with 3-D CAD and especially BIM, information is exchanged in the form of virtual models (see Figure 4). Thus, when the evolution of a printed set of plans is separated in time, the evolution and co-creation of virtual models requires overlapping of the work, and therefore, it changes the long-established practice of when different participants should start working on a project. (Taylor 2007, 994-995)

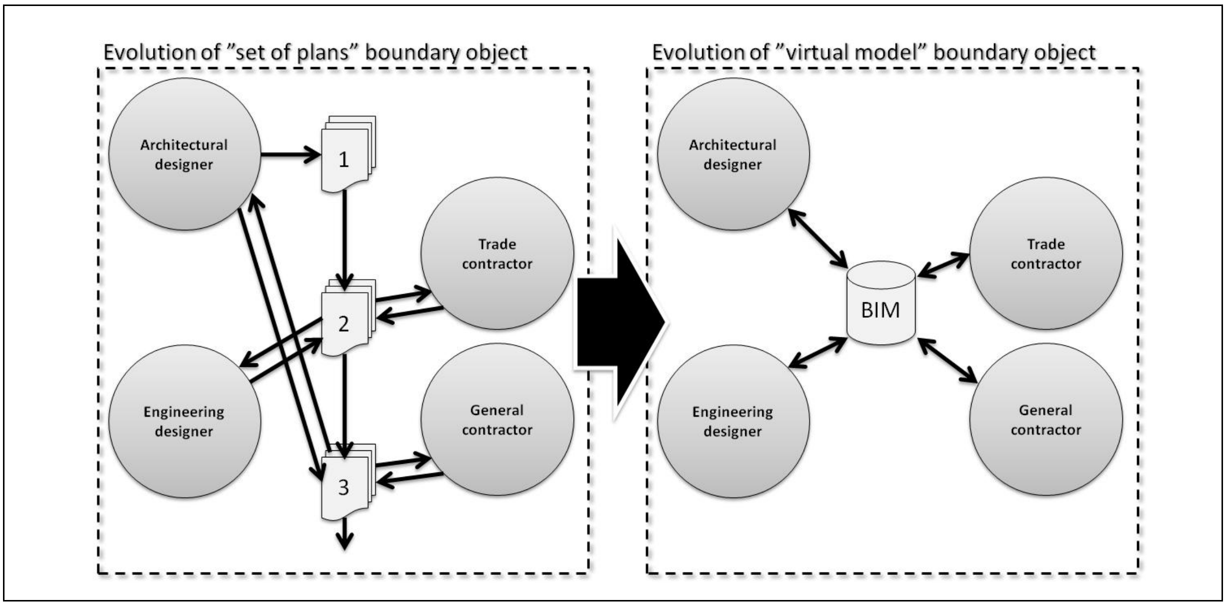

Figure 4: From paper-based set of plans to virtual model (modified from Taylor 2007, 995)

BIM is defined broadly as being "*a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle*" (Penttilä 2006, 403; Succar 2009, 357). As this definition implies, BIM methodology is not specific to any single or collections of software applications. In fact, numerous applications can be used to serve many purposes during different phases of a project. (Hannon 2007, 2) In this kind of a multi-application environment, where different applications may not directly communicate with each other, common standards for information transfer become important. The most promising effort to solve these interoperability challenges is the development of Industry Foundation Classes (IFC) by the International Alliance for Interoperability (IAI). (Alshawi & Faraj 2002, 33-34) The objective in developing IFC is to provide a common standard to transfer complete and accurate building information models between different project participants regardless of applications used and without any loss of information (Fox & Hietanen 2007, 289).

BIM is expected to bring numerous benefits and significant productivity improvements in the construction industry. In general, BIM enables easier management of all the data needed for the design, construction, usage and maintenance of buildings (Romo et al. 2005, 95). More specifically, BIM increases the quality of construction by enabling better support for decision making and improving the design quality and long-term performance of the buildings. Similarly, BIM can lower the costs during a project and the whole life-cycle of a building by providing better ways for reusing essential project information and by enabling the usage of sophisticated life-cycle analysis tools. Furthermore, BIM can reduce risks by providing higher reliability in budget control and increase efficiency by reducing design time to allow more life-cycle analyses and evaluation of multiple alternatives. (Fischer & Kam 2002, 20)

As BIM is such an extensive methodology, it cannot be implemented at once. Succar (2009, 363) identifies three maturity stages for BIM implementation which are: (1) *object-based modeling*, (2) *model-based collaboration*, and (3) *network-based integration* (see Figure 5).

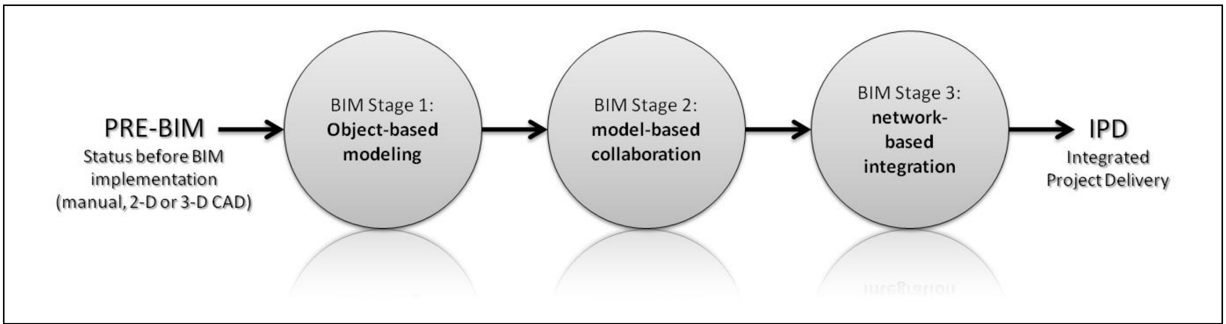

Figure 5: BIM maturity stages (modified from Succar 2009, 363)

At *object-based modeling* stage, building information models are primarily used to automate generation and coordination of 2-D documentation and 3-D visualization, with collaboration not much differing from pre-BIM stage. Next, at *model-based collaboration* stage, project participants use building information models for active collaboration within and between different phases of a project. Established practices relating to separating roles, disciplines and project phases start to fade. At final *network-based integration* stage, semantically-rich integrated building information models are created, shared and maintained collaboratively across all project phases. The final stage requires the major reconsideration of contractual relationships, risk allocation models and work processes. The ultimate goal of BIM is, however, *Integrated Project Delivery* (IPD) which is an approach that fully integrates people, systems, business structures and practices into a collaborative and highly automated process. (Succar 2009, 361-365)

In this study, the concept of building information modeling (BIM) is defined in the following way:

> ***Building information modeling (BIM)*** *is a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the life-cycle of the building, aiming in fully integrated and highly automated processes in the construction industry.*

3 Research problem, objectives and scope

The main objective of this thesis is to gain deeper understanding about the impact of organizational structure in the implementation of systemic process innovations. More specifically, the advantages and disadvantages of vertical integration will be examined in the context of BIM implementation in the construction industry. Thus, the overall research problem of this thesis is to shed more light on,

> ***what are the advantages and disadvantages of vertical integration in the implementation of a systemic process innovation such as BIM in project networks of the construction industry?***

The research problem above is extremely broad but a more specific research question will be formed after careful examination of the previous research in the literature review of this thesis (Part II). The research question based on the literature review will be presented in the end of Part II. Alongside with the research question, a synthesis of the literature review will be made in form of a constructed theoretical model, which aims to answer the overall research problem. In order to find the answer to the overall research problem, the advantages and disadvantages of vertical integration will be reviewed. In addition, the relevant background theories from the implementation of systemic process innovations will be examined; especially from the organizational (i.e. vertical integration) point of view.

There are theoretical and practical objectives for this study. The theoretical objective is to create a novel constructed model based on the previous literature providing a solution for the overall research problem. The empirical data from the case studies will be analyzed against this theoretical background in order to give new theoretical contribution to the field. The practical objective of this study is to deepen the understanding about the organizational issues affecting the implementation of a systemic process innovation among the companies facing the situation and to give possible guidelines for more successful preparation, planning and execution of the implementation. Specifically in this case, this study aims to offer new insight how both vertically integrated and vertically disintegrated firms could be more successful in implementing BIM in the construction industry.

The focus of this study is on the advantages and disadvantages of vertical integration i.e. organizational ownership structure related issues in the implementation of BIM as an example of a systemic process innovation. Therefore, other issues in BIM implementation and development, such as detailed technical issues, will not be covered unless they are related to the organizational structure. The objective of this study is not to determine whether firms should integrate vertically or not when implementing BIM but rather offer insight how the organizational structure affects the implementation.

The empirical data is based on two separate single case studies from the Finnish construction industry where BIM is being implemented in a vertically integrated project network and in a vertically disintegrated project network. These case studies concentrate especially on BIM utilization in the planning and design phase of a project, and thus, other phases (e.g. the construction phase or the operations phase) or several successive implementation projects will not be included in the study.

4 Research approach

The research approach of this thesis is a mixture of three different research paradigms; *case study research* (Section 4.1), *action research* (Section 4.2), and *constructive research* (Section 4.3). The combined research approach was chosen for its ability to provide versatile tools and rich qualitative data to solve the comprehensive research problem of this thesis. At the same time, the empirical data for this thesis was collected in two SimLab™ business process development projects and the SimLab™ method inherently includes the characteristics of case study research and action research approaches. The SimLab™ method as a data collection method will be further explained in Part III (Empirical research) of this thesis. The research paradigms, how they are applied in this study, and the research process (Section 4.4) are further described in the following.

4.1 Case study research

Case study research is "*a research strategy which focuses on understanding the dynamics present within single settings*" (Eisenhardt 1989, 534). It attempts to examine a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 1981, 59). One or several cases can be used to reach specific or general conclusions about certain phenomena (Gummesson 2003, 488). When using several cases, cross-case analysis with case-survey or case-comparison approach can be applied (Yin 1981, 62-63). The purpose of case study research is usually systemic and holistic, trying to give a full and rich description of relationships between different events and factors in the system (Gummesson 2003, 488). According to Eisenhardt (1989, 535), case studies can be used to accomplish three different aims; to provide description, to test theory, or to generate new theory.

Case study research provides the researcher with a fascinating input of real-life data from which concepts can be formed and theory can be tried (Gummesson 2003, 488). Case studies usually combine multiple data collection methods such as archives, interviews, questionnaires, and observations. Even though case studies are typically associated with qualitative data, the collected data may, in fact, be either quantitative, qualitative, or both (Eisenhardt 1989, 534-535).

This study is conducted by using a multiple case study method and cross-case analysis with the case-comparison approach. The idea behind this research was to choose two opposite extreme cases, a vertically integrated project network and a vertically disintegrated project network, and compare them in order to investigate the advantages and disadvantages of vertical integration when implementing a systemic process innovation such as BIM. In both of these cases BIM technologies were being implemented in a single pilot project. The cross-case comparison enables analyzing the advantages and disadvantages of vertical integration during the implementation of BIM. The collected data is qualitative and the data collection methods include archives, interviews, and observations. The further description of the case studies included in this thesis and the data collection and analysis methods used can be found in Part III (Empirical research).

4.2 Action research

The idea of action research was first developed by Kurt Lewin in the 1940's. During action research, researchers not only observe and document phenomena; they actually intervene and participate in the subject under study. Action research is especially useful in situations where participation and organizational change processes are necessary. (Baskerville & Pries-Heje 1999, 2-3) Kaplan (1998) introduced a concept of innovation action research where researchers work with client organizations to enhance and test an emerging theory that has been proposed to improve organizational performance. According to Kaplan (1998), researchers become active change agents who help to create phenomena that did not exist before. Thus, the main objective of innovation action research is to modify and extend the emerging theory in light of knowledge gained through experience. (Kaplan 1998, 90-91)

Generally in action research, researchers use the collected data not only for research purposes, but also for developing the subject under study. The main benefit from the research point of view is that the researcher is able to form a deep and meaningful relationship with the research subject. Action research is often also case study research and the collected empirical data can be both quantitative and qualitative. (Järvenpää & Kosonen 2003, 21-22)

The action research paradigm applies to this study in two ways, mostly through the application of the SimLab™ business process development method. First, the two case studies used in this study were not only used for data collection, but they were also development projects for developing client networks' processes and collaboration. Second, the researchers who participated in the case studies – one of them being the author of this thesis – were actively involved and acted as change agents in the development process. The further description of the case studies included in this thesis and about the SimLab™ method can be found in Part III (Empirical research).

4.3 Constructive research

Constructive research approach means "*problem solving through the construction of organizational procedures or models*". These constructed procedures or models are, thus, entities that produce solutions to explicit problems. An important characteristic of these models or procedures is that their usability can be demonstrated in real life through the implementation of the solution. All problem solving approaches, however, are not automatically constructive research. An essential part of the constructive research approach is to connect the problem and its solution with existing theory, and in addition, to demonstrate the novelty and the actual working of the solution (as illustrated in Figure 6). (Kasanen et al. 1993, 244-246)

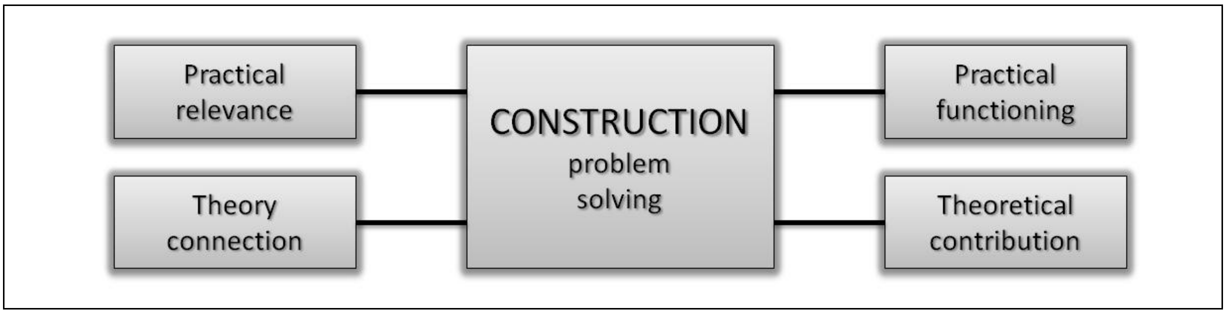

Figure 6: Elements of constructive research (Kasanen et al. 1993, 246)

The constructive research paradigm applies in this study in a way that a solution model will be constructed based on the literature review in order to answer the research problem (see

Section 8.2 Constructed theoretical model). The constructed theoretical model will be tested and improved by analyzing the collected empirical data.

4.4 Research process

The actual research process started with the data collection in two extreme case studies used in this thesis. The preliminary results from these case studies provided the final motivation for this study and guided the formulation of the research problem presented in Chapter 3. Based on the research problem and the guidance of the preliminary results, the relevant theories of vertical integration and the implementation of systemic process innovations were contextualized in the literature review in Part II. In the contextualization of the theory, both theoretical parts (advantages and disadvantages of vertical integration and the implementation of systemic process innovations) were examined in three levels; in general level, in the context of systemic innovations, and in the context of the construction industry (Chapters 6 and 7).

The literature review was followed by the theory synthesis where the relevant theories were combined into the constructed theoretical model in order to answer the research problem (Section 8.2). Based on the constructed theoretical model, the more detailed research question was formed to guide the empirical research in Part III (Section 8.3). The empirical data was analyzed with the constructed theoretical model in order to answer the detailed research question. The data analysis methods used in the empirical research will be explained in more detail in Section 10.3. Next, the findings of this study were derived from the empirical data and the constructed theoretical model was refined into the improved theoretical model based on the findings (Part IV). Finally, the general conclusions and wider implications of this study were drawn (Part V). The research process of this study is illustrated in Figure 7 below.

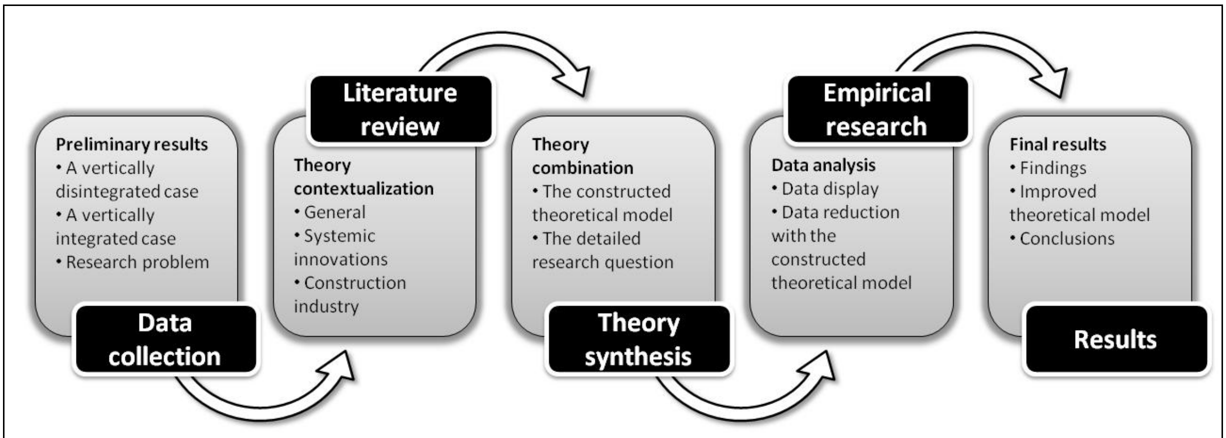

Figure 7: The research process of the study

5 Structure of the study

This Master's Thesis is organized into five parts: introduction (Part I), literature review (Part II), empirical research (Part III), findings (Part IV), and discussion (Part V). The structure of the study is illustrated in Figure 8 below.

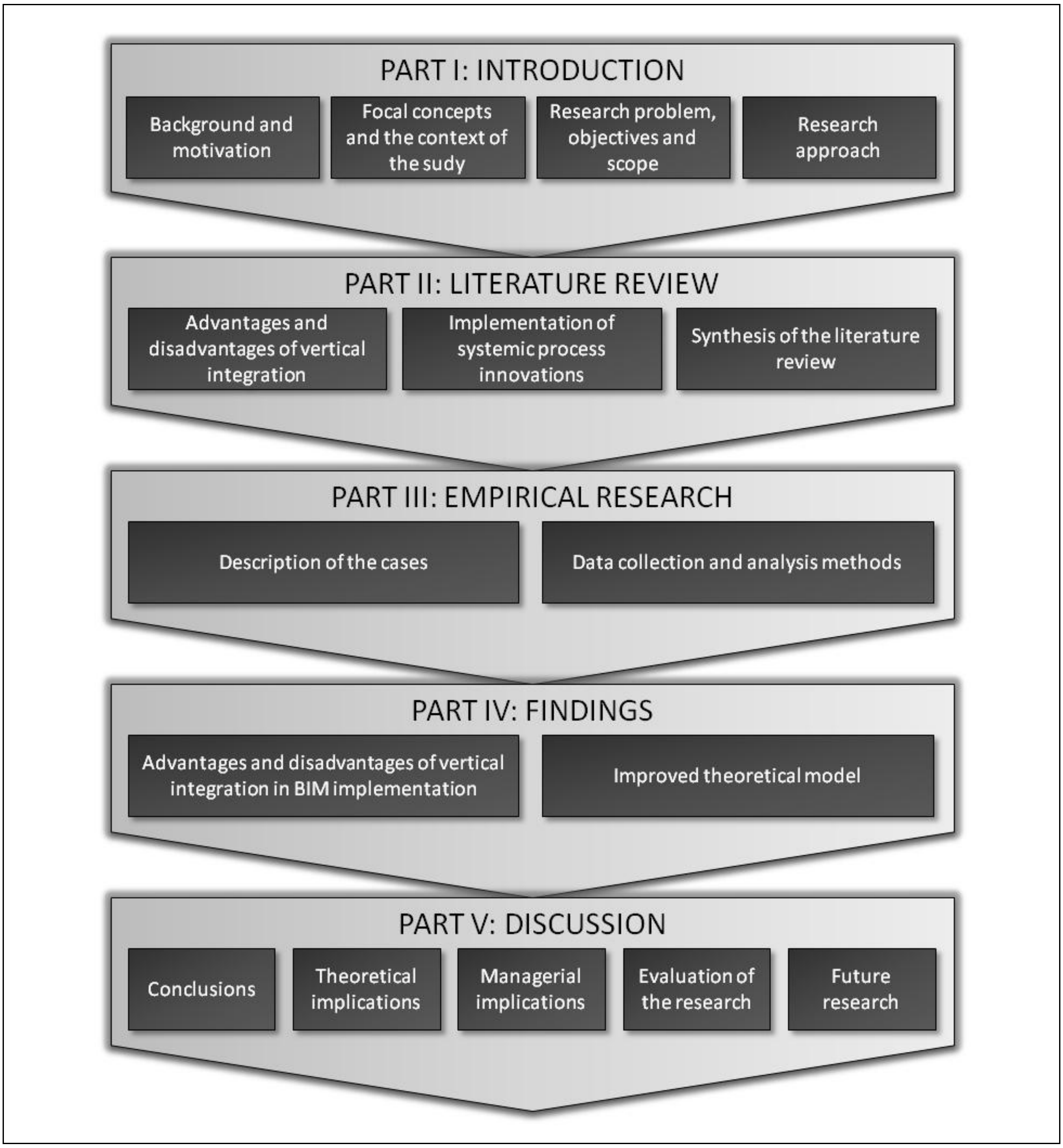

Figure 8: The structure of the study

In this introductory Part I, the background and motivation of this thesis were discussed, the focal concepts and the context of this study were defined, the research problem, objectives and scope were specified, and the research approach was explained.

The following Part II presents the literature review, which introduces the theoretical background of this study. Two different theoretical parts are presented: advantages and disadvantages of vertical integration (Chapter 6), and the implementation of systemic process innovations (Chapter 7). Following these theoretical parts, a synthesis of the literature review is presented including a short summary of the literature review, a constructed theoretical model based on the literature review, and the detailed research question based on the constructed theoretical model (Chapter 8).

In Part III, the empirical research of this thesis is presented. First, the two case studies used in this study are described and introduced (Chapter 9). Then, the data collection and analysis methods are described in more detail (Chapter 10).

Part IV presents the findings of this study. First, Chapter 11 specifies the advantages and disadvantages of vertical integration in BIM implementation by answering the detailed research question formed earlier in Chapter 8. Then, the constructed theoretical model is refined into an improved theoretical model based on the findings (Chapter 12).

Finally, Part V includes the discussion of this thesis. First, the conclusions of this study are drawn based on the findings (Chapter 13). Then, the theoretical and managerial implications are presented (Chapters 14 and 15). In Chapter 16, the validity and reliability of this study are evaluated. Finally, some topics for future research are recognized (Chapter 17).

II LITERATURE REVIEW

"History is more or less bunk."
– Henry Ford (1863-1947)

The literature review presents the theoretical background of this study and consists of three chapters; advantages and disadvantages of vertical integration (Chapter 6), implementation of systemic process innovations (Chapter 7), and synthesis of the literature review (Chapter 8). The overall purpose of this part is to review the relevant literature in order to construct a theoretical solution model and specify a detailed research question for the empirical research in Part III.

6 Advantages and disadvantages of vertical integration

There are many reported advantages from vertical integration but there are also disadvantages that firms need to take into account. These advantages and disadvantages also vary from industry to industry. The purpose of this chapter is to review the general advantages and disadvantages of vertical integration found in the literature (Section 6.1) and to find out how vertical integration go together specifically with systemic innovations (Section 6.2). Finally, it will be clarified what the impact of vertical integration is in the context of the construction industry (Section 6.3).

6.1 General advantages and disadvantages of vertical integration

The advantages and disadvantages (or benefits and costs) of vertical integration vary from industry to industry and depend on the competitive situation of the firm but there are also general issues defined in the literature. According to Blois (1972, 253-254), the most frequently cited advantages of vertical integration regardless of the industry are (1) *decreased marketing expenses*, (2) *the stability of operations*, (3) *the certainty of supplies of materials and services*, (4) *better control over product distribution*, (5) *tighter quality control*, (6) *the prompt revision of production and distribution policies*, (7) *better inventory control*, and (8) *additional profit margins or the ability to charge lower prices on final products*. Blois (1972, 254) adds that these advantages must be weighed against the disadvantages which typically are (1) *disparities between productive capacities at various stages of production*, (2) *public opinion and governmental pressure*, (3) *lack of specialization*, (4) *the inflexibility of operations*, (5) *the ex-*

tension of the management team, and (6) *lack of direct competitive pressures on the costs of intermediate products*. Blois (1972), however, does not explain these advantages or disadvantages any further in his article.

Slightly in contrast to Blois (1972), Williamson (1971) does not consider *the supply reliability* as an essential advantage but rather emphasizes (1) *the harmonization of interests* and (2) *the utilization of an efficient decision process* as the main advantages. According to Williamson (1971, 117), vertical integration enables an easier *harmonization of interests* as possible conflicts and differences can be reconciled by fiat within an integrated firm. With interorganizational conflicts, settlement by fiat is not usually possible and impartial arbitrators are often needed. Similarly, vertical integration permits an *efficient* (i.e. adaptive and sequential) *decision process* to be utilized through the ownership of successive functions. (Williamson 1971, 114-117)

Porter (1980) discusses vertical integration broadly in his seminal book, *Competitive Strategy*, and brings out the benefits and costs of vertical integration from a strategic point of view. According to Porter (1980, 303-309), the strategic benefits of vertical integration are (1) *economies of integration*, (2) *tap into technology*, (3) *assure supply and/or demand*, (4) *offset bargaining power and input cost distortions*, (5) *enhanced ability to differentiate*, (6) *elevate entry and mobility barriers*, (7) *enter a higher-return business*, and (8) *defend against foreclosure*. According to Porter (1980, 303), achieving economies – or in other words cost savings in joint production, sales, purchasing, control, and other areas – is the most cited benefit of vertical integration. Porter (1980, 303-305) further specifies the economies of integration to (1.1) *combined operations*, (1.2) *internal control and coordination*, (1.3) *information*, (1.4) *avoiding the market*, and (1.5) *stable relationships*. These benefits of economies as well as other benefits by Porter (1980) are further explained in the following.

Economies of combined operations mean that by putting technologically distinct operations together, the firm can achieve efficiencies for example through reducing the number of steps in the production process, reducing handling and transportation costs, or utilizing slack capacity. *Economies of internal control and coordination* relate to the costs of scheduling, coordinating operations, and responding to emergencies. According to Porter (1980), adjacent location facilitates coordination and control and changes in production may be easier to coordinate internally or coordination may occur more rapidly. *Economies of information* mean that vertical integration may reduce the overall cost of gaining information by reducing the need for collecting some types of information about the market. Furthermore, market information may flow more freely through an integrated firm than through a network of independent firms, and thus, allowing the integrated firm to obtain faster and more accurate information about the market. *Economies of avoiding the market* mean savings in selling, price shopping, negotiating, and transaction costs of market transactions when making transactions internally. Finally, the *economies of stable relationships* relate to the ability to develop more efficient and specialized procedures between different units, for example, dedicated logistical systems, special packaging, and unique arrangements for a record keeping and control. Furthermore, the stability of the relationships allows the upstream unit to tune its output (in quality, specifications, etc.) to the exact requirements of the downstream unit and vice versa. (Porter 1980, 303-305)

The second benefit, *tap into technology*, means that an integrated firm can benefit from accessing and exploiting technology in upstream or downstream units. As an example, many computer manufacturers have instituted backward integration into semiconductor design and manufacturing to gain a deeper understanding about the essential technology. Similarly, manufacturers of components in many industries integrate forward into systems in order to gain sophisticated understanding how the components are used. (Porter 1980, 305)

Third in Porter's (1980) list of benefits, *assure supply and/or demand*, was also brought up by Blois (1972) and Williamson (1971). According to Porter (1980, 306), vertical integration assures the firm that it will receive supplies in tight periods or have an outlet for its products in periods of low demand, and thus, reduces the uncertainty of supply and demand. The lower uncertainty is especially important when one or more units are capital intensive as it allows an easier planning of operations with lower risks of interruptions and elimination of changes in suppliers or customers. The assurance of supply and demand has been a major motivation for vertical integration especially in process industries such as petroleum, steel and aluminum. (Porter 1980, 306-307)

By *offsetting bargaining power and input cost distortions* Porter (1980) means a situation where suppliers or customers have significant bargaining power for some reason and exploit it in order to gain remarkable returns on investment. Using vertical integration to offset the bargaining power will not only decrease the costs of inputs (by backward integration) or increase the profit of outputs (by forward integration) but also allow more efficient operations by eliminating otherwise valueless practices used to cope with the powerful suppliers or customers.

Furthermore, by knowing the true costs of the input after vertical integration, the firm can adjust the price of the final product to maximize the overall profit. (Porter 1980, 307)

As the fifth benefit of vertical integration Porter (1980) mentions the *enhanced ability to differentiate* from others by offering a wider proportion of value added under the control of a single firm. This can allow, for example, a better control of distribution channels to offer superior service or a differentiation through the in-house manufacturing of proprietary components. (Porter 1980, 307-308)

Porter (1980) further elaborates that if vertical integration achieves any of these benefits mentioned above, it can *elevate entry and mobility barriers*. As the integrated firm has the competitive advantage in the form of higher prices, lower costs, or lower risk, new entrants are forced to enter as an integrated firm or they will face a serious disadvantage. If there are remarkable economies of scale or capital requirement barriers to vertical integration, the necessity to integrate will raise mobility barriers in the industry. (Porter 1980, 308)

As the seventh benefit, firms may integrate vertically simply to *enter a higher-return business*. If a certain adjacent function in the value chain has a structure that offers a greater return on investment than the opportunity cost of capital for the firm, then it is profitable to integrate even if there are no other benefits of integration. (Porter 1980, 308)

Finally, as the last benefit, Porter (1980) mentions the *defense against foreclosure*. If competitors are vertically integrated, it may be necessary to defend against foreclosure of access to suppliers or customers even if there are no other benefits from integration. This also means that new entrants must enter the business on an integrated basis, and thus, the mobility barriers are increased in the same way as described earlier. (Porter 1980, 308-309)

Porter (1980, 309-314) also defines the strategic costs (i.e. disadvantages) of vertical integration which are (1) *cost of overcoming mobility barriers*, (2) *increased operating leverage*, (3) *reduced flexibility to change partners*, (4) *higher overall exit barriers*, (5) *capital investment requirements*, (6) *foreclosure of access to supplier or consumer research and/or know-how*, (7) *maintaining balance*, (8) *dulled incentives*, and (9) *differing managerial requirements*. These costs are further explained in the following.

Vertical integration can elevate entry and mobility barriers, as discussed earlier above, but as a flip side of the coin it means overcoming these barriers to integrating firms. These *mobility barriers* can be caused by cost advantages from proprietary technology, favorable sources of raw materials or capital requirements. As a result, vertical integration occurs most frequently in industries where the technology is well known and the minimum efficient scale of a plant is not great. (Porter 1980, 309)

By *increased operating leverage* Porter (1980) means that vertical integration increases the fixed costs of a firm. Increased fixed costs, on the other hand, expose the firm to greater fluctuations in earnings, and thus, increase the business risk. The degree to which vertical integration increases the operating leverage depends on the amount of fixed costs in the business. If the business has high fixed costs, the effective increase in operating leverage can be substantial. (Porter 1980, 309-310)

As a third cost, Porter (1980) mentions the *reduced flexibility to change partners* which implies that the integrated firm is at least partly tied to the success of its in-house functions. Technological changes, changes in product design, strategic failures, or managerial problems can create problems in the success of one of these functions, and thus, put the whole firm in disadvantage. Vertical integration increases the costs of changing suppliers or customers compared to contracting with independent firms. (Porter 1980, 310-311)

By *higher overall exit barriers* Porter (1980, 311) means that vertical integration that further increases the exit barriers of individual functions such as the specialization of assets, strategic interrelationships, or emotional ties to a business may raise the overall exit barriers even further. The specialization of assets stands for the assets that are specialized by their usage or location and therefore difficult to liquidize. Strategic interrelationships mean that a function is a vital part of a total strategy involving many other functions. Emotional ties to a business by the management can be a source of an exit barrier as well. (Porter 1980, 259-263)

Fifth in Porter's (1980) list of costs, *capital investment requirements*, relates to the fact that vertical integration consumes capital resources whereas buying from independent firms uses the investment capital of others. Therefore, in order for vertical integration to be a sound choice financially, it should turn a profit greater than the firm's opportunity cost of capital. In addition, vertical integration can decrease the flexibility of allocating investment funds. As the overall performance of the integrated firm is dependent on each of the functions, the firm may be forced to invest in marginal functions to preserve the overall entity rather than allocate capital to more attractive investments. (Porter 1980, 311)

By the *foreclosure of access to supplier or consumer research and/or know-how* Porter (1980) means that the integrated firm may cut itself off from the flow of technology and knowledge from its suppliers and customers because of the increased competition and decreased collaboration. Foreclosure of technology and knowledge can be a significant risk in situations where there are numerous independent suppliers or customers doing large-scale research or have certain know-how difficult to replicate. (Porter 1980, 312)

As the seventh cost, Porter (1980) mentions *maintaining the balance*. Maintaining the balance of the productive capacities of different functions is important as it may be costly for the integrated firm to sell (or buy) the excess capacity (or demand) on the open market (i.e. competitors). Different functions of the integrated firm can go out of balance for a variety of reasons. A growing market can create temporary periods of imbalance because the efficient increase to capacity often varies from function to function. Changes in technology, product mix, or quality may also affect the effective capacity unequally in different functions. (Porter 1980, 312-313)

The eighth cost, *dulled incentives*, means that vertical integration may weaken the incentives of different functions in the integrated firm because the competition is less fierce than it would be in the open market. Whether or not these dulled incentives in fact reduce the performance in the vertically integrated firm depends on the managerial structure and governance procedures between the different functions. For example, managers may be given the freedom to use outside suppliers (or to sell to outside customers) if the inside unit is not competitive. If a healthy unit is trying to rescue a troubled unit by accepting its higher-cost inputs (or lower prices on outputs), the situation can lead to the “bad apple” problem which will damage the healthy unit and the whole firm in the long run. (Porter 1980, 313-314)

Finally, as the last cost, Porter (1980) mentions the *differing managerial requirements* which mean that functions are usually different in structure, technology, and management despite having a vertical relationship. As an example, manufacturing and retailing are fundamentally different. Understanding how to manage such different functions can be a major cost of vertical integration. The tendency to apply the same managerial style (e.g. organizational structure, controls, incentives, and budgeting guidelines) to all functions in the vertical chain introduces a serious risk for the integrated firm. (Porter 1980, 314)

Following Porter’s (1980) footsteps, Harrigan (1984) also summarizes the advantages and disadvantages associated with vertical integration. Harrigan (1984) divides the advantages into internal and competitive benefits, and disadvantages into internal costs and competitive dangers. Internal benefits include (1) *integration economies* that "*reduce costs by eliminating steps, reducing duplicate overhead, and cutting costs (technology dependent)*", (2) *the improved coordination of activities* that "*reduces inventorying and other costs*", and (3) *avoiding time-consuming tasks* which can include "*price shopping, communicating design details, or negotiating contracts*". Competitive benefits include (1) *avoiding foreclosure to inputs, services, or markets*, (2) *improved marketing or technological intelligence*, (3) *opportunity to create product differentiation (increased value added)*, (4) *the superior control of firm's economic environment (market power)*, (5) *creating credibility for new products*, and (6) *synergies by coordinating vertical activities skillfully*. (Harrigan 1984, 639)

According to Harrigan (1984), the internal costs of vertical integration include (1) *need for overhead to coordinate vertical integration*, (2) *burden of excess capacity from unevenly balanced minimum efficient scale plants (technology dependent)*, and (3) *higher costs from not achieving synergies because of a poor organization of vertically integrated functions*. Competitive dangers, on the other hand, include (1) *perpetuated obsolete processes*, (2) *higher mobility or exit barriers*, (3) *link to sick adjacent businesses*, (4) *losing access to information from suppliers or distributors*, (5) *overrated synergies*, and (6) *rash decisions* by managers to integrate "*before thinking through the most appropriate way to do so*". As with Blois (1972), neither Harrigan (1984) explains these advantages or disadvantages any further in her article. (Harrigan 1984, 639)

Mahoney (1992) examines the advantages and disadvantages of vertical integration as well, specifically from the vertical financial ownership point of view. Mahoney (1992) classifies the advantages under five major categories; (1) *profit*, (2) *coordination and control*, (3) *audit and resource allocation*, (4) *motivation*, and (5) *communication*. Similarly, the disadvantages are classified into three categories; (1) *bureaucratic costs*, (2) *strategic costs*, and (3) *production costs*. (Mahoney 1992, 568-569) This classification is further explained in the following.

By the *profit* advantage Mahoney (1992, 568) means that vertical financial ownership achieves the profit incentive more effectively because it eliminates the preventative claims on profits between separate firms. This is comparable to Porter's (1980) economies of integration and especially the economies of avoiding the market.

As the second advantage, Mahoney (1992) mentions the *coordination and control*. According to Dow (1987 cited in Mahoney 1992, 568), the integrated firm has a better control of opportunistic behavior of different functions due to the authority relationship. Managers of different functions can be required to cooperate in an adaptive way and promotions and other incentives can be adjusted accordingly. In addition, as Williamson (1971) already suggested, conflicts can be resolved more effectively internally rather than through litigation between independent firms. (Mahoney 1992, 568)

The third category, *audit and resource allocation*, relates to the fact that the auditing powers of the integrated firm are superior to contracting parties (Williamson 1975 cited in Mahoney 1992, 568). A firm has the legal right to audit all its functions but has no right to audit outside units (i.e. other firms). Therefore, integrated firms have superior information upon which they can make decisions and this improved information enables more effective allocation of resources to different tasks and functions. (Mahoney 1992, 568-569)

By *motivation* advantages Mahoney (1992, 569) means that the integrated firm has the advantage over contracting parties in developing trust and communal spirit. According to Ouchi (1980 cited in Mahoney 1992, 569), particularly successful organizations achieve a certain sense of human solidarity and these clan-like emotions can have positive effects on productivity. For example, institutional and personal trust relations, as well as justice and the due process, develop in internal labor markets (Doeringer and Piore 1971 cited in Mahoney 1992, 569), and thus, decrease behavioral uncertainty and increase motivation (Mahoney 1992, 569).

Finally, as the last advantage, Mahoney (1992) mentions the *communication*. According to Malmgren (1961 cited in Mahoney 1992, 569), a vertically integrated firm is able to develop an internal coding system which increases communication efficiencies and provides stability in operations. This standardization of language can be seen, for example, in accounting systems, blueprints, and other reporting systems. Furthermore, this information processing advantage complements the superior auditing capabilities mentioned earlier. (Mahoney 1992, 569)

Under the first category of disadvantages, *bureaucratic costs*, Mahoney (1992, 569) puts all the negative effects related to the increased size of a vertically integrated firm. For example, as the increased size often results in additional hierarchical levels, and thus, the increasing spans of control, vertical integration may lead to communication distortion because of serial accidental distortion and possibly even deliberate distortion to achieve divisional objectives (Cremer 1980; Williamson 1967 cited in Mahoney 1992, 569). Similarly, the lack of direct competitive pressures within the different functions may allow increasing levels of slack in the long run, and thus, reduce profitability due to increasing bureaucratic costs (Cyert & March 1963 cited in Mahoney 1992, 569). Furthermore, synergies from vertical integration may be overestimated due to a fact that different functions require different skills (Harrigan 1985b; Buzzell 1983 cited in Mahoney 1992, 569).

By the *strategic costs,* Mahoney (1992, 570) refers to the disadvantages that relate to the strategic flexibility of the integrated firm. First, vertical financial ownership may lead to a loss of access to information and tacit knowledge of outside suppliers and distributors as these relationships are severed due to the decision to integrate (Harrigan 1984 cited in Mahoney 1992, 570). Second, the integrated firm may invest in specialized assets that increase sunk costs and may lead to chronic excess capacity, and thus, low profitability (Chandler 1962; Rumelt 1974 cited in Mahoney 1992, 570). Third, vertical integration may lead to high exit barriers, and thus, decrease the strategic flexibility of the integrated firm (Harrigan 1985c cited in Mahoney 1992, 570). In fact, flexibility often conflicts with stability, and therefore, when a firm makes commitments to insure the stability of operations, it must usually give up some flexibility by increasing its dependence on certain economic demand (Kessler & Stern 1959 cited in Mahoney 1992, 570).

Finally, under the *production costs* Mahoney (1992, 570) puts the disadvantages that relate to the balance and scale of internal production. First, a vertically integrated firm must utilize a sufficient amount of the input to achieve minimum efficient scale in production or it will have a cost disadvantage against contracting firms that are able to achieve the full economies of scale (Stigler 1968 cited in Mahoney 1992, 570). As a second potential problem related to inefficiencies in internal production, vertical financial ownership of several adjacent inefficient units may lead to a capital drain which is especially damaging to smaller integrated firms (Williamson 1975 cited in Mahoney 1992, 570). Third, capacity imbalance between different functions in a vertically integrated firm may lead to higher overall production costs than incurred by competing contracting firms, and therefore, the competitive disadvantage of a vertically integrated firm will increase (Hayes & Wheelwright 1984 cited in Mahoney 1992, 570).

All the general advantages and disadvantages of vertical integration reviewed in this section are summarized and categorized by different types in Table 1. The following section will review how the previous research sees the role of vertical integration specifically in the boundary spanning context of systemic innovations.

Table 1: Summary of the general advantages and disadvantages of vertical integration

Type	Advantage	Disadvantage
Profit	• Decreased marketing expenses (Blois 1972) • Additional profit margins or the ability to charge lower prices on final products (Blois 1972) • Economies of integration (Porter 1980) • Enter a higher-return business (Porter 1980) • Integration economies (Harrigan 1984) • Avoiding time-consuming tasks (Harrigan 1984) • Synergies (Harrigan 1984) • Profit (Mahoney 1992)	• Lack of direct competitive pressures on the costs of intermediate products (Blois 1972) • Increased operating leverage (Porter 1980) • Capital investment requirements (Porter 1980) • Need for overhead to coordinate vertical integration (Harrigan 1984) • Higher costs from not achieving synergies (Harrigan 1984) • Link to sick adjacent businesses (Harrigan 1984) • Overrated synergies (Harrigan 1984) • Production costs (Mahoney 1992)
Stability and certainty	• Stability of operations (Blois 1972) • Certainty of supplies of materials and services (Blois 1972) • Assure supply and/or demand (Porter 1980)	• Disparities between productive capacities at various stages of production (Blois 1972) • Inflexibility of operations (Blois 1972) • Reduced flexibility to change partners (Porter 1980) • Maintaining balance (Porter 1980) • Foreclosure of access to supplier or consumer research and/or know-how (Porter 1980; Harrigan 1984) • Burden of excess capacity from unevenly balanced minimum efficient scale plants (Harrigan 1984; Chandler 1962; Rumelt 1974) • Perpetuated obsolete processes (Harrigan 1984)
Coordination and control	• Harmonization of interests (Williamson 1971) • Utilization of an efficient decision process (Williamson 1971) • Better control over product distribution (Blois 1972) • Tighter quality control (Blois 1972) • Prompt revision of production and distribution policies (Blois 1972) • Better inventory control (Blois 1972) • Improved coordination (Harrigan 1984) • Superior control of firm's economic environment (Harrigan 1984) • Coordination and control (Mahoney 1992) • Audit and resource allocation (Mahoney 1992)	• Extension of the management team (Blois 1972) • Differing managerial requirements (Porter 1980) • Bureaucratic costs (Mahoney 1992) o Increasing levels of slack (Cyert & March 1963) o Different functions require different skills (Harrigan 1985b; Buzzell 1983)
Technology management	• Tap into technology (Porter 1980) • Improved marketing or technological intelligence (Harrigan 1984)	
Strategy	• Offset bargaining power and input cost distortions (Porter 1980) • Enhanced ability to differentiate (Porter 1980; Harrigan 1984) • Elevate entry and mobility barriers (Porter 1980) • Defend against foreclosure (Porter 1980) • Avoiding foreclosure to inputs, services, or markets (Harrigan 1984) • Creating credibility for new products (Harrigan 1984)	• Public opinion and governmental pressure (Blois 1972) • Lack of specialization (Blois 1972) • Cost of overcoming mobility barriers (Porter 1980) • Higher overall exit barriers (Porter 1980; Harrigan 1985c) • Higher mobility or exit barriers (Harrigan 1984) • Rash decisions (Harrigan 1984) • Strategic costs (Mahoney 1992)
Motivation	• Motivation (Mahoney 1992) o Solidarity and clan-like emotions (Ouchi 1980) o Trust relations, justice and due process develop in internal labor markets (Doeringer & Piore 1971)	• Dulled incentives (Porter 1980)
Communication	• Communication (Mahoney 1992) o Internal coding system (Malmgren 1961)	• Bureaucratic costs (Mahoney 1992) o Communication distortion (Cremer 1980; Williamson 1967)

6.2 Vertical integration and systemic innovations

According to Chandler (1962), the organizational structure should be matched with the strategy in order it to be successfully implemented. Similarly, researchers have suggested that certain organizational structures facilitate certain types of innovations (e.g. Chesbrough & Teece 2002; Cooper 1998; Gopalakrishnan & Bierly 2001; Teece 1996). For example, Gopalakrishnan and Bierly (2001, 113) state that the successful implementation of a systemic innovation requires that many professionals involved with the innovation work together by combining their knowledge base. Furthermore, in order to facilitate the integration of the different knowledge areas, a complete open exchange of information is needed (Gopalakrishnan & Bierly 2001, 113). This kind of open exchange of information can be achieved either by vertically integrated structures or by strategic alliances between trusting partners.

Many researchers have stated that vertical integration, in particular, facilitates the development and implementation of systemic innovations (e.g. Armour & Teece 1980; Langlois & Robertson 1989; Langlois 1992; Teece 1996; Gopalakrishnan & Bierly 2001). For example, Armour and Teece (1980, 471) argue that if the innovation at one stage involves adaptation or adjustment in a preceding or a subsequent stage, then the common ownership of the various stages, i.e. vertical integration, enables the necessary adaptations and adjustments to be made in a timely and efficient fashion. Similarly, Langlois and Robertson (1989) and Langlois (1992) propose that vertical integration is the most appropriate organizational structure for integrative systemic process innovations because the necessary learning and experience proceed faster between functions in a vertically integrated environment. Furthermore, Teece (1996, 205) explains that vertical integration enables the successful development and implementation of systemic innovations by facilitating information flows and coordination, and removing institutional barriers such as cost and benefit allocation and specialized investments between different actors. Similarly, Gopalakrishnan and Bierly (2001, 113) point out that open exchange of information is easier and safer in-house than between different organizations because each firm wants to gain more from the innovation and is, therefore, unwilling to share information freely.

Teece (1996, 219), however, adds that while systemic innovations favor vertically integrated structures from the coordination point of view, some relevant technological or other capabilities needed in the development and implementation of the innovation may exist outside of the vertically integrated firm. In this case, the alliances are the best arrangement. With an alliance network, the overall coordination is, however, still needed. Therefore, larger firms may still have an advantage by using their scale to create sufficient momentum and attract smaller firms to get involved with the innovation, or simply by being able to secure minority investment positions in smaller firms that have the necessary capabilities needed in the innovation. As an example, when Toyota successfully implemented the *kanban* production system, which was a truly systemic process innovation, a huge amount of coordination was required with its vast network of suppliers. Besides being much larger in size than any of its supplier, Toyota was at the same time the largest single customer of all its suppliers. By using this dominant position, Toyota could force its suppliers to make adjustments accordingly without exposing itself to a hold-up situation. (Teece 1996, 219-220) Summarizing the discussion above, the framework of matching organization to the type of innovation, according to Chesbrough and Teece (2002, 132), is illustrated in Figure 9.

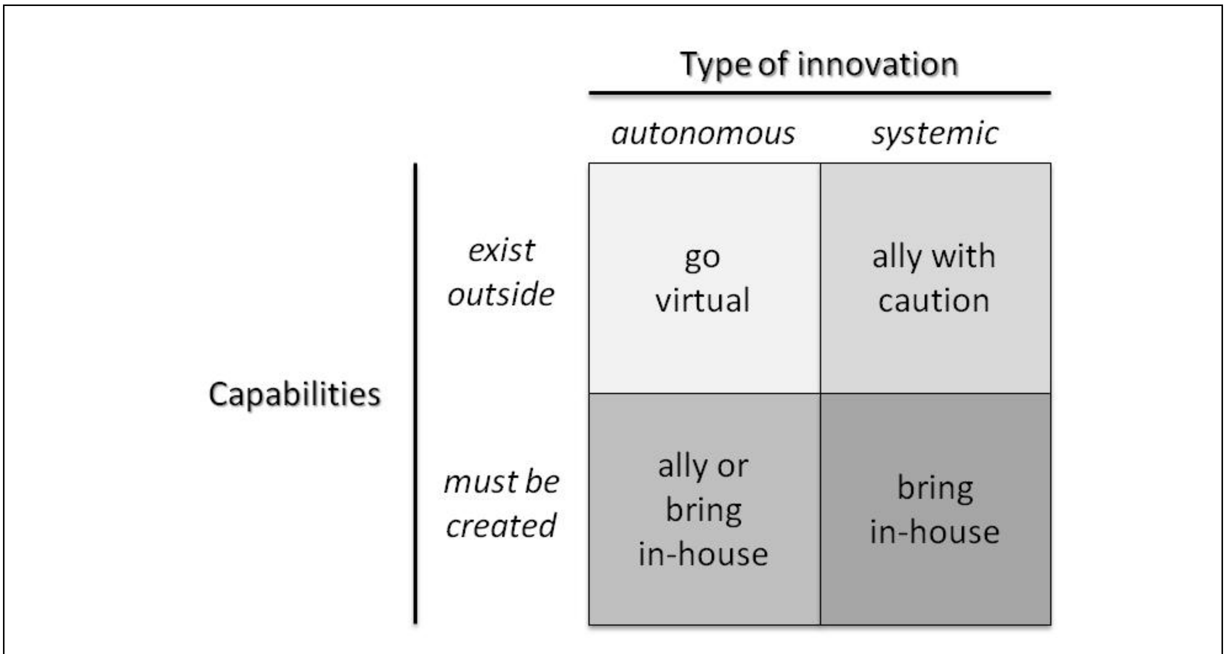

Figure 9: Matching organization to the type of innovation (Chesbrough & Teece 2002, 132)

The superiority of vertical integration in facilitating the implementation of systemic innovations is, however, based on mainly theoretical conclusions and the empirical evidence supporting this view is quite limited. Some researchers have, in fact, come up with contradictory arguments (e.g. De Laat 1999; Maula et al. 2006). De Laat (1999, 175), for example, introduces a strong argument when pointing out that most systemic innovations are just too complex and large for any vertically integrated firm to manage alone, and therefore, only alliance networks can manage systemic innovations successfully. This is especially true with systemic process innovations that cross many organizational boundaries. Similarly, Maula et al. (2006)

argue that as systemic innovations make firms increasingly dependent on each other, the innovation processes become more and more collaborative processes, and therefore, open innovation models are called for in managing systemic innovations.[1]

The advantages and disadvantages of vertical integration in the context of systemic innovations are summarized and categorized in Table 2. In the following section, it will be clarified what the role of vertical integration is in the complex and fragmented context of the construction industry.

Table 2: Summary of the advantages and disadvantages of vertical integration in the context of systemic innovations

Type	Advantage	Disadvantage
Coordination and control	• Ability to make adaptations and adjustments in a timely and efficient fashion (Armour & Teece 1980) • Facilitates coordination (Teece 1996) • Removes institutional barriers (Teece 1996)	• Too complex and large to manage alone (De Laat 1999)
Learning and experience	• Learning and experience proceed faster between functions (Langlois & Robertson 1989; Langlois 1992)	• Relevant technological or other capabilities may exist outside (Teece 1996)
Communication	• Facilitates information flows (Teece 1996) • Easier and safer exchange of information (Gopalakrishnan & Bierly 2001)	

6.3 Vertical integration in the construction industry

As already stated in Section 2.3, the construction industry is a highly fragmented industry where vertically integrated firms in a full degree cannot exist. Whereas vertical integration between different functions has been identified by many industries as an important source of competitive advantage over the years, only few studies have examined the phenomenon in the context of the construction industry (Fergusson 1993, 19). Yet, some degree of vertical integration exists for various reasons in the construction industry.

According to Krippaehne et al. (1992), construction companies usually integrate vertically in some degree as a result of strategic planning or special circumstances. Some examples of forward integration for a construction company could be *performing land-development services*, *providing design capability*, *owning and leasing commercial office and retail space*, or *offering property management services*. Similarly, the examples of backward integration could be

[1] The concept of open innovation was first introduced by Chesbrough (2003).

purchasing a plumbing company to use in operations, *owning a lumber yard to use for supplying construction materials*, *using an in-house crew to do concrete work*, or *acquiring a concrete ready-mix company to supply concrete*. (Krippaehne et al. 1992, 160)

The key reasons for construction companies to integrate vertically are, according to Krippaehne et al. (1992), (1) *to internalize the mark-up*, (2) *to improve project control*, (3) *to control supply and/or distribution channels*, and (4) *to satisfy bonding requirements*. First, by integrating certain functions the construction company can increase its share of the *mark-up* (i.e. profit margin) that would otherwise go to subcontractors or other firms participating in a project (Hammond 1984 cited in Krippaehne et al. 1992). Second, vertical integration can improve the overall *project control* by gaining the control over critical project elements such as the schedule, costs and product quality (Usdiken et al. 1988 cited in Krippaehne et al. 1992). Third, construction companies may integrate vertically to control important *supply and distribution channels*. For example, a highway contractor may purchase an asphalt plant (Friedman 1984 cited in Krippaehne et al. 1992) or a construction company may do land development to create their own market for work (Marton 1988 cited in Krippaehne et al. 1992). Finally fourth, banks and sureties may require construction companies to have a certain level of in-house expertise before *bonding* (i.e. financing) is granted (Hammond 1984 cited in Krippaehne et al. 1992). (Krippaehne et al. 1992, 162-163)

Furthermore, Krippaehne et al. (1992) specify the advantages and disadvantages of vertical integration that are specific to the construction industry. These advantages are (1) *obtaining new management talent*, (2) *improving the cost control*, (3) *influencing the demand for constructed products*, (4) *improving the economies of scale*, (5) *achieving synergies from combining inputs*, (6) *influencing the supply of construction inputs*, (7) *reducing the uncertainty over availability or cost of future supplies*, and (8) *differentiating a company from competition*. The disadvantages, on the other hand, are (1) *increased business risk from the extended operations*, (2) *increased risk from the requirement of new managerial expertise*, (3) *upsetting the existing supplier/customer relationships*, (4) *decreased strategic flexibility*, and (5) *increased fixed costs which may create cash flow problems*. (Friedman 1984 cited in Krippaehne et al. 1992, 164-165)

In addition, Krippaehne et al. (1992) emphasize that vertical integration may prevent an integrated firm from perceiving technological advances in the market. As new technology utilization is extremely important in the highly competitive construction industry, managers in the integrated firms should monitor the technical environment carefully. Taper integration (see Section 2.1) can solve this problem as part of the needs is filled by outside firms who can bring new ideas and technology into the operations of the integrated firm. (Krippaehne et al. 1992, 163)

Winch (1987; 1989a) has also considered the benefits of vertical integration in the construction industry. According to Winch (1989a), especially the transaction interfaces between the designer and main contractor, and between the main contractor and specialist subcontractor would benefit from vertical integration. These benefits include (1) *the possibility to transfer the organization and expertise from one project to another*, (2) *the facilitation of feedback loops from the construction to the design process when technical problems are encountered*, (3) *reducing the response times when natural uncertainties are met*, and (4) *reducing organizational uncertainty as an established project organization could be transferred from one project to another*. Winch (1989b cited in 1989a) also argues that it is not possible to effectively implement CAD/CAM technology within the present structure of market governance in the construction industry because of the levels of integration the technology requires. Furthermore, vertical integration would reduce the management overheads by economizing on market transaction costs such as the costs of preparing bills of quantities and other contract documents, multiple estimating efforts by subcontractors, external arbitration in disputes, and multiple contract management efforts by different disciplines. (Winch 1987, 972; 1989a, 341-342)

The main reason for construction companies not to integrate vertically is, according to Winch (1987; 1989a), the emphasis on flexibility because of the high level of uncertainty within the industry. Firms in the construction industry want to maximize their flexibility and minimize the fixed assets in order to pass the costs of uncertainty on to others. This strategy, however, has some serious negative implications to project productivity and technological change. (Winch 1987, 973; 1989a, 342)

Thus, there have been some signs of increasing vertical integration within the construction industry in recent years. For example, Cacciatori and Jacobides (2005, 1868) have studied vertical re-integration within the construction industry in the UK and determine the major trends favoring the vertical integration which are (1) *clients have limited expertise in building procurement and want turnkey solutions*, (2) *customers focus on buildability, responsiveness, and the total cost, or other systemic properties (integration of services and buildings)*, (3) *emphasis on business solution as opposed to procedural accountability promotes integrated services*, (4) *increasing view of buildings as part of a system*, (5) *the deinstitutionalization of professions makes previous limitations disappear and facilitates institutional innovation and changes in the vertical organization*, and (6) *governments recognize systemic limitations and problems with current capability structures and help provide the institutional background for new integrated solutions*. These trends may facilitate the industry transformation towards vertical integration even further in the future.

The advantages and disadvantages of vertical integration in the context of the construction industry are summarized and categorized in Table 3. Next, in order to gain more understanding about the role of vertical integration when implementing systemic process innovations, the essential issues in the implementation will be reviewed in the following Chapter 7.

Table 3: Summary of the advantages and disadvantages of vertical integration in the context of the construction industry

Type	Advantage	Disadvantage
Profit	• Internalizing the mark-up (Krippaehne et al. 1992) • Satisfying bonding requirements (Krippaehne et al. 1992) • Improving cost control (Friedman 1984) • Improving the economies of scale (Friedman 1984) • Achieving synergies from combining inputs (Friedman 1984) • Reducing the management overheads (Winch 1987; 1989a)	• Increased business risk from the extended operations (Friedman 1984) • Increased fixed costs which may create cash flow problems (Friedman 1984) • Increased fixed costs (Winch 1987; 1989a)
Stability and certainty	• Reducing the uncertainty over availability or cost of future supplies (Friedman 1984) • Reducing organizational uncertainty (Winch 1987; 1989a)	• Upsetting the existing supplier/customer relationships (Friedman 1984) • Reduced flexibility (Winch 1987; 1989a)
Coordination and control	• Improving project control (Krippaehne et al. 1992) • Controlling supply and/or distribution channels (Krippaehne et al. 1992) • Influencing the demand for constructed products (Friedman 1984) • Influencing the supply of construction inputs (Friedman 1984) • Reducing the response times when natural uncertainties are met (Winch 1987; 1989a)	• Increased risk from the requirement of new managerial expertise (Friedman 1984)
Learning and experience	• Obtaining new management talent (Friedman 1984) • Possibility to transfer the organization and expertise from one project to another (Winch 1987; 1989a) • Facilitation of feedback loops (Winch 1987; 1989a)	• May prevent from perceiving technological advances in the market (Krippaehne et al. 1992)
Technology management	• More effective implementation of technology that requires integration (Winch 1989b)	
Strategy	• Differentiating a company from competition (Friedman 1984)	• Decreased strategic flexibility (Friedman 1984)

7 Implementation of systemic process innovations

The implementation of innovations is always challenging but it is especially challenging in the case of systemic process innovations such as BIM in the construction industry. The purpose of this chapter is to review the relevant and important issues relating to the implementation of systemic process innovations. As the references of systemic process innovations as such are scarce in the literature, the frameworks and issues presented in this chapter are gathered more widely keeping in mind that they could be applicable in the case of a systemic process innovation as well. The overall focus is not in the actual process of the implementation but rather in more general success factors of the implementation that possibly relate to the organizational ownership structure and the advantages and disadvantages of vertical integration reviewed in Chapter 6. First, the general success factors in implementing organizational and operational change will be reviewed (Section 7.1). Second, as BIM and many systemic process innovations are examples of collaboration technologies, the implementation factors of collaboration technologies will be reviewed (Section 7.2). Finally, it will be reviewed what is known about implementing systemic process innovations in the context of the construction industry (Section 7.3).

7.1 Implementing organizational and operational change

Implementing systemic process innovations most definitely means some kind of an organizational and operational change. Change management literature is full of different frameworks and factors for the successful implementation of an organizational change (e.g. Nadler 1981; Kotter 1996; Salminen 2000). Nadler (1981), for example, highlights three basic problems which need to be addressed when implementing organizational change; (1) *resistance*, (2) *control*, and (3) *power*. These problems further lead to general implications for change management; (1) *need to motivate change*, (2) *need to manage the transition*, and (3) *need to shape the political dynamics of change*. The need to motivate change involves overcoming the emerging natural *resistance* to change and getting people to act according to both the short-run goals of change and the long-run goals of organizational strategy. Next, the need to manage the transition means that organizational arrangements – such as resources, plans, and management structures – need to be designed and used in a way that *control* is maintained during and after the transition. Finally, the need to shape the political dynamics of change relates to the importance of ensuring that different *power groups* support the change. (Nadler

1981, 197-200) Table 4 presents these problems, their implications, and some more specific action steps related to each implication.

Table 4: Problems, implications and related action steps for change management (Nadler 1981)

Problem	Implication	Action steps
Resistance	**Need to motivate change**	• Identify and surface dissatisfaction with the present state • Participation in change • Rewards for behavior in support of change • Time and opportunity to disengage from the present state
Control	**Need to manage the transition**	• Develop and communicate a clear image of the future • Use multiple and consistent leverage points • Develop organizational arrangements for the transition o A transition manager o Resources for the transition o Transition plan o Transition management structures • Build in feedback mechanisms
Power	**Need to shape the political dynamics of change**	• Assure the support of key power groups • Use leader behavior to generate energy in support of change • Use symbols and language • Build in stability

Similarly, Salminen (2000) has thoroughly summarized the general success factors of change management which are (1) *leadership*, (2) *management support*, (3) *need for change*, (4) *participation*, (5) *defining roles*, (6) *planning*, (7) *goal setting*, (8) *control*, (9) *training*, (10) *communication*, and (11) *motivation*. These success factors are derived and combined broadly from organizational change theories, operational change theories, and project management theories. (Salminen 2000, 89-98)

Salminen (2000) emphasizes that the success factors are present throughout the whole change project and are not specific phases of the change project life cycle. The difference between phases and success factors is that phases are things to be done following each other usually in a linear sequence, whereas success factors are more general and important throughout the change project. In addition, the change agent or project manager may not be able to directly influence the success factors, whereas influencing the execution of phases is more straightforward. As an example, communicating the vision could be one of the phases in a change project, whereas effective communication throughout the project would be an example of a success factor. (Salminen 2000, 93) Further definitions of these success factors, along with some examples of good performance, are presented in Table 5.

Table 5: Potential success factors of change management (Salminen 2000, 97)

Success factor	Definition	Examples of good performance
Leadership	The behavior and actions of the person or persons leading the change	Active and enthusiastic leader, who believes in the importance of the change, shows the way and motivates others through his/her own behavior
Management support	The role and actions of managers who have authority over issues and resources critical for the project	Top executive(s) believe in the importance of changes and communicate this belief through their behavior, champion the change project, ensure that all the necessary resources are allocated and actions taken
Need for change	Identifying and communicating the reasons for the change	Problems or opportunities requiring the changes are demonstrated clearly through the analysis and practical examples and a shared feeling of necessity of changes is created
Participation	Involving those affected by the changes in planning and implementation	People on all levels and in all parts of the organization have an opportunity to actually affect the solutions implemented
Defining roles	Defining roles and organization during the change process	Responsibilities and authorities in the change process are clearly defined, the change project organization facilitates participation and effective control, everyone knows what his/her role is during the change
Planning	Planning the change process in terms of what is to be done by whom and when	The change is planned as a project with a well-detailed work breakdown structure, resource allocation, schedule and budget, but the design of the actual solutions is to some extent left for the participatory development process and the plans are modified as needed
Goal setting	Defining a vision and goals for the change	The change effort has a clear and shared overall vision of the future state to be accomplished, as well as measurable performance goals
Control	Monitoring and controlling the progress	The execution of the plans is systematically monitored and performance of those implementing the changes coordinated and controlled to ensure effective and efficient implementations of the changes
Training	Training and educating the people	All people receive sufficient training in both implementing the changes and the new operating procedures to be implemented; the training is practical and timely
Communication	Distributing information about the changes and gathering feedback from the people	All issues related to the changes are communicated through multiple channels to everyone in the organization throughout the change effort, discussion is open and free and information flows in all directions of the organization
Motivation	Getting people motivated and committed to changes through active motivational efforts	Those in charge of the changes ensure the commitment of people through making the goals desirable and the process credible and actively promoting the importance of the changes in all possible occasions

Next, as BIM and many systemic process innovations are collaboration technologies in nature, the specific implementation factors of collaboration technologies will be reviewed in the following section.

7.2 Implementing collaboration technologies

Over the years, the focus of ICT has gradually shifted from being a source of efficiency through automation to promoting different kinds of collaboration between people and organizations. In addition to most of the information systems and applications, BIM technologies can be seen as the examples of collaboration technologies as they are used to exchange project information and promote collaborative work between different participants in a building project. Similarly other way round, collaboration technologies are usually systemic process innovations. Munkvold (2003, 3) defines collaboration technologies as "*all types of information and communication technologies that enable collaboration at various levels, from two persons co-authoring a document to interorganizational collaboration where several companies are engaged in common tasks*". As the real-life examples of collaboration technologies, Munkvold (2003, 3) mentions video and desktop conferencing, knowledge repositories, workflow management systems, online meeting schedulers, and electronic meeting support systems.

Furthermore, Munkvold (2003, 63-77) introduces a taxonomy of implementation factors for collaboration technologies which includes four categories; (1) *the organizational context*, (2) *the implementation project*, (3) *the technology factors*, and (4) *the implementation process* (see Figure 10). The factors related to the *organizational context* characterize the context in which the implementation occurs. This includes both the factors related to the external environment of the organization such as characteristics of the industry and relations to other parties (e.g. vendors, partners, customers), and the factors related to the internal characteristics of the organization such as culture, previous experience with collaboration, and ICT competence. The *implementation project* factors relate to how the implementation project is organized and executed, for example how the user training is organized or how the support infrastructure is established. The *technology factors* relate to the actual technology characteristics and these factors can be divided into two sub-categories; the factors that are more or less general for all collaboration technologies and the factors that are specific to certain technologies. The *implementation process* includes factors that characterize the nature of the implementation process such as the time frame of the implementation and the approach of the change process (e.g. top-down or bottom-up). As illustrated in Figure 10, these four factors are interconnected in a way that the organizational context frames the background and the purpose of the implementation project which in turn frames the technology and its implementation. Finally, all categories together frame the nature of the implementation process. (Munkvold 2003, 64-65) In the following, each of these categories is further explained with some illustrative examples of possible effects on implementation.

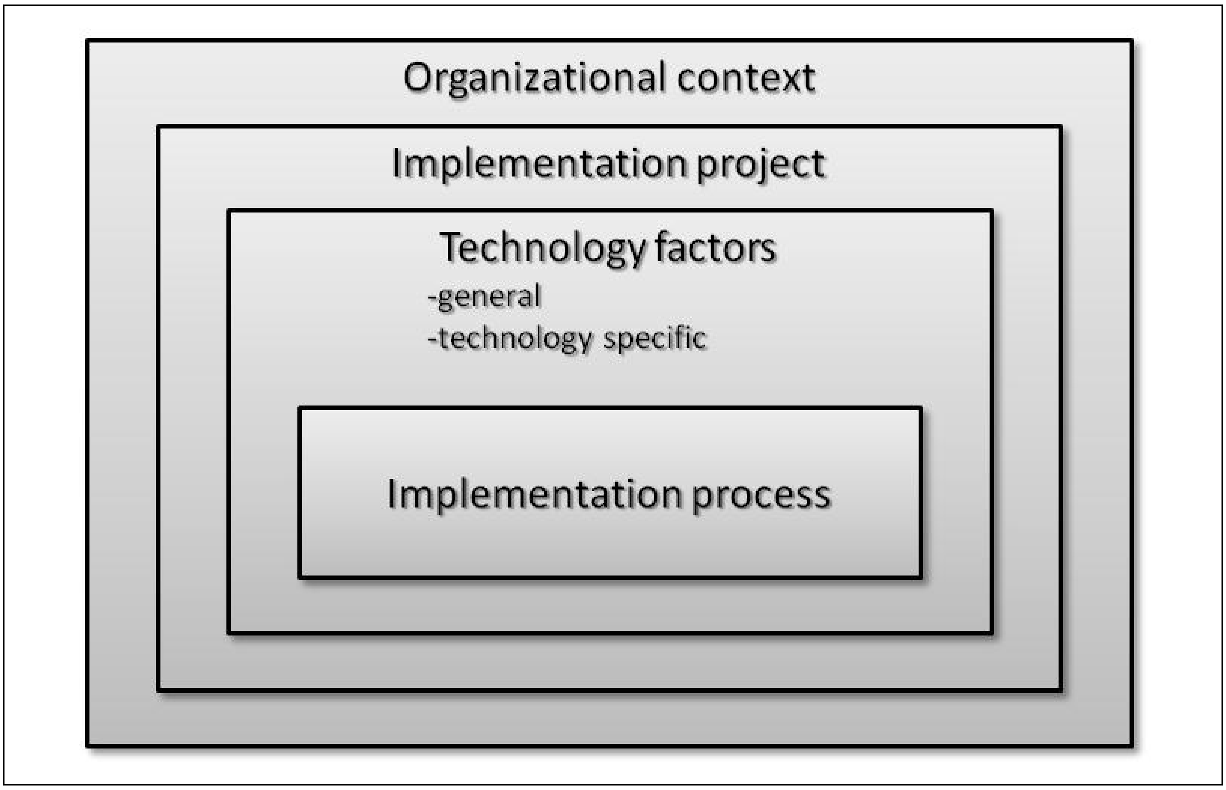

Figure 10: The categories of factors influencing implementation of collaboration technologies (Munkvold 2003, 64)

According to Munkvold (2003, 65-66), the organizational ability to adopt and use collaboration technologies is dependent on factors at several different levels which are (1) *the existing degree of collaborative work practices in the organization*, (2) *users' felt need for technology support*, (3) *individualistic versus collaborative culture*, (4) *reward systems and policy*, (5) *top management support*, (6) *management style*, (7) *existing IT infrastructure*, (8) *existing IT competence*, and (9) *economic conditions*.

In addition to these factors, Munkvold (2003, 65) brings out the influence of the external relations on implementation, and reminds that the external relations to customers, industry partners, vendors, and other third parties may play an important promoting role in the implementation project. The external relations are not, however, included as a factor in the taxonomy of implementation factors for some reason. The implementation factors related to the organizational context are presented in Table 6 along with some illustrative possible effects on implementation.

Table 6: Implementation factors related to the organizational context (Munkvold 2003, 66)

Factors	Possible effects on implementation
Existing degree of collaborative work practices in the organization	Existing collaborative work practices may have a positive effect on the users' receptivity for collaboration technology
Users' felt need for technology support	A felt need among the users has a clear positive effect on adoption of the technology
Individualistic versus collaborative culture	Organizations with a highly individualistic and competitive culture may face greater challenges in adoption of collaboration technologies than organizations already focusing on collaboration
Reward systems and policy	These structural elements are important means for stimulating collaboration and related use of collaboration technology in the company
Top management support	Top management support is important for providing organizational "legitimacy" to the implementation and for gaining access to adequate resources
Management style	Management style can impact the implementation and use of collaboration technology. However, collaboration technology can be adopted to serve different styles, and does not automatically support more collaborative and decentralized/democratic approaches
Existing IT infrastructure	Collaboration technologies require a basic IT infrastructure. The implementation project needs to take into account any necessary upgrades in this infrastructure
Existing IT competence	Lack of internal IT competence in the organization may be a barrier to effective implementation. On a short range, vendors and consultants can provide this, but the organization needs to build internal competence for future maintenance and support
Economic conditions	Economic conditions such as recession in national economy and fluctuations in market conjunctures may impact the implementation in different ways. For example, it may result in budget cuts for the implementation, or it may lead to increasing focus on how to make organizational practices more effective through collaboration technology

The implementation factors related to the implementation project, according to Munkvold (2003, 67-68), are (1) *formalized implementation strategy versus improvisation*, (2) *the composition of implementation team*, (3) *information to the users*, (4) *users' expectations*, (5) *the composition of pilot groups*, (6) *user training*, (7) *establishing a supportive infrastructure*, (8) *project champion(s)*, (9) *incentives for stimulating user adoption*, and (10) *predefined routines versus user experimentation*. Munkvold (2003, 67) especially highlights the importance of maintaining the balance between formal and informal approaches, and the importance of one or more project champions with charisma. The factors related to the implementation project are presented in Table 7 with some examples of possible effects on implementation.

Table 7: Implementation factors related to the implementation project (Munkvold 2003, 68)

Factors	Possible effects on implementation
Formalized implementation strategy versus improvisation	A formalized implementation strategy has a positive effect on project management, including scheduling, resource allocation and coordination. However, experience shows that some room for improvisation is needed
Composition of implementation team	An implementation team with a right blend of technical competence and business understanding creates the required "socio-technical balance" needed for successful implementation
Information to the users	The information provided to the users has an important bearing on their perceptions (mental models) of the collaboration technology and its potential
Users' expectations	Realistic expectations towards the new technology are important to avoid any frustration and disappointment among the users. Potential benefits of the technology should be communicated to the users, but without "overselling" it
Composition of pilot groups	Pilot groups without a real need for technology support may fail to document the potential benefits. The members of the pilot groups should be selected on the basis of their need for collaborative IT support
User training	Lack of adequate training is a recurring factor in implementation failure. The training needs to include an explicit focus on collaborative aspects
Establishing a supportive infrastructure	Some form of support infrastructure is important to handle problems early and thus avoid user frustration
Project champion(s)	Access to one or more project champions has proven instrumental to implementation success
Incentives for stimulating user adoption	Establishing clear incentives may stimulate adoption of the technology. This could be in the form of improved working conditions for the individual employees, and/or bonus schemes for increased productivity
Predefined routines versus user experimentation	Clear guidelines and routines may increase the effect of the technology. This should be balanced against giving the users room to experiment with the technology, to come up with new and creative applications

The category of technology factors includes all factors related to characteristics of the technology. The general technology-related factors are, according to Munkvold (2003, 69-70), (1) *critical mass*, (2) *disparity in work and benefit*, (3) *the disruption of social processes*, (4) *exception handling*, (5) *unobtrusive accessibility*, (6) *IT maturity*, (7) *compatibility with existing* *technologies*, (8) *compatibility with existing routines*, and (9) *the fragile nature of collaboration technologies*. Munkvold (2003, 69) emphasizes that the degree to which these factors influence the implementation depends on the organizational context and may vary for the different types of technologies. Munkvold (2003, 70-75) also gives specific factors related to different types of actual collaboration technologies but they are not presented here as these technologies are not in the focus of this study. The general factors related to the collaboration technology are presented in Table 8 with some examples of possible effects on implementation.

Table 8: Implementation factors related to the collaboration technology (Munkvold 2003, 70)

Factors	Possible effects on implementation
Critical mass	Establishing a critical mass of users is crucial for collaboration technologies where the users' benefits are dependent on universal adoption
Disparity in work and benefit	Perceived disparity in extra workload and benefit induced from the technology may represent a barrier to user adoption
Disruption of social processes	Technologies that represent disturbances to the often tacit social processes risk facing user resistance
Exception handling	Exceptions to the formal routines occur frequently in the day-to-day work practices. Some flexibility should be built into the systems, to accommodate for these exceptions
Unobtrusive accessibility	Some collaborative tools are not used as frequently as other office support tools. By offering seamless integration with the user's standard work tools, the collaboration tools also accommodate more infrequent use
IT maturity	Immature technology can create problems with stability and performance of the solution, resulting in project delays and distrust among the users
Compatibility with existing technologies	Technical incompatibility can result in project delays and frustrated users
Compatibility with existing routines	Compatibility with existing routines means less "friction" in user adoption. However, some implementations will aim at changing these routines
Fragile nature of collaboration technologies	In case of problems with a new collaboration technology, users may easily abandon this in favor of existing, substitute technologies more familiar to them

Finally, Munkvold (2003, 75-76) identifies factors that relate to the implementation process which are (1) *top-down versus bottom-up approach*, (2) *social influence mechanisms*, (3) *implementation barriers resulting from conflict between organizational context and technology characteristics*, and (4) *user learning and adaptation*. Munkvold (2003, 75-76) especially highlights the importance of finding the right balance between the top-down and the bottom-up approach. The implementation factors related to the implementation process are presented in Table 9 with some examples of possible effects on implementation.

Table 9: Implementation factors related to the implementation process (Munkvold 2003, 76)

Factors	Possible effects on implementation
Top-down versus bottom-up approach	A top-down implementation approach may ensure a coordinated process guided by an overall vision, but may face user resistance due to a lack of adaptation to local needs and practices. A bottom-up approach may result in greater “buy in” from the users, but may lack coordination and strategic vision. When possible, a “combined approach” is recommended, stimulating bottom up adoption guided by strategic vision and central coordination
Social influence mechanisms	Social influence mechanisms such as peer pressure and “word of mouth” can be more influential on user adoption of a new technology than any planned approach. The implementation team should try to capitalize on this through appointing super users and “technology ambassadors” in the organization
Implementation barriers resulting from conflict between organizational context and technology characteristics	Most implementation projects encounter unforeseen barriers threatening the project. The implementation team must deal with these as early as possible, and try to eliminate any misfit between technology and organizational context
User learning and adaptation	Users generally are able to adapt to changing work practices and use of new collaboration technology. However, this is a gradual learning process that may take long

The taxonomy by Munkvold (2003) presented above categorizes and classifies the many different factors that influence the organizational implementation of collaboration technologies. Many of these general factors can be found in IT implementation literature of different kind. Munkvold (2003, 76), thus, points out that the implementation of collaboration technologies can be seen as a variant of the broader topic of IT implementation.

In order to gain more understanding on implementing BIM as a systemic process innovation in the context of the construction industry, the following section concentrates on reviewing the essential frameworks available for implementing BIM and other systemic innovations in the construction industry.

7.3 Implementing systemic innovations in the construction industry

The project-based nature of the construction industry adds another layer of complexity to the implementation of systemic process innovations. According to Winch (1998), innovations in the construction industry are not implemented within the firms themselves but on the actual construction projects. Furthermore, as these projects are highly collaborative in nature, almost all innovations in the construction industry have to be negotiated with other actors within the project, making them more or less systemic in nature. In addition to the innovations adopted by firms and implemented in projects, the construction projects themselves offer another source for innovations through problem-solving on projects. In order for problem-solving to become an innovation, the experiences must be learned within a firm and applied to future projects. Thus, innovations in the construction industry can be either adopted by firms and implemented in projects, or they can result from problem-solving in projects and be learned by firms (illustrated in Figure 11). (Winch 1998, 273)

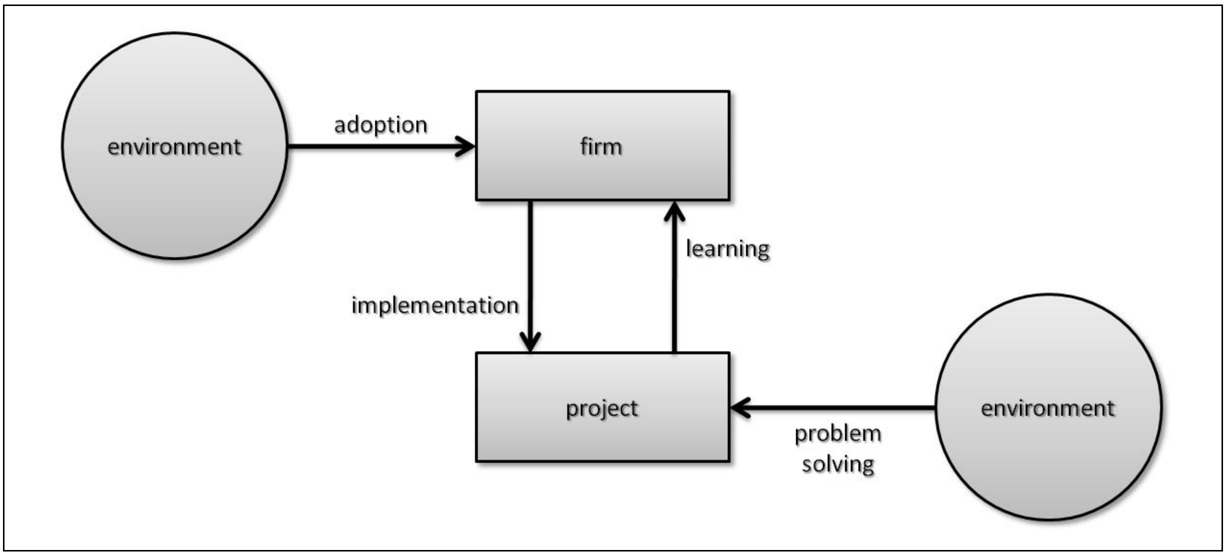

Figure 11: Innovation processes in the construction industry (Winch 1998, 273)

Even though Winch (1998) have suggested that almost all innovations in the construction industry are more or less systemic in nature, the actual references of implementing systemic innovations in the construction industry are scarce in the literature. Nevertheless, Taylor and Levitt (2004) have studied the rate of diffusion of both systemic process and product innovations in the construction industry, and found four constructs that affect the successful implementation of systemic innovations. Similarly, Taylor (2007) has investigated the implementation of 3-D CAD as an example of a systemic process innovation in design and construction networks and composed a framework for successful 3-D CAD implementation. In the following, these two frameworks are reviewed in more detail.

When investigating two different cases of systemic innovation diffusion in the American construction industry, Taylor and Levitt (2004) formed a framework consisting of four constructs that affect the successful implementation of systemic innovations. The first case study was a systemic process innovation in supply chain management and the second a systemic product innovation in prefabricated wall construction. The four constructs found were (1) *organizational variety*, (2) *the degree of interdependence*, (3) *boundary strength*, and (4) *span* (presented in Table 10). (Taylor & Levitt 2004, 9-12)

Table 10: The four constructs affecting the implementation of systemic innovations (adapted from Taylor & Levitt 2004)

Organizational variety	Increase in the variety of project participants from project to project will decrease the rate of diffusion → Organizational variety in project participants should be reduced
Degree of interdependence	As tasks become more interdependent, the rate of diffusion will decrease → Degree of interdepence of the work should be monitored
Boundary strength	The more rigid the boundary between project participants, the more the rate of diffusion will decrease → Boundary strength between project participants should be reduced
Span	The larger number of boundaries between project participants is spanned, the more the rate of diffusion will decrease → The span of the systemic innovation should be monitored

The first construct, *organizational variety*, refers to the change of different participants from project to project. According to Dubois and Gadde (2002, 625), for example, one and the same team very seldom works together in more than one project in the construction industry. Thus, Taylor and Levitt (2004) propose that the increase in the variety of project participants from project to project will decrease the rate of diffusion for a systemic innovation. Therefore, when implementing systemic innovations, project managers should try to reduce the organizational variety in project participants from project to project by working with the same people and organizations on several projects if possible. Later on, when new working practices and routines are established, the collaboration with other organizations can be carefully started again. (Taylor & Levitt 2004, 14)

The second construct, the *degree of interdependence*, refers to the interdependence of tasks and work in the project. Thompson (1967 cited in Taylor & Levitt 2004, 11) classified the task interdependence into three types; (1) *pooled interdependence*, (2) *sequential interdependence*, and (3) *reciprocal interdependence*. Pooled interdependence, the least interdependent type, describes tasks where the work does not flow between different units. Sequential interdependence, on the other hand, describes tasks where the output of one unit is the input of another unit. Finally, reciprocal interdependence is the most interdependent type and describes tasks where different units must work together and exchange information in order to produce outputs together. Taylor and Levitt (2004) propose that as tasks become more interdependent, the rate of diffusion for a systemic innovation will decrease. Therefore, when implementing systemic innovations, the degree of interdependence of the work should be monitored. In order to understand how a systemic innovation can be implemented during multiple projects, project managers have to know where and what kind of interdependencies of tasks exists in the project. If interdependencies are reciprocal, project managers should pay careful attention to managing the other three constructs affecting the successful implementation of systemic innovations. (Taylor & Levitt 2004, 11-14)

The third construct, *boundary strength*, refers to the rigidity of the boundaries between different project participants. According to Taylor and Levitt (2004, 12), this boundary strength arises from the existence of separate distribution channels, different labor training requirements, the jurisdictions of labor unions, scope of services of different subcontractors, different classification and coding systems, and path dependence (i.e. decision making based on past experience). Taylor and Levitt (2004) propose that the more rigid the boundary between project participants, the more the rate of diffusion for a systemic innovation will decrease. Therefore, when implementing systemic innovations, the boundary strength should be reduced between the different project participants impacted by the innovation. In order to do this, project managers should create an environment that develops mutual trust between different participants, for example by encouraging meetings and discussions between the participants or even requiring the project team members to work in the same location. (Taylor & Levitt 2004, 11-14)

Finally, the fourth construct, the *span*, refers to the number of boundaries between different project participants that are spanned by the systemic innovation. In some cases, the span can be reduced to zero by vertical integration. Taylor and Levitt (2004) propose that the larger number of boundaries between project participants is spanned, the more the rate of diffusion for a systemic innovation will decrease. Therefore, when implementing systemic innovations, the span of the systemic innovation should be monitored in order to specify how many participants are being impacted. If there are firms that integrate the work of multiple project participants, for example a MEP contractor that does mechanical, electrical, and plumbing work, then project managers should consider using them to decrease the span of the systemic innovation. (Taylor & Levitt 2004, 12-14)

Later on, when investigating the implementation of 3-D CAD in 26 design and construction organizations, Taylor (2007) composed a framework for successful 3-D CAD implementation in the construction industry. The framework highlights the importance of addressing regulative, technological, work, and organizational issues at the interorganizational interfaces between design and construction firms when implementing a systemic process innovation such as 3-D CAD. The framework is illustrated in Figure 12 and will be further explained in the following.

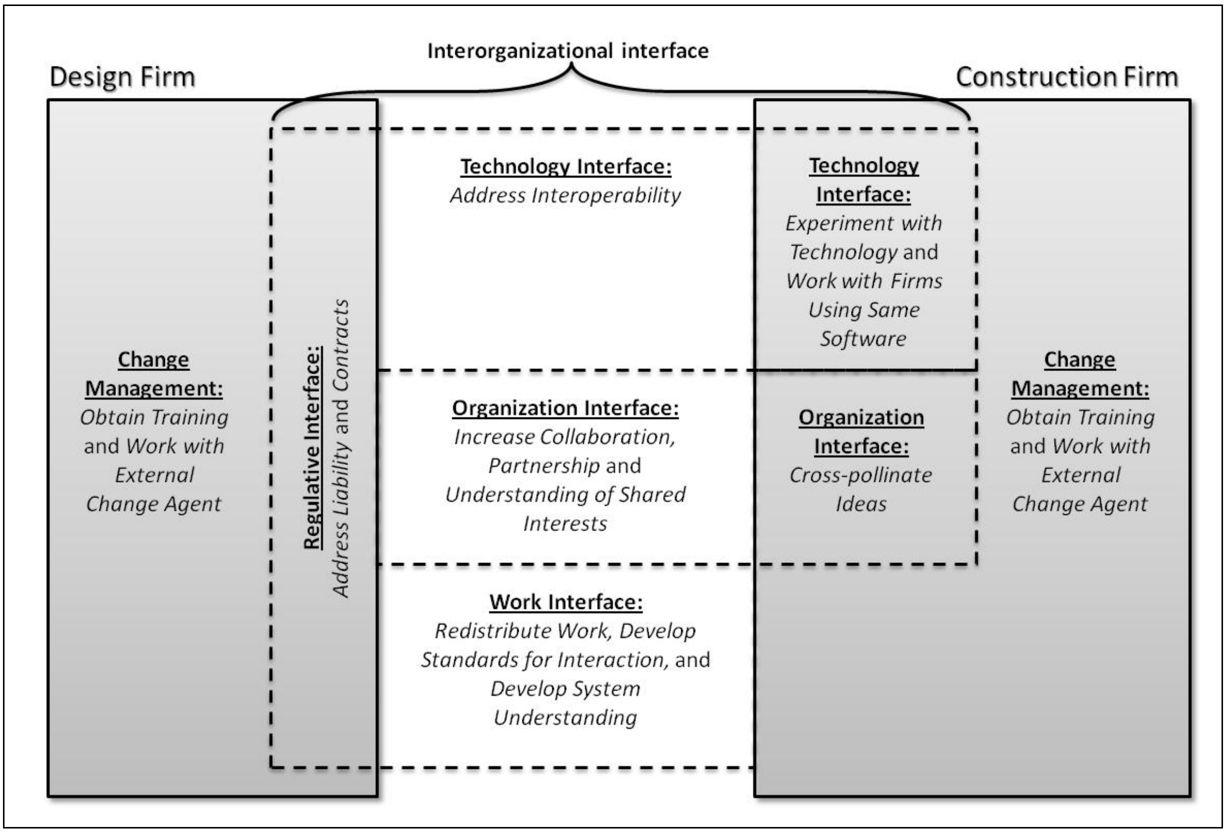

Figure 12: The framework for a successful 3-D CAD implementation in the construction industry (Taylor 2007, 1000)

The framework is divided into three parts; (1) *design firm perspective*, (2) *interorganizational interface*, and (3) *construction firm perspective*. From the design firm perspective, the key factors in the successful implementation of 3-D CAD are the *regulative interface* and the *internal change management*. One of the stated benefits of 3-D CAD over the traditional printed set of plans is more accuracy (Barron 2003 cited in Taylor 2007, 998). This, however, has its effect on the liability and contracts of designers as they become more responsible for the accuracy in the 3-D CAD models. Therefore, when implementing 3-D CAD, the issues of liability and contractual constraints need to be addressed at the regulative interface between designers and downstream contractors. The key issues in the internal change management from the design firm perspective are to obtain sufficient training and to work with an external change agent such as a larger or more experienced project participant or a national agency (e.g. Tekes in Finland). (Taylor 2007, 997-1000)

In the second part of the framework, the shared interorganizational interface, the key factors are the *technology interface*, the *organization interface*, and the *work interface*. In order to share and co-create a virtual model of the building, the 3-D CAD software must be capable of opening and editing the model in all participating firms. Therefore, when implementing 3-D CAD, firms need to address the interoperability of technology at the interorganizational technology interface. The key issues in the organization interface are to increase collaboration between firms, to develop partnerships between firms, and to understand shared interests among firms. According to Taylor (2007), networks that increase collaboration between firms are more effective in implementing 3-D CAD across organizations. Similarly, networks that develop deeper partnerships and work with the same firms from project to project are able to strengthen interorganizational learning associated with the new technology. Moreover, understanding the shared interests is important as if firms do not consider the interests of others the implementation can be counterproductive to the other due to interdependencies in the work. The key issues in the work interface are to redistribute work among firms, to develop standards for interaction, and to develop system understanding of the project. 3-D CAD tools change the pattern of work between different project participants, and thus, the work need to be mutually redistributed. In order for it to work, new standards for interaction need to be developed as well. Furthermore, developing holistic system understanding of the project helps the mutual adjustment of different firms. (Taylor 2007, 999-1000)

Finally, from the construction firm perspective, the key factors in the successful implementation of 3-D CAD are the *technology interface*, the *organization interface*, and the *internal change management*. The key issues in the technology interface are to experiment with technology and to work with firms using the same software. According to Taylor (2007), contractors have been described as having difficulties adopting new technologies, and thus, need enough time to experiment with the new technology in order to implement it successfully. In addition, contractors use the models from design firms as an input in their own work, and therefore, it is important to work with firms using the same software and file formats. In the organization interface the key issue is to take advantage of opportunities to cross-pollinate ideas across firms about constructability. The co-creation of a virtual model enables construction firms to articulate their knowledge of constructability issues more clearly and earlier in the project, which promotes the beneficial use of 3-D CAD, and thus, the successful implementation. Finally, similar to the design firm perspective, the key issues in the internal change management from the construction firm perspective are to obtain sufficient training and to work with an external change agent such as a more experienced project participant or a national agency. (Taylor 2007, 998)

The framework presented above describes the factors in the successful implementation of 3-D CAD in the context of interorganizational design and construction networks. Taylor (2007), however, discusses the implications of a vertically integrated context as well. Regarding to the technology interface, a single integrated firm may standardize on a specific software platform which facilitates the implementation at least from the interoperability perspective. Similarly, regarding to the regulative and work interface, the liability and contractual issues arising from the redistribution of work are easier to manage within the hierarchy. Taylor (2007) also adds that within an integrated firm, the organization and work interface is between individuals or teams that work together from project to project, which makes the required mutual adjustment in the implementation easier. (Taylor 2007, 1000-1001)

In the following Chapter 8, the literature review will be shortly summarized and further synthesized into a constructed theoretical model which will be tested later on with the empirical data in Part III. In addition, the more detailed research questions will be formed based on the constructed theoretical model and the literature review.

8 Synthesis of the literature review

In this chapter, the literature review will be shortly summarized (Section 8.1). Based on the literature review, a theoretical model will be constructed (Section 8.2) which will answer the overall research problem and later on guide the empirical research of this study. Furthermore, the overall research problem will be further defined into a more detailed research question based on the constructed theoretical model (Section 8.3).

8.1 Summary of the literature review

Advantages and disadvantages of vertical integration

Chapter 6 presented the advantages and disadvantages of vertical integration from three perspectives; in general level, in the context of systemic innovations, and in the context of the construction industry. Generally, vertical integration entails many advantages but there are also disadvantages that firms need to take into account. These advantages and disadvantages vary from industry to industry. The general advantages and disadvantages can be divided into seven types; profit, stability and certainty, coordination and control, technology management, strategy, motivation, and communication. Profit relates to economies and diseconomies of vertical integration such as decreased marketing expenses. Stability and certainty relate to the stability of operations and certainty of supply and demand that vertical integration enables. These, however, may come with a cost of inflexibility and foreclosure of access to outside knowledge. Coordination and control relate to improved coordination and better control, and on the other hand, the costs of increased bureaucracy. Technology management relates to technological issues such as improved technological intelligence. Strategy relates to the strategic costs and benefits of vertical integration such as elevating entry and mobility barriers. Motivational advantages relate to solidarity and trust, and disadvantages to dulled incentives within the integrated units. Finally, communication relates to the benefits of the internal coding system and the costs of communication distortion introduced by increased bureaucracy.

Many researchers have suggested that vertical integration facilitates the development and implementation of systemic innovations. This view is, however, based on mainly theoretical conclusions and some researchers have come up with contradictory arguments. The advantages and disadvantages of vertical integration in the context of systemic innovations can be divided into three types; coordination and control, learning and experience, and communication. Coordination and control relate to the elimination of institutional barriers and an increased ability for an integrated firm to make adaptations and adjustments in a timely and efficient fashion when implementing systemic innovations. The downside is that systemic innovations are often too complex and large to manage by a single integrated firm. Learning and experience, on the other hand, relate to the benefits of faster learning and experience accumulation between units in an integrated firm. The downside is that relevant technological or other capabilities needed in the systemic innovation may exist outside. Finally, communication benefits relate to the fact that vertical integration facilitates the information flows between integrated units as it is easier and safer to exchange information.

The construction industry is a highly fragmented project-based industry where vertically integrated firms in a full degree cannot exist. Some degree of vertical integration, however, exists in the construction industry for various reasons. The advantages and disadvantages of vertical integration in the context of the construction industry can be divided into six types; profit, stability and certainty, coordination and control, learning and experience, technology management, and strategy. Profit relates to the economies and diseconomies such as internalizing the mark-up or increased fixed costs. Stability and certainty relate to benefits such as the reduced uncertainty over the availability or cost of future supplies, or costs such as the reduced flexibility. Similarly, coordination and control relate to benefits such as the improved project control and reduced response times when natural uncertainties appear, or costs such as the increased risk from the requirement of new managerial expertise. The benefits related to learning and experience include, for example, the possibility to transfer the organization and expertise from one project to another. The downside is, however, that vertical integration may prevent the firm from perceiving technological advances in the market. From the technology management point of view, vertical integration enables the more effective implementation of technologies that require integration. Finally, strategy relates to strategic advantages such as the ability to differentiate a firm from competition, or strategic disadvantages such as the decreased strategic flexibility.

Implementation of systemic process innovations

Chapter 7 introduced the implementation of innovations from three perspectives; the general implementation of organizational change, the implementation of collaborative technologies as an example of systemic process innovations, and the implementation of systemic process innovations in the construction industry. The implementation of innovations is especially challenging when implementing systemic process innovations. Implementing systemic process innovations means implementing some kind of an organizational and operational change. When implementing organizational change, three basic problems need to be addressed; resistance, control, and power. In order to address the problem of resistance and control, one needs to motivate change and manage the transition. Similarly, in order to address the problem of power within different groups, one needs to shape the political dynamics of change to ensure that different power groups support the change. More specifically, the general success factors of change management can be specified in eleven elements; leadership, management support, need for change, participation, defining roles, planning, goal setting, control, training, communication, and motivation. These success factors are present throughout the whole change project and are not specific phases of the change project life cycle.

Systemic process innovations are often collaboration technologies. Collaboration technologies are all types of information and communication technologies that enable collaboration at various levels, from two people co-authoring a document to interorganizational collaboration where several companies are engaged in common tasks. The implementation factors for collaboration technologies can be viewed from four interrelated levels or categories; the organizational context, the implementation project, the technology factors, and the implementation process. The factors related to the organizational context characterize the context in which the implementation occurs. This includes both the factors related to the external environment of the organization such as characteristics of the industry and relations to other parties, and the factors related to the internal characteristics of the organization such as culture, previous experience with collaboration, and ICT competence. The implementation project factors relate to how the implementation project is organized and executed, for example how the user training is organized or how the support infrastructure is established. The technology factors relate to the actual technology characteristics. The implementation process includes factors that characterize the nature of the implementation process such as the time frame of the implementation and the approach of the change process.

The project-based nature of the construction industry adds another layer of complexity to the implementation of systemic process innovations. The following four constructs affect the successful implementation of systemic innovations in the construction industry; organizational variety, degree of interdependence, boundary strength, and span. Organizational variety refers to the change of different participants from project to project and it should be reduced in order to facilitate the successful implementation. The degree of interdependence refers to the interdependence of tasks in the project and it should be monitored in order to know where and what kind of interdependencies of tasks exists in the project. Boundary strength refers to the rigidity of the boundaries between project participants and it should be reduced in order to facilitate the successful implementation. Finally, the span refers to the number of boundaries between project participants that are spanned by the systemic innovation. The span should be monitored and reduced if possible.

More specifically, when implementing 3-D CAD, an example of a systemic process innovation in the construction industry similar to BIM, it is important to address regulative, technological, work, and organizational issues at the interorganizational interfaces between project participants. Vertical integration may simplify the issues at these interfaces. Regarding to technological issues, a single integrated firm may standardize on a specific software platform which facilitates the implementation from the interoperability perspective. Similarly, regarding to regulative and work issues, the liability and contractual issues arising from the redistribution of work are easier to manage within the integrated firm. Moreover, within an integrated firm, the organization and work interface is between individuals or teams that work together from project to project, which makes the required mutual adjustment in the implementation easier.

8.2 Constructed theoretical model

The overall research problem of this thesis was to find out *what are the advantages and disadvantages of vertical integration in the implementation of a systemic process innovation such as BIM in project networks of the construction industry*. In this section, a theoretical model is constructed to answer the research problem. The constructed theoretical model is derived from the literature review in Chapters 6 and 7.

The idea of the constructed theoretical model is to combine the relevant advantages and disadvantages of vertical integration with the relevant factors in the implementation of systemic process innovations that are affected by the organizational structure. Many of the advantages and disadvantages presented in Chapter 6 relate to strategic and economic issues of vertical integration which have little to do with the implementation of systemic process innovations. Similarly, many of the factors in the implementation presented in Chapter 7 have little to do with the organizational structure i.e. vertical integration. These irrelevant issues are, thus, left out from the constructed theoretical model.

In the construction of the theoretical model, the framework of the potential success factors of change management by Salminen (2000) was used as a basis because it has the most extensive combination of success factors to start with (Table 5 in Section 7.1). Next, all the relevant advantages and disadvantages from Chapter 6 were combined with the relevant implementation factors from Chapter 7 and added to the model. As a result, the theoretical model was constructed (see Table 11 on the following page).

In the final analysis, six relevant implementation factors emerged and related to all of them could be identified both advantages and disadvantages of vertical integration regarding the implementation of systemic process innovations. These implementation factors are (1) *management support*, (2) *coordination and control*, (3) *learning and experience*, (4) *technology management*, (5) *communication*, and (6) *motivation*. These factors, their related advantages and disadvantages, and how they are derived from the literature review will be explained in more detail in the following.

Table 11: Constructed theoretical model – The advantages and disadvantages of vertical integration in the implementation of systemic process innovations

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Management support	The role and actions of managers who have authority over issues and resources critical for the implementation	✓ Top management support over several integrated units at once ✓ Effective allocation of necessary resources between integrated units	✓ Broad management with differing managerial requirements may lead to diverse support over different units
Coordination and control	Planning the implementation, coordinating and controlling the progress of the implementation over several projects	✓ Easier management of changing liability and contractual issues as there is no need to negotiate contracts ✓ Ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion through the better coordination and control ✓ Stable relationships of different units reduce uncertainty, boundary strength and enable utilization of efficient processes	✓ Inflexibility to change partners or processes when needed ✓ Broad management with differing managerial requirements may be difficult to coordinate and control ✓ Innovations are too complex and large to manage and coordinate under a single integrated firm
Learning and experience	User training and accumulation of learning and experience regarding the innovation	✓ Learning and experience proceed faster between integrated units ✓ Enables cumulative learning through the possibility to transfer the same organization and expertise from one project to another which reduces the organizational variety ✓ Enables feedback loops and cross-pollination of ideas between different units	✓ May prevent access to external research, know-how, and relevant capabilities related to the innovation
Technology management	Managing technological issues related to the existing technology and the innovation to be implemented	✓ Jointly selected systems and software platform ensure interoperability between integrated units and compatibility with existing technologies ✓ Possibility to experiment with technology between integrated units ✓ Possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units	✓ Relevant technological capabilities may exist outside ✓ May prevent from perceiving technological advances in the market
Communication	Distributing information about the innovation and its implementation	✓ Enables faster and more accurate information flow between integrated units ✓ Enables easier and safer exchange of information between integrated units ✓ Enables more efficient communication through a developed internal coding system	✓ Increased hierarchical levels and spans of control may lead to accidental or even deliberate communication distortion
Motivation	Getting people motivated and committed through goal setting and identifying the need for change	✓ Enables trust, solidarity, and communal spirit to develop between integrated units ✓ Ability to understand shared interests and holistic goals can motivate units that do not directly benefit from the innovation	✓ Absent internal competition may decrease motivation to change

The first implementation factor, *management support*, emerged primarily from the frameworks of Salminen (2002) and Munkvold (2003) (see Table 5 and Table 6). Both of them highlighted the importance of the management support for providing legitimacy for the implementation and gaining access to critical resources. The management support does not directly come up in the advantages and disadvantages of vertical integration. However, as vertical integration enables better control and coordination over several integrated units (Blois 1972; Harrigan 1984; Mahoney 1992), top management support over all these units is realized as well (first advantage in the model). Mahoney (1992) also brings up the benefit of audit and resource allocation in vertically integrated firms which can be translated into the more effective allocation of necessary resources between integrated units (second advantage in the model), as mentioned by Salminen (2000) and Munkvold (2003) as one of the elements of the management support. As for the disadvantages related to the management support, Blois (1972) and Porter (1980) mention the extension of the management team and differing managerial requirements which could lead to diverse management support over different integrated units, and thus, hinder the implementation (single disadvantage in the model).

The second factor in implementation, *coordination and control*, came up heavily from the literature in the advantages and disadvantages of vertical integration (see Chapter 6). Planning, control and coordination activities are, however, focal factors in change management and implementation as well (see Tables 4, 5, 7, and 9). The advantages of vertical integration related to the coordination and control are easier management of changing liability and contractual issues as there is no need to negotiate contracts (first advantage in the model, derived from Harrigan 1984; Krippaehne et al. 1992; Taylor 2007), ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion through the better coordination and control (second advantage in the model, derived from Armour & Teece 1980; Teece 1996; Winch 1987; 1989a; Taylor 2007), and stable relationships of different units which reduce uncertainty, boundary strength and enable the utilization of efficient processes (third advantage in the model, derived from Williamson 1971; Blois 1972; Winch 1987; 1989a; Taylor & Levitt 2004; Taylor 2007). All these advantages facilitate the implementation of systemic process innovations. The disadvantages of vertical integration related to the coordination and control are inflexibility to change partners or processes when needed (first disadvantage in the model, derived from Blois 1972; Porter 1980; Harrigan 1984; Winch 1987; 1989a), broad management with differing managerial requirements which may be difficult to coordinate and control (second disadvantage in the model, derived from Blois 1972; Porter 1980; Mahoney 1992), and the fact that systemic process innovations may be too complex and large to manage and coordinate under a single integrated firm (third disadvantage in the model, derived from De Laat 1999; Maula et al. 2006). These disadvantages may hinder the implementation of systemic process innovations in vertically integrated organizations.

The third implementation factor, *learning and experience*, emerged first from the complex nature of a systemic process innovation and the project-based nature of the construction industry. As a systemic process innovation is a collection of interconnected innovations related to the boundary spanning working practices of the whole business system (see the definition in Section 2.2), it cannot be implemented at once. In the project-based construction industry, this means that the implementation occurs over several projects. Therefore, cumulative learning and experience is pivotal in the successful implementation of systemic process innovations. The implementation frameworks in Chapter 7, however, emphasize the user training and participation which are closely related and integrated to the learning and experience in this model. The advantages of vertical integration related to the learning and experience are faster proceeding of learning and experience between integrated units (first advantage in the model, derived from Langlois & Robertson 1989; Langlois 1992), cumulative learning through the possibility to transfer the same organization and expertise from one project to another which reduces the organizational variety (second advantage in the model, derived from Winch 1987; 1989a; Taylor & Levitt 2004), and facilitation feedback loops and cross-pollination of ideas between different units (third advantage in the model, derived from Winch 1987; 1989a; Taylor 2007). These advantages may facilitate the implementation of systemic process innovations in vertically integrated organizations. The disadvantage, on the other hand, is that vertical integration may prevent access to external research, know-how, and relevant capabilities related to the systemic process innovation which may hinder the implementation (single disadvantage in the model, derived from Porter 1980; Harrigan 1984; Teece 1996; Krippaehne et al. 1992).

The fourth factor in implementation, *technology management*, came up primarily from the framework of implementing collaboration technologies by Munkvold (2003) (see Section 7.2) and from the framework of successful 3-D CAD implementation by Taylor (2007) (see Section 7.3). Some technological issues appeared in the advantages and disadvantages of vertical integration as well such as improved technological intelligence (Porter 1980; Harrigan 1984; Teece 1996; Krippaehne et al. 1992). The advantages of vertical integration related to the technology management are the ability to ensure the interoperability of technology between integrated units and compatibility with existing technologies by selecting specific systems and software platforms (first advantage in the model, derived from Munkvold 2003; Taylor 2007), the possibility to experiment with technology between integrated units (second advantage in the model, derived from Taylor 2007), and the possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units (third advantage in the model, derived from Nadler 1981; Munkvold 2003). These advantages may facilitate the implementation of systemic process innovations in vertically integrated organizations. The disadvantages are, on the other hand, that vertical integration may prevent the firm from perceiving technological advances related to the systemic process innovation in the market (first disadvantage in the model, derived from Teece 1996) or some relevant technological capabilities needed in the systemic process innovation may exist outside of the integrated firm which may hinder the implementation (second disadvantage in the model, derived from Krippaehne et al. 1992).

The fifth implementation factor, *communication*, emerged from the frameworks of Salminen (2000) and Munkvold (2003) (see Table 5 and Table 7) where the information sharing between all participants in the implementation was emphasized. At the same time, communication was highly emphasized in the context of systemic innovations where a complete open exchange of information between different participants is essential. The advantages of vertical integration related to the communication are faster and more accurate information flow between integrated units (first advantage in the model, derived from Porter 1980; Teece 1996), the easier and safer exchange of information between integrated units (second advantage in the model, derived from Gopalakrishnan & Bierly 2001), and more efficient communication through an internal coding system that can develop in integrated environment (third advantage in the model, derived from Mahoney 1992). These advantages may facilitate the implementation of systemic process innovations in vertically integrated organizations. The disadvantage is, however, the possible communication distortion which may be accidental or deliberate and arises from the increased hierarchical levels and spans of control and possible hinders the implementation (single disadvantage in the model, derived from Mahoney 1992).

Finally, the sixth factor in implementation, *motivation*, came up from the different implementation frameworks in Chapter 7. In order for the implementation to be successful, different participants need to be motivated to implement and use the systemic process innovation at hand. Salminen (2000) also specified the need for change and goal setting as separate success factors which are closely related and integrated to the motivation in this model. The advantages of vertical integration related to the motivation are the development of trust, solidarity, and communal spirit between integrated units (first advantage in the model, derived from Mahoney 1992), and the ability to understand shared interests and holistic goals which can motivate units that do not directly benefit from the systemic process innovation (second advantage in the model, derived from Taylor 2007). These advantages may facilitate the implementation of systemic process innovations in vertically integrated organizations. The disadvantage, on the other hand, may be that the absence of internal competition decreases the overall motivation to change and implement new technologies (single disadvantage in the model, derived from Porter 1980).

The framework by Salminen (2000), which was used as a basis of the constructed theoretical model presented here, included also other success factors not mentioned here such as leadership and defining roles. These were, however, not found to be affected by vertical integration in the implementation of systemic process innovations based on the literature review. Furthermore, as Salminen (2000, 93) pointed out, these factors are not specific phases of an implementation process but rather factors that are present throughout the whole implementation. Thus, the constructed theoretical model presents how vertically integrated organizational structure may affect the implementation of systemic process innovations in project networks by specifying the advantages and disadvantages related to each implementation factor.

8.3 The detailed research question

The constructed theoretical model presented in the previous section will be tested in the following empirical part of this thesis (Part III). The first objective is to find out how these advantages and disadvantages of vertical integration apply to the two empirical cases examined in this study. The second objective is to find, on one hand, possible new implementation factors, and on the other hand, possible new advantages and disadvantages of vertical integration that could complement the constructed theoretical model. As the project network in the other case study is vertically integrated and the other vertically disintegrated, the vertically integrated case will be a primary case in the empirical research. The vertically disintegrated case will be used to verify the findings when possible as often, for example, an advantage of vertical integration (i.e. hierarchy) can be a disadvantage of vertical disintegration (i.e. network of firms) and vice versa.

Nevertheless, the following detailed research question will be answered based on the empirical data of this study:

> ***RQ:*** *What are the structurally relevant BIM implementation factors and the related advantages and disadvantages of vertical integration?*

Finally, based on the findings of the empirical research, the constructed theoretical model will be refined into an improved theoretical model in Chapter 12.

III EMPIRICAL RESEARCH

"If the only tool you have is a hammer,
you tend to see every problem as a nail."
– Abraham Maslow (1908-1970)

Part III describes the empirical research of this thesis. The part consists of two chapters; description of the cases (Chapter 9) and data collection and analysis methods (Chapter 10). The overall purpose of this part is to describe what kind of empirical data was collected, how it was collected, and how it was analyzed before presenting the actual findings of this study in Part IV.

9 Description of the cases

The empirical data analyzed in this study comes from two separate SimLab™ process simulation projects. The SimLab™ process simulation method will be further explained in the following chapter in Section 10.1. In this chapter, these two cases are introduced by going through the background of the two cases (Section 9.1), describing both cases in more detail (Section 9.2), and identifying the key differences between the two cases (Section 9.3).

9.1 Background of the cases

ECPIP Finland research project

The two cases analyzed in this study were part of the ECPIP Finland (Engineering and Construction Project Information Platform) research project (see Hirvensalo et al. 2009). The project was led by Enterprise Simulation Laboratory SimLab from Helsinki University of Technology (TKK, nowadays Aalto University School of Science and Technology) in collaboration with Building Informatics team from Technical Research Centre of Finland (VTT). ECPIP Finland started in the beginning of 2007 and ended in August 2009. The project had two separate research teams; one concentrating on the infrastructure industry and the other on the building industry.

The overall objective of the project was to support information technology driven process development in the Finnish architecture, engineering, construction and operations (AECO) sector. The idea was to gather the leading companies in the Finnish AECO industry, including real estate owners, contractors, engineering firms, suppliers, software developers, and research units to a series of SimLab™ simulation projects where current processes would be developed to fully utilize the possibilities of the new technology such as BIM in the building industry.

ECPIP Finland project was funded by the Finnish Funding Agency for Technology and Innovation (Tekes) and 9 partner companies from the Finnish construction and IT industry that participated in the project. The project also collaborated with two universities from the United States; CIFE (Center for Integrated Facility Engineering) from Stanford University and the Global Project Network Dynamics Lab from Columbia University.

Selection of the cases

This Master's Thesis has been completed between 2008 and 2010 within the team focusing on the building industry in the ECPIP Finland project. Working as a researcher in the project actually generated the idea for this Master's Thesis. The building industry side of ECPIP Finland included two opposite extreme cases where both were implementing the same BIM technologies; one with a vertically disintegrated project network and the other with a vertically integrated project network.

These cases provided an interesting chance for comparative research in order to investigate the impact of vertical integration in the implementation of this kind of technology. In other words, in the process of this thesis, these cases were not selected by the researcher in order to solve the particular problem. In fact, these cases rather selected the researcher and inspired him to come up with a fascinating research problem for this thesis.

9.2 Case descriptions

Two cases studied in this thesis, Case Alpha and Case Beta, were two different building projects where BIM technologies were being tested and implemented. In Case Alpha, there was a vertically disintegrated project network where the BIM implementation was initiated by the owner. Respectively in Case Beta, there was a vertically integrated project network where the BIM implementation was initiated by the contractor. The project networks and the implementation projects are described in more detail in the following. The case descriptions are based on the project documentations and the interviews.

Case Alpha: Vertically disintegrated project network – Owner driven BIM implementation

The pilot project in the first case, Case Alpha, was a unique university building project designed and constructed by a vertically disintegrated project network between 2003 and 2006. The project was an advanced BIM pilot project initiated by the building owner organization. The building owner organization is a public organization and has been actively promoting the utilization of BIM technologies in Finland for years. The motive behind this initiative towards BIM is to improve the decision making and the use of more accurate information over the whole life cycle of buildings. Especially interesting from the owner's point of view are the new possibilities that BIM technologies are offering to the facilities management (FM). Additionally, as a large public organization, it has a responsibility as well as a possibility to take the development in the construction industry further.

As an example of their pioneering work, the owner organization has started to require the use of BIM by architects in all of their projects valued over 1 M€ since the end of 2007 and plans to make it mandatory for other design disciplines as well. In order to back up this requirement, the owner organization has produced and published the BIM guidelines for different stakeholders in building projects. These guidelines are not tool-specific and they specify the general data content requirements for different building information models during each phase of the design. Before starting to require the use of BIM, the owner organization had carried out a number of pilot projects in order to study and develop the use of building information models in their projects. The project in Case Alpha was one of the most significant projects among these pilot projects. In fact, even though the project was completed already in 2006, the scope of BIM use in the project is still considered to be highly advanced.

The project stakeholders in vertically disintegrated network of Case Alpha consisted of the following participants: end user, owner, project consultant, cost estimator, architect, structural engineer, MEP (mechanical, electrical, and plumbing) designer, main contractor, and MEP contractor. In addition to these actors, the project also involved various subcontractors and suppliers, authorities, software providers, and a BIM team that was formed to solve mainly technological interoperability issues between different BIM tools during the project. These additional actors are important regarding the BIM utilization as the software providers provide the BIM software, the subcontractors and suppliers need to be able to handle BIM-based design and manufacturing data, and the authorities need to handle BIM-based designs in the building permit process (see the illustration of the project network in Figure 13).

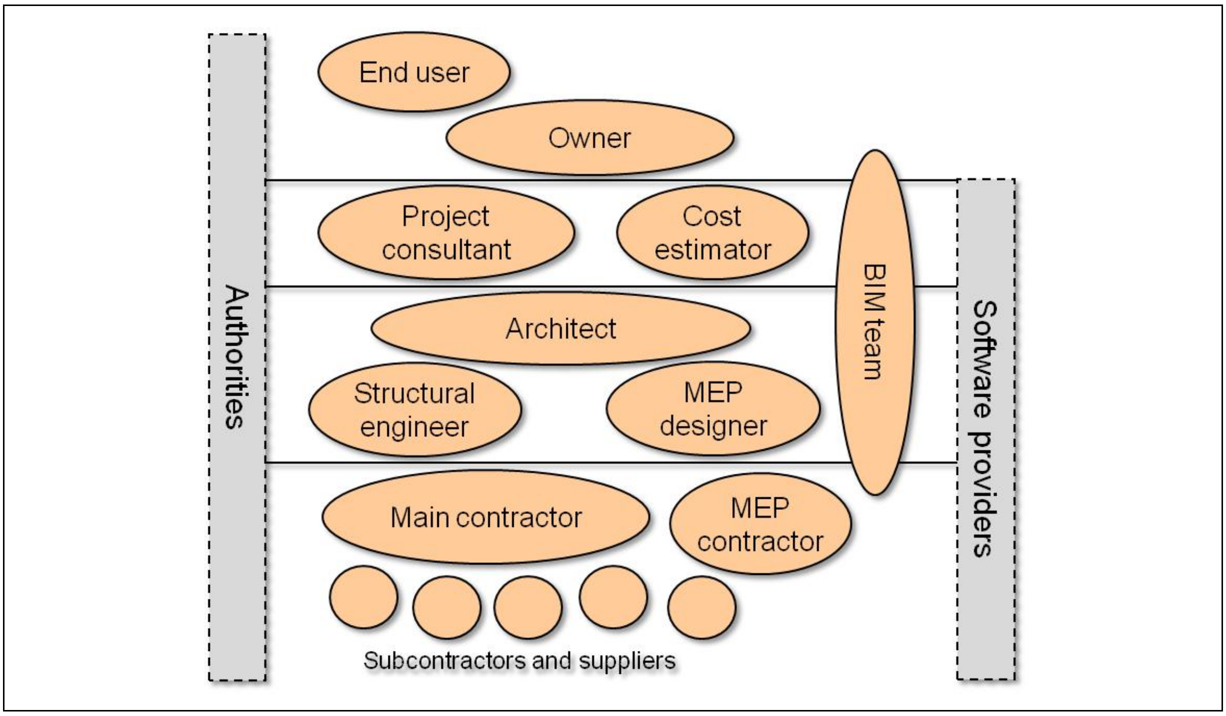

Figure 13: Case Alpha – Vertically disintegrated project network

The pilot project in Case Alpha was based on an architectural competition. The project was managed by an external project consultant and a fixed-price incentive contract was applied. The project consultant was not experienced in BIM-based projects. The architect as well as all the specialist designers used BIM tools in the project. The architect had only little previous experience from integrated BIM-based projects while the structural engineers and the MEP designers had completed many BIM-based projects before. The main contractor alongside with the MEP contractor and subcontractors were responsible for the construction. For all the contractors, BIM was a fairly new issue. Cost estimations were made based on both building information models and by traditional means in order to develop the BIM-based cost estimation. Building information models were, thus, utilized more or less during all the phases of the project.

Overall, the pilot project in Case Alpha was an important learning experience for all the actors in the project network. A number of benefits were achieved, as well as different technological, process-related, and attitudinal challenges were encountered. The main technological challenges experienced were related to IFC problems and other interoperability problems between different BIM tools. The main process-related problems in the project were related to the collaboration and alignment of different actors. Moreover, as BIM changes the focus of the design to the early phases, the essential question was when to actually involve different actors to the project and in what kind of role. Finally, as always when there are any changes introduced to a working environment, there are some attitudinal challenges. In this project, the less BIM-experienced actors found it difficult to find relevant benefits from BIM to their own work. For example, the project consultant managed and coordinated the project basically in the traditional way and did not see how BIM tools could be utilized in the project management. In fact, the coordination of the BIM-based project from the holistic point of view was more or less left aside in the project. Thus, the need for some kind of a BIM coordinator role emerged in the project. There was a BIM team formed in the project, but their role was mainly to solve the technological problems related to the BIM utilization. At the end, it should be acknowledged that the implementation of BIM is a slow process and it takes many pilot projects to get things forward. Simultaneously, the buildings need to be built which means that the traditional work processes are still in place in parallel for some time.

Case Beta: Vertically integrated project network – Contractor driven BIM implementation

The pilot project in the second case, Case Beta, was a typical residential building project designed and constructed by a vertically integrated project network. The planning and design phase of the project started in the fall of 2007 and the construction phase in September 2009. The construction phase was originally scheduled to start in the beginning of 2009 but the schedule has stretched because of various unexpected changes in both the project and the economic climate. The project in Case Beta was a BIM pilot project initiated by a large private construction company where the owner, all the designers, and the main contractor are all from the same parent organization. The main motive behind the BIM implementation in this case has been the automation of quantity surveying and the utilization of 4-D models at the construction site.

In order to support the implementation and utilization of BIM in its projects, the construction company has been developing an internal BIM infrastructure which is realized as a collection of tools, processes, training, and instructions needed for the successful creation and utilization of the building information models. The BIM infrastructure has been developed to support the use of specific BIM tools that are being used within the company and it contains the instructions for different phases of a project in detailed level. One of the objectives of the pilot project in Case Beta was to test this BIM infrastructure in practice with the designers and develop it further. However, the BIM-based design and construction is not an established practice yet for the construction company. In fact, the BIM pilot project in Case Beta is one of their most advanced BIM pilot projects yet. Even though the majority of their projects are still carried out using the traditional practice, the objective is to fully implement the BIM-based approach in the near future.

The project stakeholders in vertically integrated network of Case Beta consisted of the following participants: owner, project manager, cost estimator, architect, structural engineer, MEP designer, main contractor, and BIM coordinator who managed the BIM implementation and utilization in the project. In addition to these actors, the project also involved various external stakeholders such as subcontractors and suppliers, authorities, software providers providing the BIM tools, and end users who may not be involved in the project until the building is finished due to the residential nature of the building. Figure 14 illustrates the project network and the boundaries between the vertically integrated construction company and the external stakeholders.

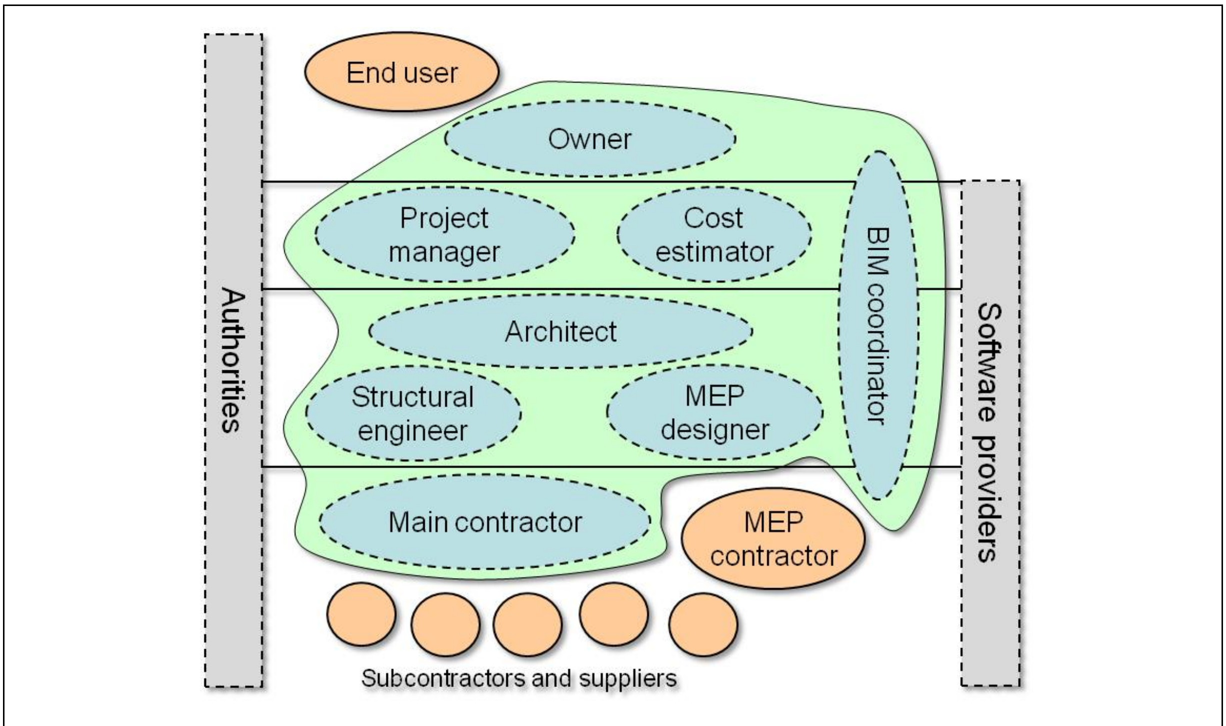

Figure 14: Case Beta – Vertically integrated project network

The pilot project in Case Beta was based on a developer contracting meaning that the construction company acquires the lot and independently designs, builds, and markets the building. The building to be designed, built, and marketed was a five-storey residential building. The project was managed by an internal project manager who had had some experience of BIM over the years. The architect as well as all the specialist designers used BIM tools in the project. The architect was experienced in BIM tools but did not have a lot of experience in integrated BIM-based projects. Similarly, the MEP designers were accustomed to use the

BIM tools in their design but they did not have a lot of experience of BIM-based collaboration with other designers. The structural designers, however, were not experienced in current BIM tools and this pilot project was the first BIM-based project for the most of them. Cost estimations were made internally based on both building information models and by traditional means in order to develop the BIM-based cost estimation. The contractor side of the company was fairly experienced in utilizing BIM at the construction site, and thus, one of the goals of the pilot project was to develop the cooperation between the designers and production in the overall BIM-based design and construction process.

Overall, the pilot project in Case Beta was an important milestone for the construction company in taking the BIM-based construction process forward. A number of benefits were achieved, as well as different technological, process-related, and attitudinal challenges were experienced. The main benefits at this stage came from the visually rich information that building information models provide, and from the merging of the different designers' models. Most of the technological problems in the pilot project arose from the usability issues and incomplete features of the BIM software. The intensive collaboration between the designers and the software providers, however, takes the development forward. In addition, the large construction company had some difficulty in the IT management when new BIM tools were needed to be acquired and installed. The main process-related problems were related to the collaboration and alignment of different designers. The challenge of coordinating the BIM-based design process from the holistic point of view was addressed quite successfully by the role of the BIM coordinator. However, according to the interviews, the design team would have wanted a coordinator of their own among the designers, focusing just on the design. The shared location of different stakeholders seemed to facilitate the collaboration and communication as people could just walk to the next door to discuss about a problem or to get feedback. The attitudinal problems in the project were strongly related to the perceived benefits from BIM. Often times, people could not see any benefits from BIM in their own work, and therefore, it was sometimes difficult to accept the changes that BIM introduced.

9.3 Key differences of the cases

In the analysis of this study, the two cases described in the previous sections will be examined with the constructed theoretical model. As the constructed theoretical model presents the advantages and disadvantages of vertical integration when implementing a systemic process innovation, the Case Beta with the vertically integrated project network will be used as a primary case. The Case Alpha with the vertically disintegrated project network will be used to verify the findings when possible as it presents the flip side of the coin. Even though the cases include the same phenomenon i.e. the implementation and utilization of BIM, there are some fundamental differences between the cases that need to be taken into account when analyzing the findings and reaching the conclusions. These differences may even influence the comparability of these cases. The key differences between two cases are presented in Table 12 below. These differences will be taken into account when analyzing the results and evaluating the validity of this study.

Table 12: The key differences between the case studies

Comparison criteria	CASE ALPHA	CASE BETA
Type of the project network	Vertically disintegrated	Vertically integrated
Type of the organization	Public	Private
Type of the project	Unique university building	Typical residential building
Time of the project	2003 - 2006	2007 -
Motive of development	Owner driven	Contractor driven
Previous BIM projects by focal firm	Many	Few

10 Data collection and analysis methods

The empirical data for this study has been collected in two SimLab™ process simulation projects. In this chapter it is described in detail what the SimLab™ business process development method is (Section 10.1), how the data was collected in these simulation projects (Section 10.2), and how the data was analyzed (Section 10.3) in order to reach the findings presented in Part IV of this thesis.

10.1 SimLab™ business process development method

The SimLab™ business process development method, which has been developed in the Enterprise Simulation Laboratory SimLab at Helsinki University of Technology (TKK, nowadays Aalto University School of Science and Technology), provides an interactive learning environment and functions as a platform to build common understanding and to promote innovative development ideas for networked processes (e.g. Smeds 1997; Forssén & Haho 2001; Smeds et al. 2005; Smeds et al. 2006). The core of the method is a carefully prepared and facilitated process simulation where the selected process is discussed and developed with all the key actors from the different partner organizations involved in the process (Smeds et al. 2005, 341). A SimLab™ process simulation project typically lasts for 3 to 6 months and consists of seven steps (illustrated in Figure 15).

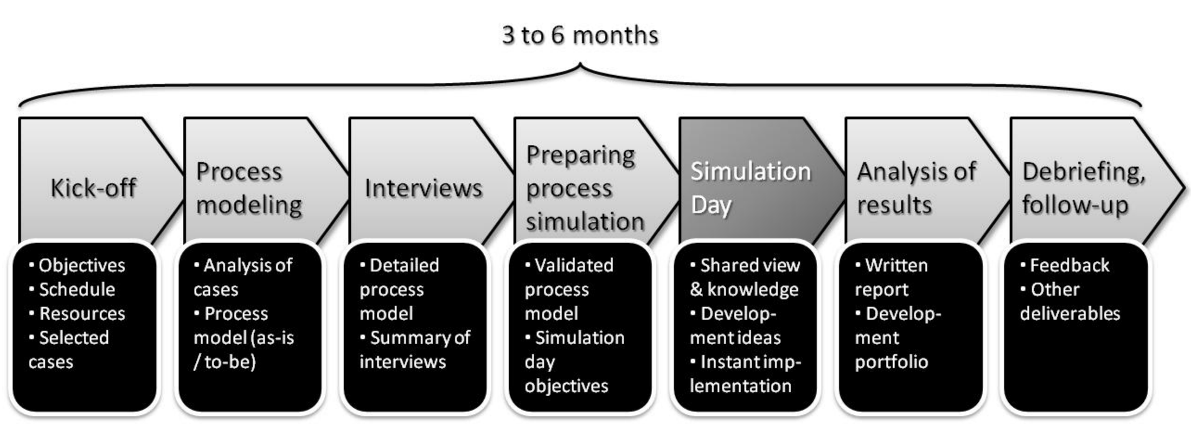

Figure 15: The SimLab™ process simulation project (adapted from Smeds et al. 2005, 342)

A simulation project starts with a kick-off meeting where the objectives, schedule and resources are specified together with the researchers and representatives from the case companies. Additionally, the cases and processes to be simulated are selected and defined at the kick-off meeting. After the kick-off meeting, the researchers analyze the selected cases and facilitate group modeling sessions in order to create a visual model of the process to be developed. These group modeling sessions are basically group interviews where the aim is to create a preliminary process model of the selected process. The processes to be examined can be either current as-is or future to-be processes. The preliminary process model is then refined based on the interviews of all the key participants involved in the process. After the analysis of the interviews, the researchers finalize the detailed visual process model, validate the model with the companies involved, and start to prepare the SimLab™ Process Simulation Day. (Smeds et al. 2006, 191)

A simulation project culminates in the simulation day where all the key actors of the selected case discuss and develop the process. The simulation day is often divided into a morning session with the actual process simulation and an afternoon group work session. In the morning session, the discussion is structured by the visual process model and facilitated by the researchers. In the afternoon group work session, the participants gather to smaller groups and start to develop solutions to the most urgent challenges that came up in the process simulation. The overall objective of the simulation day is to create a shared view and knowledge of the process at hand, to find important development ideas, and to create motivation for process development and change. The participants can usually immediately implement some of the learning in their own work. After the simulation day, the researchers analyze the results for the written report which is presented to the stakeholders in a debriefing session. (Smeds et al. 2006, 190-192)

Simulation projects provide a lot of rich case data for scientific research. Typical data collection methods included in the SimLab™ business process development method are archives, interviews, observation, and questionnaires. For example, the pre-simulation interviews and process modeling sessions are transcribed, archival data is gathered from the stakeholders, the simulation day is audio and video recorded and observed by several researchers, a feedback questionnaire is filled by the participants after the simulation day, and often follow-up interviews are conducted (Smeds et al. 2005, 342).

The empirical data for this study was collected in two different SimLab™ process simulation projects. These simulation projects were already finished when the writing of this thesis started. However, the extensive collection of empirical data collected in these simulation projects provided a rich source of data in various forms. The detailed description of how the SimLab™ business process development method was used with some modifications in the data collection of this study is presented in the following.

10.2 Data collection methods

As already mentioned previously, SimLab™ process simulation projects typically combine multiple data collection methods such as archives, interviews, observations, and questionnaires. The archives used in this study consisted of project documentation including project plans and schedules, meeting memos, and process charts. The archives were used as a basis for preparing for the interviews, and to form an overall understanding about the projects. The facts from the archives also helped the interviewees to remember the actual events and the progression of the projects.

The interviews included both single and group interviews. The interviews were semi-structured theme interviews meaning that a pre-planned questionnaire was used as a steering tool in the interview sessions (Hirsjärvi & Hurme 2004). The pre-planned questionnaire used in both of the case studies can be found from the appendices of this thesis (see Appendix 1). Overall, 46 individuals from 13 different organizations participated in these interview sessions during these two case studies. Few of the individuals participated in both of the case studies. Altogether, the interview material alone consisted of over 600 pages of transcribed text. Researchers and interviewees were identified in the transcriptions in order to be able to trace a comment. Different expressions or long pauses were noted if they were especially meaningful. All the interview material was stored in a database for later use.

After the interviews, altogether three full-day process simulation events were held to further validate the results of the interviews, and to support the development and utilization of BIM technologies in the pilot projects. Altogether 66 individuals from 14 different organizations participated in these three process simulation events. In addition to the empirical data from the archives and the interviews, these process simulation events provided a rich source of observation data. Altogether, over 150 pages of transcribed text and over 18 hours of video recordings were produced from three process simulations. In the following, the data collection is described in more detail in both of the cases.

Data collection in Case Alpha: Vertically disintegrated project network

The empirical data in Case Alpha was collected during the fall 2007. Thus, the actual pilot project was finished (from 2003 to 2006) when the process simulation project started. Data collection followed the SimLab™ business process development method with some modifications (see Section 10.1). The author of this thesis was a member of the research team which included altogether four researchers (three from TKK SimLab and one from VTT Building Informatics). Case Alpha included only one process simulation.

The kick-off meeting for the process simulation was held in June 2007. At the meeting, the researchers and key stakeholders agreed on the objectives and the preliminary schedule for the process simulation. The actual data collection started in July 2007 by gathering all the project documentation possible to find in the project. This documentation included project plans and schedules, meeting memos from different phases of the project, and building information models that were handed in to the database of the project. The collected project documentation was used to form an overall understanding about the progression of the project. Additionally, based on these documents the research team created a preliminary process model to be used to guide the interviews. The facts gathered from the project documentation to the process model helped the interviewees to remember the actual events better and therefore facilitated the refinement of the process model during the interviews.

Altogether 10 interview sessions were arranged between August and October 2007. The interviews included both single and group interviews and altogether 21 individuals from nine different organizations. The main objective of the interviews was to model the process of the project to be used in the process simulation. Additionally, researchers wanted to find out the main benefits and challenges related to BIM that were encountered during the project. In order to reach this goal, researchers selected all the key individuals who were somehow affected by BIM in the project to be interviewed. Among these individuals were end users of the building, representatives from the owner, project consultant, structural engineers, MEP designer, cost estimators, representatives from software providers of the BIM software, and representatives from the main contractor.

The interviews were arranged as semi-structured theme interviews meaning that a pre-planned questionnaire was used to guide the interview sessions (Hirsjärvi & Hurme 2004). The pre-planned questionnaire had five themes and a few questions under each theme (see Appendix 1). The idea was not to follow this questionnaire strictly, but to use it as a tool to make sure that all the important topics were covered during the interview. There were three to four researchers present in each interview. The author of this thesis was personally present in 8 of the 10 interview sessions arranged. All the interviews were audio recorded and transcribed. Thus, when a researcher could not attend an interview session, the recordings could be listened and transcribed texts could be read. Altogether, almost 200 pages of transcribed text were produced from the interviews of Case Alpha.

In addition to the pre-planned questionnaire, the visual process model was also used to structure the interviews. One of the main goals of the interviews was to refine the process model in order it to be used in the process simulation, but it also served as a tool for researchers to systematically go through each step of the project. Simultaneously, the results from each interview were validated in the next interview as they were cumulatively marked into the process model. The visual process model also helped the interviewees to remember the actual events and the progression of the project. The questionnaire and the process model were used together as guidance, for example, while asking questions about the specific phase in the process, the attention was paid to the topics in the questionnaire as well.

After the interview sessions, the SimLab™ process simulation event was held in the end of October 2007. The full day event was divided into two parts; a morning session with the process simulation and an afternoon group work session. Researchers prepared the process simulation event by analyzing the interviews, finalizing the visual process model and mapping the benefits and challenges of BIM on the process model. In the morning session of the event, the process was discussed through in front of a large visualization of the process model. The discussion was facilitated by the researchers and the focus was especially on the benefits and challenges of BIM during the project. In the afternoon group work session, the participants were divided into smaller groups to discuss more specifically on how to gain more benefits from BIM and overcome the challenges. Altogether 25 individuals from 11 different organizations participated in the process simulation event. In addition, 9 researchers from TKK SimLab and VTT Building Informatics team were present at the event. The process simulation event was audio and video recorded and transcribed, producing altogether 29 pages of transcribed text.

After the process simulation event, the researchers started to analyze data from the process simulation and the group work. Based on the analysis, the researchers produced a final report which presented the results of Case Alpha. The final report was published in December 2007 for the participating organizations. All the empirical data from Case Alpha that has been used in this Master's Thesis is presented in Table 13 below.

Table 13: Empirical data from Case Alpha used in this thesis

EMPIRICAL DATA	People	Pages
Owner, architect, project consultant (Group interview, August 2007)	3	33
End users (Group interview, August 2007)	2	5
Owner (Single interview, August 2007)	1	5
Main contractor (Group interview, August 2007)	2	30
Structural engineers (Group interview, August 2007)	2	17
MEP designer (Single interview, August 2007)	1	16
Architects (Group interview, September 2007)	2	33
Software provider (Single interview, October 2007)	1	16
Structural engineer (Single interview, October 2007)	1	10
Cost estimators (Group interview, October 2007)	2	16
SimLab™ process simulation day (October 2007)	25	29
Final report (December 2007)	-	39
Pages total		249

Data collection in Case Beta: Vertically integrated project network

The empirical data in Case Beta was collected during the year 2008. Thus, the actual pilot project was simultaneously going on when the process simulation project was executed. As in Case Alpha, the data collection in Case Beta followed the SimLab™ business process development method with some modifications (see Section 10.1). The author of this thesis was a member of the research team which included altogether three researchers (two from TKK

SimLab and one from VTT Building Informatics). Contrary to Case Alpha, Case Beta included two process simulations; the first was completed in the spring 2008 and the second in the fall 2008. The first process simulation concentrated on the initial part of the planning and design process whereas the second concentrated on the latter part of the process.

The first process simulation in Case Beta started with a kick-off meeting in January 2008 where the objectives and the preliminary schedule were determined and approved by the researchers and the representatives from the case company. The actual data collection started after the kick-off meeting by reviewing the project documentation. Among the project documentation received were project plans and schedules, memos from planning and design meetings, and existing process charts from the case company. In the beginning of February 2008, the researchers created a preliminary process model of the planning and design phase with the assistance of the development team from the case company. The preliminary process model was based on the project documentation and used as a starting point for the interviews.

During February 2008, altogether 20 individuals from the case company were interviewed in 15 single and group interview sessions. Among the interviewees were representatives from the development team, BIM coordinator, structural engineers, project manager, MEP designers, architects, the cost estimator, representatives from sales and marketing, different managers, and the precast concrete designer. Since the design phase of the pilot project was not yet completed at the time of the interviews, the overall process was divided into two parts; a completed and a forthcoming part. Regarding to the completed part of the process, the aim of the interviews was to gather experiences, both positive and negative, and to create an as-is process model to be used in further development. With the forthcoming part of the design process, the aim was to sketch a to-be process model and to inquire advance feelings of the future process from the participants. Based on all the interviews, the preliminary process model was developed into a refined process model of the planning and design phase that included both, the completed part and the forthcoming part of the process.

Similarly as in Case Alpha, the interviews were arranged as semi-structured theme interviews with the same pre-planned questionnaire (see Appendix 1). The idea was not to follow this questionnaire strictly, but to use it as a tool to make sure that all the important topics were covered during the interview. There were two to three researchers present in each interview. The author of this thesis was personally present in all 15 interview sessions arranged. All the interviews were audio recorded and transcribed for the data analysis purposes. Altogether, over 200 pages of transcribed text were produced from the interviews of the first process simulation in Case Beta.

After the interviews, the research team started to prepare for the first process simulation event. During the preparation, researchers analyzed the interviews and simplified the visual process model in order to be able to use it as a tool for discussion in the process simulation. The process simulation event was held in the beginning of March 2008. The day was divided into a morning session with the process simulation and an afternoon group work session. The main objectives of the whole day were to identify the most important challenges in BIM utilization in the residential building production, and to find possible solutions or development ideas for these challenges. In addition, one important goal was to increase the common understanding of BIM-based building process among the participants. Altogether 16 individuals from the case company, three individuals from software providers, and eight researchers from TKK SimLab and VTT Building Informatics team participated in the first process simulation event. The whole event was recorded in audio and video for research purposes and produced 59 pages of transcribed text.

After the first process simulation event, the research team started to analyze the data from the process simulation. Based on the analysis of both the interviews and the process simulation, a final report presenting the results was written in April and published in May 2008. All the empirical data from the first process simulation in Case Beta that has been used in this Master's Thesis is presented in Table 14 below.

Table 14: Empirical data from the first process simulation in Case Beta used in this thesis

EMPIRICAL DATA FROM THE FIRST PROCESS SIMULATION	People	Pages
Development team, BIM coordinator (Group interview, January 2008)	2	10
Procurement manager (Single interview, February 2008)	1	12
Structural engineers (Group interview, February 2008)	2	10
Project manager (Single interview, February 2008)	1	15
Development team, BIM coordinator (Group interview, February 2008)	3	2
MEP designers (Group interview, February 2008)	3	20
Architects (Group interview, February 2008)	3	25
MEP designer (Single interview, February 2008)	1	20
Cost estimator (Single interview, February 2008)	1	22
Project engineer (Single interview, February 2008)	1	19
Sales manager (Single interview, February 2008)	1	28
MEP development manager (Single interview, February 2008)	1	12
Business manager (Single interview, February 2008)	1	21
Development manager (Single interview, February 2008)	1	8
Precast concrete designer (Single interview, February 2008)	1	15
SimLab™ process simulation day (March 2008)	19	59
Final report (May 2008)	-	31
Pages total		329

The second process simulation in Case Beta started in August 2008, and it was a follow-up to the first process simulation. In the actual pilot project, the design process had progressed almost to an end, and therefore it was possible to examine the real life experiences also from the latter part of the design process. The second process simulation started with a kick-off meeting in the middle of August 2008 with similar procedures as in the first process simulation. After the kick-off meeting, the researchers reviewed the project documentation that had been produced in the pilot project after the first process simulation. Based on the new documentation, the research team created a new preliminary process model for the interviews.

During October and November 2008, altogether 20 individuals were interviewed from seven different organizations in 14 interview sessions. Among the interviewees from the case company were the architect, the precast concrete designer, structural engineers, MEP designers, the project manager, the cost estimator, and different managers. In addition, also other actors outside the case company were interviewed. These included representatives from software providers, representatives from a concrete supplier, a representative from a steel supplier, and a representative from a structural engineering firm. The objective of the interviews was to create an as-is process model of the whole planning and design process. As the group of participants constituted of wider audience, all of them were not directly associated with the actual pilot project. For this reason, the researchers also wanted to gather more general experiences and broader insight regarding the challenges of BIM implementation and utilization.

Similarly as in Case Alpha and the previous process simulation, the interviews were arranged as semi-structured theme interviews with the same pre-planned questionnaire (see Appendix 1). There were two to three researchers present in each interview. The author of this thesis was personally present in all 14 interview sessions arranged. Once again, all the interviews were audio recorded and transcribed for the data analysis purposes. Altogether, over 150 pages of transcribed text were produced from the interviews of the second process simulation in Case Beta.

After the interviews, the researchers started to prepare for the second process simulation event by analyzing the interviews and finalizing the process model. The process simulation event was held in the middle of November 2008 and it was once again divided into a morning session with the process simulation and an afternoon group work session. As in the previous process simulation, also in the second process simulation the main objectives were to identify the challenges of BIM utilization and come up with possible solutions for them. Additionally, as the group of participants was wider this time, one important goal was to support the development of BIM utilization and create a change supporting dialogue within the whole industry. In total 45 individuals from 12 different organizations attended the second process simulation event. The event was recorded in audio and video for research purposes and produced 79 pages of transcribed text.

After the second process simulation event of Case Beta, the researchers started to analyze the data from the process simulation. Based on the analysis of the interviews and the process simulation, a report was written and published in December 2008. After the publication of the report, there were two additional feedback sessions with the case company; one in December 2008 and one in February 2009. These feedback sessions were a valuable source of additional empirical data for this thesis. All the empirical data from two process simulations in Case Beta that has been used in this Master's Thesis is presented in Table 15 below.

Table 15: Empirical data from the second process simulation in Case Beta used in this thesis

EMPIRICAL DATA FROM THE SECOND PROCESS SIMULATION	People	Pages
Architect (Single interview, October 2008)	1	22
Precast concrete designer (Single interview, October 2008)	1	5
Structural engineers (Group interview, October 2008)	2	23
MEP designer (Single interview, October 2008)	1	14
Project manager (Single interview, October 2008)	1	6
Cost estimator (Single interview, October 2008)	1	5
MEP development manager (Single interview, October 2008)	1	11
MEP designers (Group interview, October 2008)	3	13
Structural design developer (Single interview, October 2008)	1	10
Software provider (Group interview, October 2008)	2	12
Software provider (Single interview, October 2008)	1	12
Concrete supplier (Group interview, November 2008)	2	9
Steel supplier (Single interview, November 2008)	1	11
Structural engineer (Single interview, November 2008)	1	18
SimLab™ process simulation day (November 2008)	45	79
Final report (December 2008)	-	32
Feedback session 1 (December 2008)	2	26
Feedback session 2 (February 2009)	10	4
Pages total		312

10.3 Data analysis methods

The empirical data analyzed in this thesis is qualitative by nature. Essentially, all data is qualitative as it refers to essences of people, objects, and situations (Berg 1989 cited in Miles & Huberman 1994, 9). The qualitative data in this study is, however, in the form of words collected through interviews and observation, as described in earlier sections. Words, however, can have various meanings and the meaning can be altered in the process which creates a challenge for the qualitative data analysis. The strength of this kind of qualitative data, on the other hand, is that it provides rich and holistic view on naturally occurring ordinary events in natural settings. (Miles & Huberman 1994, 9-10)

According to Miles and Huberman (1994, 10-11), qualitative data analysis consists of three concurrent flows of activity; (1) *data reduction*, (2) *data display*, and (3) *conclusion drawing/verification*. Together with data collection, these activities form an interactive and iterative process. *Data reduction* refers to the process of selecting, focusing, simplifying, abstracting, and transforming the raw data in transcriptions and field notes. Data reduction is part of the analysis and occurs before, during, and after data collection in form of sharpening, sorting, focusing, discarding, and organizing data in a way that conclusions can be drawn and verified. The coding of data is a common method for data reduction. Different categories for coding can be derived from a particular research question, hypothesis, construct, or theme. These categories are then used code the segments of data in order to organize and find the meaningful segments from a vast amount of data. (Miles & Huberman 1994, 56-66)

Data display refers to organizing and assembling information in a way that allows conclusion drawing and action. The displays can be, for example, different types of matrices, graphs, charts, or networks. As with data reduction, the creation and use of different displays is part of the analysis. *Conclusion drawing* refers to the process of deciding what things mean by noting regularities, patterns, explanations, possible configurations, causal flows, and propositions. Conclusions, however, need to be verified as well. *Conclusion verification*, thus, refers to the practice of testing the plausibility, sturdiness, and confirmability of the conclusions. (Miles & Huberman 1994, 10-11) The interactive process of qualitative data analysis is illustrated in Figure 16 below.

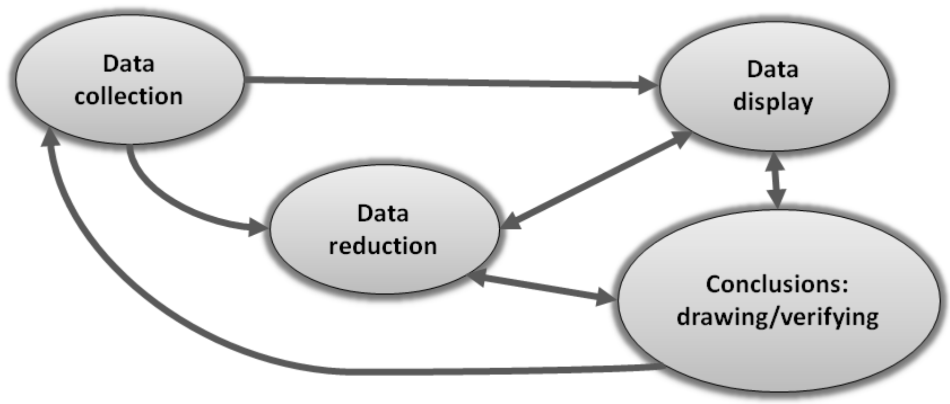

Figure 16: The interactive process of qualitative data analysis (Miles & Huberman 1994, 12)

In this study, the empirical data described in the earlier sections of this chapter was analyzed by using the constructed theoretical model presented in Section 8.2. The constructed theoretical model provided the categories for data coding and classification. The data reduction and analysis consisted of three stages. In the first stage, all the 890 pages of transcribed data was gone through line by line by highlighting all the organizational structure related quotes concerning the BIM implementation. This resulted in total 148 quotes from the both case studies. At this stage, these quotes were also given a descriptive label. In the second stage, the collected quotes were classified with the six implementation factors in the constructed theoretical model. The six implementation factors from the model were (1) *management support*, (2) *coordination and control*, (3) *learning and experience*, (4) *technology management*, (5) *communication*, and (6) *motivation*. After the classification, there was a group of 12 quotes that did not fit into any of the six implementation factors. This group formed an additional implementation factor which was later named *defining roles*. Figure 17 illustrates how the 148 quotes were distributed under different implementation factors.

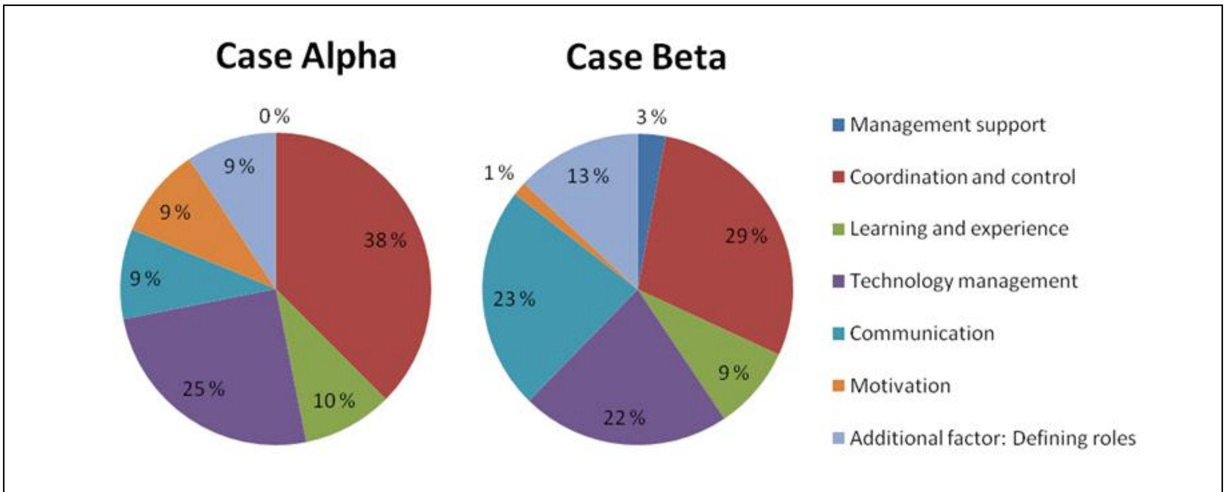

Figure 17: The distribution of the quotes under different implementation factors

In the final stage of the analysis, the quotes under each implementation factors were compared with the advantages and disadvantages of vertical integration in the constructed theoretical model. The conclusions were drawn based on the comparison. Some of the quotes supported the advantages and disadvantages in the model and some of the quotes introduced totally new perspectives. On the other hand, some of the advantages and disadvantages in the model were not supported at all by any of the quotes. During the analysis, data displays were created in form of matrices based on the constructed theoretical model. The matrices evolved during different data reduction and analysis stages. The findings of the data analysis will be presented in the following Part IV (Findings).

IV FINDINGS

"An investment in knowledge
always pays the best interest."
– Benjamin Franklin (1706-1790)

In this part, the findings of this study will be presented and categorized based on the theoretical model constructed in Section 8.2. The part consists of two chapters; advantages and disadvantages of vertical integration in BIM implementation (Chapter 11) where the advantages and disadvantages of vertical integration found in the empirical data are compared with the constructed theoretical model in order to answer the detailed research question of this study, and the improved theoretical model (Chapter 12) where the findings are generalized and integrated into a more simple and illustrative theoretical model.

11 Advantages and disadvantages of vertical integration in BIM implementation

The constructed theoretical model in Section 8.2 synthesizes the structurally relevant implementation factors and the related advantages and disadvantages of vertical integration when implementing systemic process innovations. In the following, the detailed research question formed in Section 8.3 will be answered using the constructed theoretical model as a framework. The advantages and disadvantages of vertical integration when implementing BIM are categorized by structurally relevant implementation factors in the model; management support (Section 11.1), coordination and control (Section 11.2), learning and experience (Section 11.3), technology management (Section 11.4), communication (Section 11.5), and motivation (Section 11.6). In addition to these six implementation factors, an additional structurally relevant factor emerged from the empirical research; defining roles (Section 11.7).

11.1 Management support

The first structurally relevant implementation factor, *management support*, refers to the role and actions of managers who have authority over issues and resources critical for the implementation. Based on the constructed theoretical model, the advantages of vertical integration related to the management support are (1) *top management support over several integrated* *units at once* and (2) *the effective allocation of necessary resources between integrated units*. The disadvantage, according to the model, is that *broad management with differing managerial requirements may lead to diverse support over different units*.

The case studies included only a few references related to the management support issues. In fact, the Case Alpha with the vertically disintegrated project network did not include any references that would support the advantages or disadvantages of vertical integration presented in the model or provide any new perspective related to the management support. The reason behind this may be the fact that these issues were not relevant in these specific case studies or they may not be relevant advantages of vertical integration at all in the implementation of systemic process innovations. Further research is required to find out if vertical integration impacts positively on the management support required in the implementation of BIM and other systemic process innovations.

The Case Beta with the vertically integrated project network, however, included a couple of references that support the disadvantage stated in the model but none supporting the advantages. In Case Beta, the participants in different units seemed to be generally aware of the management support over the BIM implementation but the diverse support between different units by different types of managers was also noticed. The BIM coordinator in Case Beta described the issue in the feedback session in the following way:

> *"we have different types of people as managers, some are extremely careful and want to do things the same way as before, others are more innovative… but I guess most of them are more on the careful and safe side…"*[2]

Thus, different types of people as managers may have its effect on diverse support between different units which may hinder the overall implementation. In addition, varying economic situations of different integrated units were also found to impact the management support regarding the BIM implementation. The manager of the design team in Case Beta described the situation in the interview as follows:

> *"the earning power of the designers is not that good at the moment… it may not be the first thing in mind to invest in BIM development when the business of the unit is not that healthy…"*

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[2] All the quotes in the findings have been translated from Finnish to English by the author of this thesis.

As Munkvold (2003) suggested, the economic conditions may impact the implementation in different ways (see Table 6). Thus, a bad economic situation of a single integrated unit may impact the management support of that unit leading to diverse overall management support.

Table 16 illustrates how the findings impact the management support related advantages and disadvantages in the constructed theoretical model. In the table, the issues supported by the findings are marked in green whereas the issues not supported are marked in red. The new findings and additions are in bold green with larger font size.

Table 16: The findings related to the management support

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Management support	The role and actions of managers who have authority over issues and resources critical for the implementation	✓ Top management support over several integrated units at once ✓ Effective allocation of necessary resources between integrated units	✓ Broad management with differing managerial requirements, **different types of people as managers**, and **different economic situations of different integrated units** may lead to diverse support over different units

11.2 Coordination and control

The second structurally relevant implementation factor, *coordination and control*, refers to planning the implementation, coordinating and controlling the progress of the implementation over several projects. Based on the constructed theoretical model, the advantages of vertical integration related to the coordination and control are (1) *easier management of changing liability and contractual issues as there is no need to negotiate contracts*, (2) *ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion through the better coordination and control*, and (3) *stable relationships of different units reduce uncertainty, boundary strength and enable utilization of efficient processes*. The disadvantages are (1) *inflexibility to change partners or processes when needed*, (2) *broad management with differing managerial requirements may be difficult to coordinate and control*, and (3) *innovations are too complex and large to manage and coordinate under a single integrated firm*.

Most of the classified citations in both case studies were related to coordination and control issues. Case Alpha with the vertically disintegrated project network provided a strong support to the first two advantages of vertical integration in the model but did not provide any support to disadvantages or offer any new perspective to either of them. Case Beta with the vertically integrated project network, however, provided a strong support to most of the advantages and disadvantages in the model. These findings are presented in the following.

The first advantage, the easier management of changing liability and contractual issues in a vertically integrated project network was acknowledged in both case studies. In Case Alpha, the inflexible contracts between vertically disintegrated participants and the difficulty to define the new rules and needs for new work together was found to hinder the implementation of BIM. The scope of work defined at the beginning of the project for different participants proved to be too small later on in the project. For example, cost estimations based on the building information model were done too rarely and some secondary structure details needed by the main contractor were not modeled into the structural model because it was not in the scope of the structural design contract. The main contractor in Case Alpha described the issue in the interview in the following way:

> *"we thought we can get more or less everything modeled in the building information model… when the construction started, the structural engineer said that we wouldn't get the certain details in the model because it wasn't specified in the contract… we were really surprised…"*

In Case Beta, the flexible contracts between the vertically integrated participants proved to be beneficial in the implementation of BIM as the scope of work was easy the change when needed. The level of detail in the building information model was adjusted based on the need and resources during the project. The structural engineer in Case Beta described the advantage in the interview as follows:

> *"we defined really ambitious goals for the modeling… we wanted to have a large enough scope for the modeling and thought we could update the goals during the project… there were some issues with the schedule and resources but we were able to adjust the work accordingly…"*

The second advantage, the ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion in a vertically integrated project network was strongly acknowledged in both case studies. In Case Alpha, this appeared as difficulty for vertically disintegrated project network to utilize all the relevant participants as early in the project as would have been beneficial for BIM utilization. For example, the contractor perspective would have been beneficial right from the beginning of the project but it was difficult bring them in because of the required tendering processes. The owner in Case Alpha described the issue in the process simulation event in the following way:

> *"The goal setting for the project was a little bit different from usual projects… It was really unfortunate we couldn't get all the participants together at this point…"*

In Case Beta, the redistribution of new work created by the BIM implementation proved to be flexible between the vertically integrated units. For example, the structural engineer and the precast concrete designer could easily make adjustments in the distribution of work between them by negotiating together when needed. Similarly, it was easy to utilize the relevant participants in the project when needed as most of them were located in the same building. The MEP designer in Case Beta described the advantage in the interview as follows:

> *"in practice, the MEP and structural design can start at the same time with the architect if needed as we practically sit next to each other… I think this flexibility is an advantage for us… we all work for the same goal…"*

The third advantage, the stable relationships which reduce uncertainty, boundary strength and enable utilization of efficient processes was not acknowledged in either of the case studies. The reason behind this may be the fact that the case studies were based on single projects where BIM was being implemented. BIM is, however, such an extensive methodology that it needs several successive projects to be implemented. A study of several successive implementation projects could bring out the benefits related to the stable relationships or this issue may not be relevant at all in the implementation of BIM. The case studies of this study did not provide any new advantages related to the coordination and control either.

The first disadvantage, the inflexibility to change partners or processes when needed was briefly acknowledged in Case Beta. When implementing BIM, vertically integrated firm is stuck with the competence and experience of its own units. When all units start the implementation from scratch, it may prove to be even more difficult as all the participants need to learn the basics first. Ability to use more experienced external partners could boost the implementation. The development manager in Case Beta described the disadvantage regarding the partners in the interview in the following way:

> *"when two units are learning something new together, it may not be the best way to go… at some point we thought of having a project with a more experienced*

> *partner…we could test our practices first and later on offer better guidelines to our own units…"*

Thus, in Case Beta, this may not be an issue as the vertically integrated units in this case do business with external firms as well. But in vertically integrated firms where all the business is done between the integrated units, this may well be an issue when implementing a systemic process innovation. What comes to the inflexibility to change processes, it was not acknowledged in the case studies. Further examination of several successive implementation projects would be needed to find out if vertical integration impacts the ability to make the needed process changes as Harrigan (1984) suggested.

The second disadvantage, the broad management with differing managerial requirements which may be difficult to coordinate and control was also briefly acknowledged in Case Beta. The implementation of BIM requires the standardization of practices in different units and managers of these units are responsible to make it happen. According to Case Beta, different units, especially in different geographical locations usually have different working methods for various reasons. These diverse practices may not be that easy to unify even in a vertically integrated firm. The manager of the design team in Case Beta described the problem in the interview as follows:

> *"in one city they have learned to do things this way… and in another that way… and that's the reason why it's so difficult to find common working methods in a large company like this…"*

The third disadvantage, which states that systemic innovations are too complex and large to manage and coordinate under a single integrated firm, was clearly identified in Case Beta. Full utilization of BIM means that all the participants in a construction project implement and use it. However, there is no such a vertically integrated firm in the construction industry that integrates all the participants of the construction project. In Case Beta, the construction company included the owner, all the designers, and the main contractor but, for example, subcontractors and suppliers were external firms. Thus, the construction company has no direct control over subcontractors or suppliers regarding the BIM implementation. Similarly, as the integrated units use BIM with external firms as well, the common practices need to be developed with all of them individually which makes the implementation more complex. Thus, a vertically integrated firm needs to take both internal and external implementation into account. The BIM coordinator in Case Beta described the issue in the interview in the following way:

> *"the design team has been developing their BIM guidelines to be used with other firms as well which have introduced some contradictions with our own guidelines…"*

Table 17 illustrates how the findings impact the coordination and control related advantages and disadvantages in the constructed theoretical model.

Table 17: The findings related to the coordination and control

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Coordination and control	Planning the implementation, coordinating and controlling the progress of the implementation over several projects	✓ Easier management of changing liability and contractual issues as there is no need to negotiate contracts ✓ Ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion through the better coordination and control **and the shared location** ✓ Stable relationships of different units reduce uncertainty, boundary strength and enable utilization of efficient processes	✓ Inflexibility to change partners or processes when needed ✓ Broad management with differing managerial requirements and **geographical locations** may be difficult to coordinate and control ✓ Innovations are too complex and large to manage and coordinate under a single integrated firm, **thus, need to take both internal and external implementation into account**

11.3 Learning and experience

The third structurally relevant implementation factor, *learning and experience*, refers to user training and accumulation of learning and experience regarding the innovation. Based on the constructed theoretical model, the advantages of vertical integration related to the learning and experience are (1) *learning and experience proceed faster between integrated units*, (2) vertical integration *enables cumulative learning through the possibility to transfer the same organization and expertise from one project to another which reduces the organizational variety*, and (3) vertical integration *enables feedback loops and cross-pollination of ideas between different units*. The disadvantage is that vertical integration *may prevent access to external research, know-how, and relevant capabilities related to the innovation*.

Both case studies supported the advantages and the disadvantage related to learning and experience in the model. Case Alpha with the vertically disintegrated project network provided support especially to the second advantage of cumulative learning and the disadvantage of preventing access to external knowledge. Case Beta with the vertically integrated project network supported all the advantages and the disadvantage in the model. Neither case, however, introduced any new perspective to the model. The findings are presented in the following.

The first advantage, learning and experience proceed faster between integrated units was briefly identified in Case Beta. The different design units felt that in addition to their own learning during the project, they had gained a vast amount of learning and experience from the holistic process and each other during the single project. The structural engineer in Case Beta described the learning in the interview as follows:

> *"we have learned a lot from BIM during this project… and especially the common understanding about the holistic modeling process has been increasing… within all the design disciplines… I think it's a clear benefit for us…"*

The second advantage, cumulative learning through the possibility to transfer the same organization and expertise was acknowledged in both cases. In Case Alpha, different participants mentioned that it would be beneficial to continue with the same team in another project which would allow the learning and experience related to the BIM implementation to accumulate even further. The architect in Case Alpha described the issue in the interview in the following way:

> *"we had really good experiences from this project… now, if we could do another project with the same team, it would be so easy and we could learn even more…"*

In Case Beta, the benefits of cumulative learning were acknowledged in the company and the plan was to use the same team in the following BIM project. The actual realized benefits could not, however, be studied as the case studies of this study included only two single projects from two different environments and not successive projects. The architect in Case Beta described the advantage in the interview as follows:

> *"we just had a kick-off meeting of the next BIM project and it seems that we'll continue with the same team… it would be stupid to break up the team and start from the beginning… I think we have an advantage here…"*

The third advantage, which states that vertical integration enables feedback loops and cross-pollination of ideas between different units, was briefly identified in Case Beta. The vertically integrated firm used feedback sessions which ensured that learning and experience from the project would flow between different units. These sessions provided also important feedback and new ideas for planning the next BIM project. The BIM coordinator in Case Beta described the issue in the feedback session in the following way:

> *"we organize feedback sessions where we gather the relevant people and ask them what worked and what didn't in the project… It's a sort of debriefing session regarding the BIM experiences…"*

The disadvantage of preventing access to external research, know-how, and relevant capabilities was clearly identified in both cases. In Case Alpha, it was easy for the vertically disintegrated project network to gather a proper team with relevant competence and experience for the project as the team members could be chosen based on their capabilities in the tendering process. The owner in Case Alpha described the issue in the interview as follows:

> *"we asked from different design firms if they had capabilities and resources to do this project… and then put it out to tender and started to plan and prepare the project…"*

In Case Beta, the vertically integrated firm executed the project with its integrated units that had the given competence level at the time. Thus, the project team was not formed based on the competence level which did not give the best possible starting point for the implementation project. The structural engineer in Case Beta described the situation in the interview in the following way:

> *"well, my own BIM competence was probably not at the level it should have been when the project started… and it was sometimes difficult to try to solve the problems on my own…"*

In this case, however, accessing external research and know-how was not considered as a problem as the integrated units do business with external firms as well and participate in interorganizational research projects. The vertically integrated firm also collaborated with software firms in the project in order to gain relevant BIM competence. But in vertically integrated firms where all the business is done between the integrated units, this may well be an issue when implementing a systemic process innovation. At least the participation in interorganizational research projects should be considered.

Table 18 illustrates how the findings impact the learning and experience related advantages and disadvantages in the constructed theoretical model.

Table 18: The findings related to the learning and experience

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Learning and experience	User training and accumulation of learning and experience regarding the innovation	✓ Learning and experience proceed faster between integrated units ✓ Enables cumulative learning through the possibility to transfer the same organization and expertise from one project to another which reduces the organizational variety ✓ Enables feedback loops and cross-pollination of ideas between different units	✓ May prevent access to external research, know-how, and relevant capabilities related to the innovation

11.4 Technology management

The fourth structurally relevant implementation factor, *technology management*, refers to managing technological issues related to the existing technology and the innovation to be implemented. Based on the constructed theoretical model, the advantages of vertical integration related to the technology management are (1) *jointly selected systems and software platform ensure interoperability between integrated units and compatibility with existing technologies*, (2) *possibility to experiment with technology between integrated units*, and (3) *possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units*. The disadvantages are (1) *relevant technological capabilities may exist outside* and (2) vertical integration *may prevent from perceiving technological advances in the market*.

The technology management related issues were the second most cited issues in the case studies. Both case studies provided a strong support to all three advantages of vertical integration in the model but did not provide any support to the two disadvantages. However, Case Beta introduced an additional disadvantage which was stiffness and slowness of centralized IT department and bureaucracy. These findings are presented in the following.

The first advantage of jointly selected systems and software platform was identified in both case studies. In Case Alpha, there were problems with transferring data between the building information models of different design disciplines. The problem of interoperability should have been solved by the IFC but in this case the IFC development was still at underdeveloped stage. Thus, the usage of inherently interoperable software would have decreased the problems. The architect in Case Alpha described the problem in the interview as follows:

> *"the biggest disappointment was probably that we couldn't exploit the model when we wanted to… not because of our own problems or problems with the other designer… but because of IFC problems… it was really frustrating because we all were ready to go forward…"*

In Case Beta, the vertically integrated units made a decision together to use specific systems and software in order to make the project as easy as possible. For example, the precast concrete designer was used to work with specific software but agreed to change it because the other software was better from the holistic perspective. The structural engineer in Case Beta described the situation in the interview in the following way:

> *"we decided together which software and which version we would use in the project… we made the decision in concert with others…"*

The second advantage, the possibility to experiment with technology between integrated units, was briefly identified in both case studies. In Case Alpha, the participants acknowledged the difficulty of experimenting with technology between different firms. In order for BIM to diffuse successfully in a vertically disintegrated environment, the working methods between different firms should be similar and standardized in a way that experiences with one firm could be used with others. The architect in Case Alpha described the issue in the interview as follows:

> *"we don't have established working methods with other design disciplines regarding BIM yet… the interorganizational working methods should be simple and standardized in order for [BIM] to diffuse… otherwise it's going to be a method only for vertically integrated firms or solid alliances…"*

In Case Beta, the vertically integrated units were able to test the technology together and find the best combinations and working methods. The MEP designer in Case Beta described the advantage in the interview in the following way:

> *"we've had a lot of internal tests on how to get the information transferred between different models… we have experimented with different programs and found the best ways to do things at the moment…"*

The third advantage, possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units was identified in both case studies as well. In

Case Alpha, the vertically disintegrated firms found it difficult to establish shared guidelines and databases together. The cost estimator in Case Alpha described the issue in the interview as follows:

> *"we still don't have common databases for component price levels in the construction industry… individual firms have their own restricted databases… but we need a common database that everyone could use…"*

In Case Beta, the vertically integrated firm had developed internal databases and product libraries for its own use. They were also developing a company-wide supporting infrastructure with guidelines and processes regarding BIM. Even though the integrated firm does business with external firms as well, they found it difficult to develop the supportive infrastructure to be used with the external firms as well. The MEP development manager in Case Beta described the issue in the interview in the following way:

> *"there's no way we could use these product libraries and databases with external firms at the moment… there's enough work with our own units…"*

Regarding the disadvantages related to technology management, neither case provided any reference supporting the two disadvantages in the constructed theoretical model. The reason behind this may be the fact that the technology related to BIM, and other systemic process innovations as well, is usually available in open market. When it comes to process technologies, the technology itself is rarely a source of competitive advantage but rather how the firm is able to utilize it.

Case Beta, however, introduced an additional disadvantage of vertical integration related to technology management; stiffness and slowness of centralized IT department and bureaucracy. In Case Beta, there emerged new needs for software tools such as model checkers and model viewers to be used in different units during the project. The problem was that these tools could not be installed on time because of stiff and slow centralized IT department and related bureaucracy. The few people that had these tools installed could of course do the work needed but the wider inability to use these tools hindered the implementation and learning in the project. The architect in Case Beta described the problem in the interview as follows:

> *"there's a lot of pressure in our IT department at the moment… and I guess our needs are not the top priority there at the moment… sometimes it takes months to get new programs installed…"*

Table 19 illustrates how the findings impact the technology management related advantages and disadvantages in the constructed theoretical model.

Table 19: The findings related to the technology management

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Technology management	Managing technological issues related to the existing technology and the innovation to be implemented	✓ Jointly selected systems and software platform ensure interoperability between integrated units and compatibility with existing technologies ✓ Possibility to experiment with technology between integrated units ✓ Possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units	✓ Relevant technological capabilities may exist outside ✓ May prevent from perceiving technological advances in the market ✓ **Stiffness and slowness of centralized IT department and bureaucracy**

11.5 Communication

The fifth structurally relevant implementation factor, *communication*, refers to distributing information about the innovation and its implementation. Based on the constructed theoretical model, the advantages of vertical integration related to the communication are (1) *faster and more accurate information flow between integrated units*, (2) *easier and safer exchange of information between integrated units*, and (3) *more efficient communication through a developed internal coding system*. The disadvantage is that the *increased hierarchical levels and spans of control may lead to accidental or even deliberate communication distortion*.

Case Alpha with vertically disintegrated project network did not include any references that would support the advantages or disadvantages of vertical integration presented in the constructed theoretical model. Case Beta with vertically integrated project network, on the other hand, included plenty of references related to the communication. Case Beta provided strong support to the first two advantages and the disadvantage presented in the constructed theoretical model but also introduced new perspectives to these issues. The findings are presented in the following.

The first two advantages, faster and more accurate information flow and easier and safer exchange of information between integrated units, were both clearly identified in Case Beta. These two advantages were combined during the analysis as they were so close to each other. The role of shared location was, however, highlighted to be the main source of these advantages. All the designers in Case Beta felt that the shared location enables easier and faster information exchange between the integrated units. In addition to easier and faster formal communication between the units, the shared location enables especially easier informal communication which was found to be beneficial in the implementation of BIM. The architect in Case Beta described the advantage in the interview in the following way:

> *"when we are in the same building, it is so easy to go to talk with another designer… it takes two minutes and you are solving the problem together… or you can discuss about different issues on a coffee break… it's a great advantage…"*

The third advantage, more efficient communication through a developed internal coding system, was not identified in the case studies. The reason behind this may be the fact that BIM was such a new issue in the cases and the internal coding system related to BIM was not developed yet. Further research of successive projects with the same team would possibly reveal if this is an advantage for vertically integrated firms.

The disadvantage of increased hierarchical levels and spans of control which may lead to accidental or even deliberate communication distortion was identified in Case Beta with a new perspective of "sibling envy" caused by the independence of integrated units. Interestingly, the BIM coordinator in Case Beta felt that it is sometimes easier to work with external firms. For some reason the independence of integrated units caused "sibling envy" between them which resulted in unwillingness to share certain information and also some degree of change resistance. The BIM coordinator in Case Beta described the problem in the feedback session as follows:

> *"some things are easier with internal units… but new ideas are easier to sell to external partners… I don't know, it's some kind of a love-hate relationship between us… when they found new benefits from BIM, they didn't want to share them with us but rather keep it as a secret… it was surprising…"*

The communication in a vertically integrated firm may be also taken for granted which can lead to accidental communication distortion. In Case Beta, the participants felt that it was not always clear why different things were done during the implementation project. Some participants also felt that their feedback was not being noticed which caused some frustration. The BIM coordinator in Case Beta described the issue in the feedback session as follows:

> *"maybe we were just pushing things forward so fast… and people forgot why we are really doing these things… maybe some things were taken for granted and that's why it was unclear… this needs to change in the future…"*

Table 20 illustrates how the findings impact the communication related advantages and disadvantages in the constructed theoretical model.

Table 20: The findings related to the communication

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Communication	Distributing information about the innovation and its implementation	✓ **Shared location** enables faster and more accurate information flow and easier and safer exchange of information between integrated units **in formal and informal way** ✓ Enables more efficient communication through a developed internal coding system	✓ Increased hierarchical levels and spans of control or **independence of units** may lead to accidental or even deliberate communication distortion and **"sibling envy"**

11.6 Motivation

The sixth structurally relevant implementation factor, *motivation*, refers to getting people motivated and committed through goal setting and identifying the need for change. Based on the constructed theoretical model, the advantages of vertical integration related to the motivation are (1) *development of trust, solidarity, and communal spirit between integrated units* and (2) *ability to understand shared interests and holistic goals can motivate units that do not directly benefit from the innovation*. The disadvantage is that the *absent internal competition may decrease motivation to change*.

The case studies included only a few references related to the motivation issues. Both case studies supported the second advantage of understanding shared interests but neither one of them supported the first advantage of developing trust or the disadvantage of the absent internal competition. The reason behind this may be the fact that these issues are not relevant in the implementation of BIM or they could not be seen in only one implementation project. As the implementation of BIM needs several implementation projects, a study of these several successive projects could bring out evidence related to the advantage of developing trust or the disadvantage of absent internal competition. Any new perspective related to the motivation was not found from the cases either.

Both case studies supported the second advantage which states that the ability to understand shared interests and holistic goals can motivate units that do not directly benefit from the systemic innovation. In Case Alpha, it became clear that there are conflicts of interests between different vertically disintegrated firms regarding the BIM utilization. A firm may not have motivation to do extra work if it is not paid for even if other firms would benefit from it. For example, the owner may not want to pay for the designers to take the building information models to the level of detail that is required by the main contractor. Thus, the main contractor needs to do extra work in order to be able to utilize the building information models and this extra work may not be included in the contracts. The architect in Case Alpha described the issue in the interview as follows:

> *"when we start using BIM, it means extra work for us... and someone's going to benefit from that extra work... there are different beneficiaries... but somehow we should get paid for that benefit..."*

In Case Beta, the benefits for others was seen as a source for motivation especially when own benefits from BIM remained more or less unclear. For example, the structural engineer did not see the clear benefits from BIM in his own work but knowing that it would help others in the same integrated firm gave him extra motivation in the implementation. The structural engineer in Case Beta described the advantage in the interview in the following way:

> *"there has to be another unit that benefits from this... otherwise it doesn't make any sense... of course it motivates us... you can't stop when you encounter the first problem because someone else relies on you..."*

Table 21 illustrates how the findings impact the motivation related advantages and disadvantages in the constructed theoretical model.

Table 21: The findings related to the motivation

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Motivation	Getting people motivated and committed through goal setting and identifying the need for change	✓ Enables trust, solidarity, and communal spirit to develop between integrated units ✓ Ability to understand shared interests and holistic goals can motivate units that do not directly benefit from the innovation	✓ Absent internal competition may decrease motivation to change

11.7 Additional factor: Defining roles

In addition to the six implementation factors in the constructed theoretical model, the empirical data introduced one advantage and one disadvantage of vertical integration related to an additional structurally relevant implementation factor; *defining roles*. Defining roles was one of the success factors in the original framework introduced by Salminen (2000) (see Table 5) but it was not included in the constructed theoretical model because it was not supported by other theories related to the advantages and disadvantages of vertical integration and the implementation of systemic process innovations.

Thus, the seventh structurally relevant implementation factor, *defining roles*, refers to defining the needed roles and organization during the implementation of a systemic innovation. Based on the empirical data, the advantage of vertical integration related to defining roles is *easier definition and fulfillment of the new roles needed in the implementation from the holistic perspective*. The disadvantage, however, is that *"buck passing" may emerge which means that everything related to the implementation is pushed to a new role.* Both case studies included references related to the advantage of easier definition and fulfillment of new roles but only Case Beta provided evidence related to the disadvantage of "buck passing". The findings are presented in the following.

The empirical data suggests that it is easier to define and fulfill the new roles needed in the implementation from the holistic perspective in a vertically integrated project network. One essential emerging new role in the case studies was a so-called BIM coordinator who is responsible for managing the tools and processes related to the BIM utilization from the holistic perspective. In Case Alpha, there was a BIM team that was formed to solve BIM problems during the project but this team solved mainly the emerging technological interoperability issues and did not guide the implementation from the holistic point of view. The BIM coordinator role could have been suitable for the project consultant but he did not have the competence or will to take the role. Thus, the fragmentation in the vertically disintegrated project network made it difficult to fulfill the new role needed in the implementation.

In Case Beta, however, it was easier to define and fulfill the new role of BIM coordinator during the project. The role was not predefined but rather emerged during the implementation and the scope of the role increased based on the needs emerged in the project. In the end, the role of BIM coordinator was seen crucial especially during the BIM implementation. The design team planned to have a designer as a BIM coordinator as well in the next project. It was acknowledged, however, that as the BIM becomes the established practice the separate role of BIM coordinator may not be needed anymore and the tasks of the role will be done by different participants themselves. The BIM coordinator in Case Beta described the issue in the feedback session as follows:

> *"my role was not a planned BIM coordinator role… I just did the necessary things in order for [BIM] to work from the holistic perspective… The scope of my tasks increased based on the needs that emerged during the project…"*

The empirical data also introduced a disadvantage of "buck passing" in the vertically integrated project network in Case Beta which means that everything related to the implementation is pushed to a new role and others do not want to take any responsibility. According to the empirical data, the new role of BIM coordinator emerged as some kind of a miracle worker and the more the BIM coordinator did things for the different participants in order to facilitate the implementation, the more they expected the BIM coordinator to do for them. The BIM coordinator in Case Beta described the issue in the feedback session in the following way:

> *"BIM coordinator did pretty much all the model checking, merging and clash detections in the project… it's not normal, the designers should do them… the more you do for them, the more they expect you to do for them… the roles and tasks were totally blurred…"*

Table 22 on the following page illustrates how all the findings impact the constructed theoretical model. In addition to the six original structurally relevant implementation factors, an additional implementation factor, defining roles, is introduced. Related to the defining roles, there is a new advantage and a new disadvantage introduced to the model. The findings also introduce a totally new disadvantage related to the technology management in the model. Otherwise, the findings either supported or did not support the advantages and disadvantages in the original constructed theoretical model. In some cases, the findings also introduced some new additions to the existing advantages and disadvantages.

In the following chapter, the constructed theoretical model is refined into an improved theoretical model based on these findings. The improved theoretical model will represent a more simple and illustrative model which describes the role of vertical integration when implementing BIM.

Table 22: The impact of the findings in the constructed theoretical model[3]

Factor in implementation	Definition	Advantages of vertical integration	Disadvantages of vertical integration
Management support	The role and actions of managers who have authority over issues and resources critical for the implementation	✓ Top management support over several integrated units at once ✓ Effective allocation of necessary resources between integrated units	✓ Broad management with differing managerial requirements, **different types of people as managers**, and **different economic situations of different integrated units** may lead to diverse support over different units
Coordination and control	Planning the implementation, coordinating and controlling the progress of the implementation over several projects	✓ Easier management of changing liability and contractual issues as there is no need to negotiate contracts ✓ Ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion through the better coordination and control **and the shared location** ✓ Stable relationships of different units reduce uncertainty, boundary strength and enable utilization of efficient processes	✓ Inflexibility to change partners or processes when needed ✓ Broad management with differing managerial requirements and **geographical locations** may be difficult to coordinate and control ✓ Innovations are too complex and large to manage and coordinate under a single integrated firm, **thus, need to take both internal and external implementation into account**
Learning and experience	User training and accumulation of learning and experience regarding the innovation	✓ Learning and experience proceed faster between integrated units ✓ Enables cumulative learning through the possibility to transfer the same organization and expertise from one project to another which reduces the organizational variety ✓ Enables feedback loops and cross-pollination of ideas between different units	✓ May prevent access to external research, know-how, and relevant capabilities related to the innovation
Technology management	Managing technological issues related to the existing technology and the innovation to be implemented	✓ Jointly selected systems and software platform ensure interoperability between integrated units and compatibility with existing technologies ✓ Possibility to experiment with technology between integrated units ✓ Possibility to establish shared supportive infrastructure, guidelines, and feedback mechanisms for all integrated units	✓ Relevant technological capabilities may exist outside ✓ May prevent from perceiving technological advances in the market ✓ **Stiffness and slowness of centralized IT department and bureaucracy**
Communication	Distributing information about the innovation and its implementation	✓ **Shared location** enables faster and more accurate information flow and easier and safer exchange of information between integrated units **in formal and informal way** ✓ Enables more efficient communication through a developed internal coding system	✓ Increased hierarchical levels and spans of control or **independence of units** may lead to accidental or even deliberate communication distortion and **"sibling envy"**
Motivation	Getting people motivated and committed through goal setting and identifying the need for change	✓ Enables trust, solidarity, and communal spirit to develop between integrated units ✓ Ability to understand shared interests and holistic goals can motivate units that do not directly benefit from the innovation	✓ Absent internal competition may decrease motivation to change
Defining roles	**Defining the needed roles and organization during the implementation**	✓ **Easier to define and fulfill the new roles needed in the implementation from the holistic perspective**	✓ **"Buck passing" may emerge which means that everything related to the implementation is be pushed to a new role**

[3] The advantages and disadvantages supported by the findings are marked in green whereas the ones not supported are marked in red. The new findings and additions are in bold green with larger font size.

12 Improved theoretical model

This chapter presents the improved theoretical model based on the findings of this study. The improved theoretical model is a more simple and illustrative representation of the original constructed theoretical model with the changes and additions introduced by the empirical research. The advantages and disadvantages in the model that were not supported by the empirical data are still kept in the improved theoretical model as the determination of their relevance would require further research. The improved theoretical model is presented in Figure 18 on the following page.

The framework illustrates the advantages and disadvantages of vertical integration in BIM implementation. It presents seven implementation factors which all have both advantages and disadvantages created by the vertically integrated project network structure when implementing BIM. These structurally relevant implementation factors are (1) *management support*, (2) *coordination and control*, (3) *learning and experience*, (4) *technology management*, (5) *communication*, (6) *motivation*, and (7) *defining roles*.

Management support is a vital element in all implementation efforts. Vertical integration may affect positively on gaining broad management support when implementing BIM and other systemic process innovations as the top management support can be achieved at once over several integrated units. Similarly, these managers have the authority over critical resources for the implementation, and thus, vertical integration may enable more effective allocation of these resources from the holistic perspective. The disadvantage is, however, that broad management in a vertically integrated firm may lead to diverse support over different integrated units. This diverse support may arise from different types of managerial backgrounds and varying economic situations of different integrated units.

Coordination and control is essential in BIM implementation where different actors need to change and adjust simultaneously. Vertical integration facilitates this kind of mutual adjustment as it is easier to manage the emerging liability and contractual issues when different actors are under the same firm. Vertically integrated firm can also make needed adaptations, adjustments, and redistribution of work more efficiently and in time especially when the integrated units are located in shared facilities. Stable relationships of the integrated units also reduce uncertainty and boundary strength, and thus, possibly enable the utilization of more efficient processes in the long run.

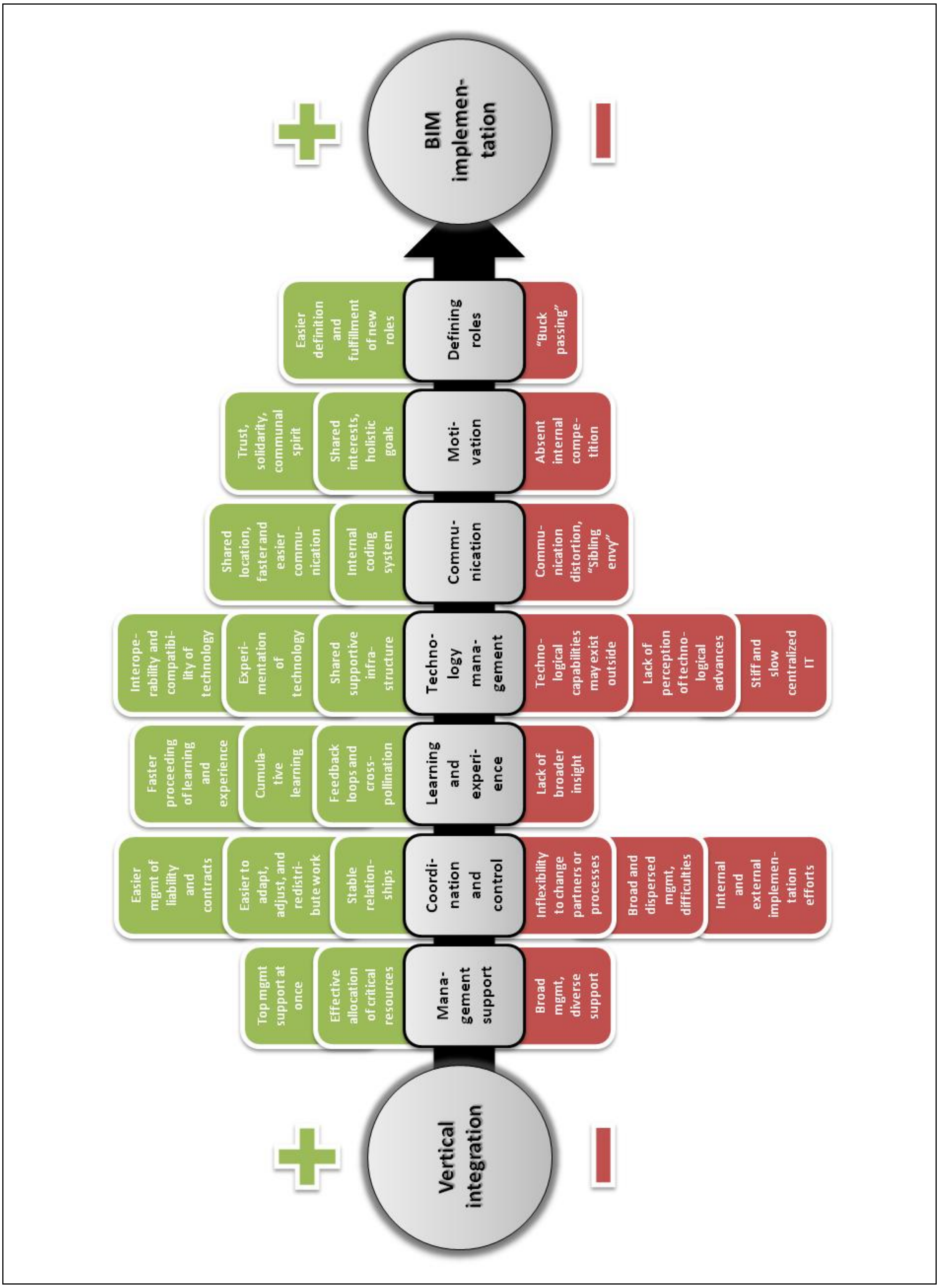

Figure 18: Improved theoretical model – The advantages and disadvantages of vertical integration in BIM implementation

As a disadvantage, vertical integration may create inflexibility to change partners or established processes when needed in the implementation. Also, the broad and geographically dispersed management in a vertically integrated firm may introduce additional coordination and control difficulties. Finally, BIM is too complex and large to manage under a single integrated firm alone, and thus, a vertically integrated firm needs to take both internal and external issues into account in the implementation, especially when also doing business with external firms.

Learning and experience accumulation is especially important in BIM implementation as several successive implementation projects are needed in the process. In vertically integrated firms, learning and experience proceed faster between integrated units as they interact with each other also in other occasions than just the implementation project. Vertical integration also enables cumulative learning through the possibility to transfer the same people and expertise from one implementation project to a next. Under a single integrated firm, it is also easier to enable feedback loops and cross-pollination of ideas between different integrated units which will promote the implementation. As a downside, however, vertical integration may prevent access to external knowledge and capabilities related to BIM causing the lack of broader insight. This can be overcome by participating in interorganizational research projects and collaborating with external firms.

Technology management is a central implementation factor in BIM implementation where there are various technologies that need to be interoperable with each other. Vertically integrated firm can jointly select the software tools to be used in order to ensure the interoperability between different integrated units and the compatibility with existing technologies. Integrated units in a vertically integrated firm can also more easily experiment with the technology before making the final decisions. In addition, a vertically integrated firm can establish a shared supportive infrastructure for BIM with detailed guidelines and feedback mechanisms which will make the implementation efforts easier in the long run. Vertical integration can, however, introduce some disadvantages as well. Relevant technological capabilities related to BIM may exist outside or vertical integration may prevent from perceiving technological advances related to BIM in the market. These problems can probably be solved with broader collaboration with external firms. More practical problem, however, can be the stiffness and slowness of the centralized IT department and bureaucracy in a vertically integrated firm which could seriously hinder the implementation efforts. For example, the installation of the needed software tools may take too long which affects the schedule and learning in the implementation project.

Communication is a basic factor in BIM implementation as information about BIM and the changes introduced by the implementation need to be distributed to all relevant actors regularly. Vertical integration facilitates communication as especially the shared location enables faster and easier information exchange between different integrated units in both formal and informal way. Vertically integrated firms are often also able to develop an internal coding system which may enable more efficient communication in the long run. The downside, however, is that increased hierarchical levels and spans of control may lead to independence of units which may cause communication distortion and even “sibling envy”. The communication distortion may be accidental when things are taken for granted in large organization or even deliberate caused by “sibling envy” between different integrated units.

Motivation is especially important factor in BIM implementation as the benefits of BIM may not be equally distributed in a project network. Vertical integration may affect the motivation in positive and negative ways. Trust, solidarity, and communal spirit often develop within vertically integrated firms, and these can impact the motivation positively. But more specifically, the ability to understand and have shared interests and holistic goals will motivate even those integrated units that do not directly benefit from BIM. The downside may be that the absent internal competition between integrated units may decrease the general motivation to change and implement new things.

Finally, *defining roles* in BIM implementation is crucial as the needed roles and the organization during the implementation need to be defined in order for the implementation to be successful. In addition, there has emerged a need for a boundary spanning role of BIM coordinator who is responsible for coordinating the BIM implementation from the holistic perspective. In a vertically integrated firm, it may be easier to define possible new roles needed during the implementation as they can better understand the needs for a new role from the holistic perspective. Also, these roles, especially boundary spanning roles, are probably easier to fulfill as there is no need to negotiate all the details with other units to make it happen. The disadvantage may be, however, that once this kind of a new role has been established, everything related to the BIM implementation is pushed to this new role in a vertically integrated firm, and thus, causing “buck passing” which may hinder the overall implementation efforts.

In the following Part V, the findings of this Master’s Thesis are discussed by presenting the conclusions and further implications of this study.

V DISCUSSION

"Success is neither magical nor mysterious. Success is the natural consequence of consistently applying the basic fundamentals."
– Jim Rohn (born 1930)

This is the final and concluding part of this Master's Thesis. The part consists of five chapters. First, the findings of this study will be concluded (Chapter 13). Second, the theoretical and managerial implications of this study will be discussed (Chapters 14 and 15). Third, the validity and reliability of this study will be evaluated (Chapter 16). Finally, some topics for future research will be proposed (Chapter 17).

13 Conclusions

The objective of this Master's Thesis was to examine the advantages and disadvantages of vertical integration when implementing BIM, an example of a systemic process innovation. The study was conducted with a constructive research approach in a multiple case study setting. The initial research problem was first approached by an extensive literature review. The literature review included theories from the advantages and disadvantages of vertical integration, and the implementation of systemic process innovations. Based on the literature review, a constructed theoretical model and a detailed research question were formed and later tested with the empirical data from two opposite case studies with vertically integrated and disintegrated project networks. The vertically integrated case was used as a primary case study offering the perspective to vertical integration and the vertically disintegrated case supported the findings from the opposite view. In order to test the original constructed theoretical model, the following detailed research question was formulated:

RQ*: What are the structurally relevant BIM implementation factors and the related advantages and disadvantages of vertical integration?*

Based on the findings, there are seven structurally relevant BIM implementation factors; management support, coordination and control, learning and experience, technology management, communication, motivation, and defining roles. The case studies provided diverse support to different advantages and disadvantages related to these seven implementation factors. The few findings related to the *management support* did not support the two advantages presented in the original constructed theoretical model. These were the top management support over several integrated units at once, and effective allocation of resources between integrated units. Further research would be required in order to specify the significance of these two advantages. The findings, however, supported the disadvantage whereby the broad management with differing managerial requirements may lead to diverse support over different units. Instead of differing managerial requirements, the different types of people as managers and varying economic situations of different integrated units emerged to be the sources of diverse management support which may have negative implications for the overall implementation of BIM.

The findings related to the *coordination and control* supported the advantages of vertical integration related to the easier management of changing liability and contractual issues, and the ability to make adaptations, adjustments, and redistribution of work in a timely and efficient fashion which is facilitated especially by the shared location. The findings, however, did not support the advantage of stable relationships, and thus further research is needed. Regarding the disadvantages, the findings supported all three disadvantages in the original constructed theoretical model except the inflexibility to change processes as a part of the first disadvantage. In the issue of broad management, the findings highlighted the diverse geographical locations as a source of coordination and control difficulties. Finally, as BIM spans more broadly than just within the vertically integrated firm, both internal and external implementation need to be taken into account which makes the implementation more complex for vertically integrated firms.

In *learning and experience*, the findings supported all the advantages and the disadvantage presented in the original constructed theoretical model. The findings especially highlighted the advantage of cumulative learning and the disadvantage of not accessing relevant capabilities. The other two advantages in the model were faster proceeding of learning and experience, and feedback loops and cross-pollination between integrated units. The findings did not provide any new perspective related to the learning and experience issues in the model either.

The findings related to the *technology management* supported all the advantages of vertical integration in the original constructed theoretical model. These advantages were ensuring the interoperability through joint selection of software, experimenting with technology, and establishing shared supportive infrastructure. The findings, however, did not support the two disadvantages which stated that technological capabilities may exist outside, or that vertical integration may prevent from perceiving technological advances in the market. These would require further research. However, the findings introduced an additional disadvantage of vertical integration which was stiffness and slowness of centralized IT department and bureaucracy. The inability to make quick adjustments in the IT environment of a vertically integrated firm may hinder the implementation of BIM.

In *communication*, the findings supported the advantages of vertical integration related to faster and easier exchange of information between the integrated units but highlighted the shared location as a source for these advantages. The findings, however, did not support the advantage of more efficient communication through a developed internal coding system, and thus, would require more longitudinal research. The findings also supported the disadvantage of increased hierarchical levels and spans of control which may lead to accidental or even deliberate communication distortion. Here, accidental communication distortion may arise because communication is taken for granted in a vertically integrated firm. Similarly, deliberate communication distortion may arise from “sibling envy” caused by the independence of different integrated units.

The findings related to the *motivation* supported only the advantage of understanding the shared interests and holistic goals. The advantage of developing trust and solidarity, and the disadvantage of absent internal competition were not supported by the empirical data, and thus, need further research. The emergence of new work and the need to redistribute work in BIM implementation may cause conflicts of interests between different participants, and thus, decrease motivation. This issue seems to be easier to handle in a vertically integrated firm as understanding the shared interests and holistic goals can motivate those integrated units that do not directly benefit from BIM.

The findings also introduced an additional structurally relevant implementation factor that was not in the original constructed theoretical model, *defining roles*. The advantage related to defining roles was that it is easier to define and fulfill the new roles needed in BIM implementation from the holistic perspective in vertically integrated project network. The disadvantage is, however, that “buck passing” may emerge in vertically integrated project network which means that everything related to the implementation may be pushed to a new role, and thus, hindering the implementation.

Based on the empirical analysis, an improved theoretical model was formed in Chapter 12 which provided the final answer to the research question of this study. The unconfirmed advantages and disadvantages were also included in the improved theoretical model as it would require further research to determine their significance in the implementation of BIM.

14 Theoretical implications

The theoretical objective of this study was to create a novel constructed theoretical model based on the previous literature providing a solution for the overall research problem. The empirical data from the case studies was analyzed against this constructed theoretical model in order to give new theoretical contribution to the field. The model combined the theories of vertical integration and the implementation of systemic process innovations in a new way reinforcing them and providing new insight into these areas. The study especially complements the area of systemic process innovations where there has been only little previous research. Above all, this study contributes to the complex and current field of BIM implementation in the construction industry.

The model introduced seven structurally relevant implementation factors with related advantages and disadvantages of vertical integration. These factors were management support, coordination and control, learning and experience, technology management, communication, motivation, and defining roles. The findings related to the advantages and disadvantages in these factors both reinforced the previous knowledge and provided new knowledge. Some of the advantages and disadvantages in the model could not be confirmed in the empirical research. These could not, however, be challenged by the empirical data either, and therefore, they were kept in the improved theoretical model. In order to determine the significance of these unconfirmed issues, further research is needed.

Related to the implementation factor of management support, the findings reinforced the disadvantage of diverse management support caused by broad management, originally introduced by Blois (1972) and Porter (1980). In addition to differing managerial requirements, the findings introduced different types of people as managers and varying economic situations of different integrated units as sources for the diverse management support.

In the implementation factor of coordination and control, the results verified the advantage of easier management of changing liability and contractual issues by Harrigan (1984), Krippaehne et al. (1992), and Taylor (2007), and the advantage of ability to make efficient and timely adjustments by Armour and Teece (1980), Teece (1996), Winch (1987; 1989a), and

Taylor (2007). The shared location in increasing this ability was emphasized in the case studies. The results were also in line with all the disadvantages in the model. These were inflexibility to change partners by Blois (1972), Porter (1980), and Winch (1987; 1989a), the difficulties in coordinating and controlling the broad management by Blois (1972), Porter (1980), and Mahoney (1992), and the complexity and largeness of a systemic innovation to coordinate under a single firm by De Laat (1999) and Maula et al. (2006). In the difficulties in coordinating and controlling the broad management, the diverse geographical locations were highlighted in the case studies. The complexity and largeness of BIM, however, introduced another layer of complexity for vertically integrated firms as they need to take both internal and external implementation efforts into account.

Regarding the learning and experience, the findings validated all the advantages and disadvantages in the model. These were the advantage of faster proceeding of learning and experience by Langlois and Robertson (1989) and Langlois (1992), cumulative learning from project to project by Winch (1987; 1989a) and Taylor and Levitt (2004), and feedback loops and cross-pollination of ideas by Winch (1987; 1989a) and Taylor (2007). The disadvantage of preventing access to external knowledge and capabilities by Porter (1980), Harrigan (1984), Teece (1996), and Krippaehne et al. (1992) was also supported by the findings.

Related to the implementation factor of technology management, the results confirmed all the advantages in the model. These were the easier ensuring of interoperability and compatibility of technologies by Munkvold (2003) and Taylor (2007), the possibility to experiment with technology by Taylor (2007), and the easier establishment of shared supportive infrastructure by Nadler (1981) and Munkvold (2003). In addition, the findings introduced a totally new disadvantage of stiff and slow centralized IT department and bureaucracy which hindered the implementation of BIM in vertically integrated project network. It would require further research to investigate whether or not this was a case-specific issue or more general problem of vertically integrated firms. However, the increased hierarchical levels and bureaucracy in vertically integrated organizations certainly support the finding.

In the implementation factor of communication, the findings reinforced the advantage of faster and easier information exchange by Porter (1980), Teece (1996), and Gopalakrishnan and Bierly (2001). Especially the shared location in enabling faster and easier communication in both formal and informal way was emphasized in case studies. The disadvantage of accidental and deliberate communication distortions by Mahoney (1992) was also supported by the findings with some new perspectives. First of all, the communication may be taken for granted in a vertically integrated organization which can cause accidental communication distortion. In addition, the independence of integrated units may lead to “sibling envy” between different units which can cause deliberate communication distortion. This again could have been case-specific issue, and thus, would need further research. According to Khoja (2008), “sibling rivalry” should actually have positive influence on the innovativeness and efficiency of different units. Khoja (2008) proposes that the greater the competition between different units, the greater the innovation and performance. In this case, however, the integrated units were not competing against each other which makes the situation different.

Regarding the motivation, the results validated the advantage of motivating units that do not directly benefit from the systemic innovation by understanding shared interests and holistic goals by Taylor (2007). Other advantages or disadvantages related to motivation were not found in the empirical research.

Finally, related to the emerged implementation factor of defining roles, the findings provided new knowledge to both advantages and disadvantages of vertical integration. As an advantage, it seems to be easier for a vertically integrated firm to define and fulfill the new roles needed in the implementation from the holistic perspective. In the case studies, one of these new roles was a BIM coordinator who was responsible for the BIM implementation from the holistic perspective. In the vertically integrated case the role was fulfilled as the need emerged during the implementation project whereas in the vertically disintegrated case the need was detected but the role was not fulfilled. The easier management of changing contractual issues and the ability to make quick adjustments in a vertically integrated firm certainly support this view. As a disadvantage, on the other hand, “buck passing” may emerge in vertically integrated firm which means that everything related to the implementation is pushed to a new role. In this case, the BIM coordinator felt overworked in the project because others were passing the buck in BIM-related issues. According to Olian and Rynes (1991, 306), a holistic process or systems emphasis reduces “buck passing” as it encourages employees to think of themselves as internal customers and suppliers. In order to specify if the holistic process emphasis would work, or whether or not this “buck passing” issue was a case-specific problem in the first place, further research in the area is needed. Overall, the implementation factor of defining roles is closely related to coordination and control, and the advantage of easier redistribution of work. These two were, however, kept separately as the empirical data provided so many specific quotes related to the issues in defining roles. The difference here is that redistribution of work refers to overall redistribution of tasks required by BIM and the coordination of this redistribution whereas issues related to defining roles refer to the roles needed in the actual implementation project.

15 Managerial implications

The practical objective of this study was to deepen the understanding about the organizational issues affecting the implementation of a systemic process innovation among the companies facing the situation and to give possible guidelines for more successful preparation, planning and execution of the implementation. Specifically in the context of BIM implementation, this study aimed to offer new insight how both vertically integrated and vertically disintegrated firms could be more successful in implementing BIM in the construction industry.

According to the findings of this study, the organizational structure of the project network does impact the implementation of BIM. More specifically, vertical integration has its advantages and disadvantages during the BIM implementation. These advantages and disadvantages need to be taken into account in order to implement BIM more successfully. Thus, managers should understand how the organizational structure of their company and project network could influence the implementation efforts and plan accordingly when implementing BIM. The improved theoretical model presented in Chapter 12 provides a framework for vertically integrated firms to understand these issues.

Managerial implications can be drawn for both vertically integrated and disintegrated project networks from the findings of this study. For vertically integrated firms, it is interesting to understand how they could overcome some of the disadvantages presented in the model. Similarly for vertically disintegrated project networks, it is interesting to understand how they could gain some of the advantages in the model without actually integrating vertically. A more extensive analysis of these solutions would, however, require further research. The recommendations based on the findings of this study are presented from both of these perspectives in the following.

Recommendations for vertically integrated project networks:

- *Understand the advantages and disadvantages of vertical integration in BIM implementation and plan the implementation projects accordingly*

- *Collaborate with external firms and research organizations in order to get access to relevant external knowledge and capabilities related to BIM*
- *BIM-related technological needs should be given higher priority in centralized IT department in order to enable a frictionless implementation project*
- *Emphasize the holistic process and systems perspective of BIM in order to increase motivation for implementation and decrease "buck passing"*

Recommendations for vertically disintegrated project networks (i.e. pure networks):

- *All firms should understand the advantages and disadvantages of pure networks in BIM implementation and plan the implementation projects accordingly*
- *Owners should select the whole team of designers and contractors at once as early as possible in the project in order to enable good collaboration, cumulative learning, and interoperability of technologies*
- *Designers, contractors, and other relevant actors should form strategic alliances over several projects in order to enable more flexible contracts, cumulative learning, and interoperability of technologies*
- *Shared locations should be used in order to enable faster and easier communication in formal and informal way especially between different design disciplines during implementation projects*

16 Evaluation of the research

Qualitative research is traditionally evaluated with the criteria of *internal validity*, *external validity*, *reliability*, and *objectivity*. *Internal validity* refers to the "truth value" of a given study meaning the extent to which it establishes how things really work and really are. There are several threats to the internal validity of a study (e.g. history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, selection) for which research design must compensate either by controlling or randomizing processes. *External validity* refers to the applicability or generalizability of a study in other contexts. There are threats to external validity of a study as well (e.g. selection effects, setting effects, history effects, construct effects) that need to be taken into account in order to achieve applicability.

Reliability is a precondition for validity and refers to consistency, predictability, dependability, stability, and accuracy of a study. Reliability typically rests on replication, meaning that every repetition of the same study will lead to similar findings. Finally, *objectivity* refers to neutrality, meaning that a given study is free of bias, values, and prejudice. (Guba & Lincoln 1989, 234-235)

Lincoln and Guba (1985), however, propose that qualitative research should be evaluated with more appropriate criteria of *credibility*, *transferability*, *dependability*, and *confirmability*. *Credibility* is parallel to internal validity and can be improved by prolonged engagement, persistent observation, triangulation (i.e. using multiple sources, methods, investigators, and theories), using peer debriefings to test the findings with a disinterested peer, negative case analysis, referential adequacy (e.g. creating databases for data) and member checks (i.e. discussing the results with different stakeholders and other researchers). *Transferability* is parallel to external validity and can be improved by providing thick description (i.e. detailed descriptions of the context and data collection of a study) which enables the application of a study to other settings by others. *Dependability* is parallel to reliability and can be improved by dependability audits where the documented research process is checked. Finally, *confirmability* is parallel to objectivity and can be improved by the confirmability audits where the data, findings, interpretations, and recommendations are evaluated. (Lincoln & Guba 1985, 301-328) In the following, this study is evaluated with these four criteria.

The credibility of this study was improved by triangulation, referential adequacy, peer debriefings, and member checks. Regarding the triangulation, multiple sources were used in data collection as numerous people related to the implementation project were interviewed and different archives used in both case studies (see Section 10.2 Data collection methods). Also, multiple methods were used as the empirical data was collected through interviews, archives, and observation in project modeling sessions, process simulation events, and feedback sessions. Furthermore, multiple researchers were used as the research team consisted of 3-4 people at all times. Regarding the referential adequacy, all the collected data (field notes, recordings, transcriptions, background documents etc.) was stored in a database where it was organized and easily accessible for analysis. Finally regarding the peer debriefings and member checks, the preliminary findings of this study have been often discussed with both the different members of the research team and other researchers. In addition, the preliminary findings have been discussed with representatives from the case companies and their project networks as well.

In order to improve the transferability of this study, the context, research approach, and empirical data collection and analysis methods are described in detailed level to provide thick description. The context of the study is thoroughly presented in Chapter 2 and the research approach and process is openly described in Chapter 4. Similarly, the descriptions of the both cases and the data collection and analysis methods are extensively described in Chapters 9 and 10. The pre-planned questionnaire for the interviews in both case studies is presented in Appendix 1. The data analysis methods and findings are presented separately from case descriptions and data collection which enables the neutral evaluation of this study.

Dependability and confirmability have been improved by regular evaluations of the research process, the empirical data, the findings, and the interpretations by both the instructor and the supervisor of this Master's Thesis during the execution of this study. The instructor has supervised all the simulation projects from which the empirical data for this study was collected. In addition, this study has been presented to several other researchers and stakeholders which improves the dependability and confirmability of this study.

There are some limitations to this study. First of all, the study investigated only two project networks and two separate implementation projects in the construction industry. The two opposite project networks, however, provided good insights into the focus of this study. With more cases targeting on different project networks, the generalizability of the findings could have been further improved. The scope of two case studies was, however, enough for a Master's Thesis.

Similarly, the study included only two separate implementation projects with several unique features which may affect the generalizability of this study. First of all, some of the elements in the constructed theoretical model could not be confirmed in the cases as they would have required more longitudinal research. As the overall BIM implementation requires several successive implementation projects, longitudinal research would have provided stronger findings and better generalizability of the results. Also, the case studies were from the Finnish construction industry, and thus, the findings may not be generalizable to other countries. For example, the different industrial structures or even cultural differences in other countries could affect the findings. Furthermore, there were some fundamental differences in the case studies used in this thesis (see Table 12). These differences including the type of the focal organization, type and time of the project, and previous experience and competence level may have affected the findings, and thus, the generalizability of this study. Executing the same study with other project networks and other implementation projects could lead to different results because of the features described above.

Finally, the collection of the empirical data used in this study was made before formulating the actual research problem and objectives. This may have affected the findings as the specific questions related to the constructed theoretical model and the detailed research question could not be directly asked in the interviews. However, the preliminary results from the case studies guided the formulation of the research problem and the extensive empirical data was more than sufficient to do the analysis and reach conclusions. Nevertheless, follow-up interviews could have further improved the findings of this study.

17 Future research

The findings of this study raise several topics for future research. First of all, some of the advantages and disadvantages in the model could not be confirmed in the empirical research of this study. These were, for example, the advantage of top management support over several integrated units at once related to the implementation factor of management support, and the advantage of stable relationships between integrated units in coordination and control which reduces uncertainty, boundary strength, and enables utilization of efficient processes. As the overall BIM implementation requires several successive implementation projects, and this study examined only two single projects from two different project networks, more longitudinal research would be needed in these project networks in order to draw further conclusions on those unconfirmed advantages and disadvantages in the model.

Second, it would be interesting to examine how the longitudinal research described above would possibly change the existing implementation factors and the related advantages and disadvantages in the model, or if it would introduce totally new structurally relevant implementation factors with additional advantages and disadvantages that are relevant in the long run. A further examination of several successive BIM implementation projects within these same project networks would probably introduce interesting new insights to the model.

Third, this study has focused on examining the advantages and disadvantages of a vertically integrated firm when implementing BIM. Even though a vertically disintegrated case was used as a part of the empirical research to reflect these advantages and disadvantages from the opposite environment, the advantages and disadvantages of a pure network structure of firms were not thoroughly examined. Some of the advantages and disadvantages of pure networks can be derived directly from the advantages and disadvantages of vertical integration as they represent the other side of the coin, but there might be some additional issues that could not be seen in this study. Moreover, there are also other organizational structures between these two extremes (e.g. quasi-integration, taper integration) and it would be interesting to study the impact of each of these different structures in the implementation of BIM.

Fourth, the managerial implications of this study suggested that there may be solutions for vertically disintegrated project networks to gain some of the advantages of vertical integration without actually integrating vertically. Similarly, there may be solutions for vertically integrated project networks to overcome some of the disadvantages presented in the model. A more extensive analysis of these possible solutions would require further research.

Finally, this study examined the advantages and disadvantages of vertical integration when implementing BIM in the project networks of the construction industry. The model should be tested with other systemic process innovations and in other industrial contexts as well. This could reveal which of the implementation factors and the related advantages and disadvantages in the model are innovation-specific or industry-specific, and which of them could be generalized more widely. Other systemic process innovations and other industrial contexts could even introduce totally new structurally relevant implementation factors to the model.

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Appendices

Appendix 1: The pre-planned questionnaire for the interviews

Appendix 1: The pre-planned questionnaire for the interviews

The five themes and a number of preliminary questions that structured the interviews are presented in this appendix. All of these themes were covered in every interview but various follow-up questions arose depending on the answer and background of the interviewee. The interviews were made in Finnish. Here, the author has translated the questions into English.

Theme 1: The roles of different stakeholders

- What are the tasks and roles of each stakeholder?
- When did each stakeholder come to the project?
- When were contracts made with each stakeholder?
- What kinds of issues were included in the contracts relating to BIM?
- Did new roles arise because of BIM?
- Did the traditional tasks of different stakeholders change because of BIM?

The questions in theme 1 focused on defining the roles of different stakeholders in the project and finding out how BIM might affect their roles in the project.

Theme 2: The phases of the pilot project

- What were the phases in the project?
- What was the content of each phase?
- How did the project progress?
- What were the essential decision making points during the project?
- What were the important information flows and how was information transformed?

The questions in theme 2 focused on defining the phases of the project and finding out if BIM affected these phases.

Theme 3: Collaboration in the pilot project

- What were the overall collaboration practices in the project?
- How did the collaboration between different parties function?
    - between different designers?
    - between designers and contractors?

    - between designers and owners/end users?
    - between contractors and owners/end users?
- What was the effect of BIM in collaboration?
- What kind of benefits or challenges did BIM cause to interorganizational or intraorganizational collaboration?

The questions in theme 3 focused on finding out how different stakeholders collaborated in the project and how BIM contributed to collaboration.

Theme 4: BIM in the pilot project

- Which of the project stakeholders used BIM tools in the project?
- In which phases was BIM used in the project?
- What were the experienced benefits and challenges of BIM? How were the challenges solved in the project?
- How did the communication of different designers work using the models?
- How was clash detection done?
- How were the models shared between different stakeholders?
- How or by whom was the BIM implementation and utilization managed in the project?

The questions in theme 4 focused on the experiences of BIM use in the pilot project. The objective was to find out how BIM was used, what were the challenges and benefits from BIM, and how the implementation of BIM was managed.

Theme 5: The future of BIM

- How is BIM changing the construction process?
- What are the central changes needed in order to make it work?
- How can the needed changes be implemented?
- What are the most significant opportunities from BIM tools?
- What are the central challenges faced at the moment / in the future?

The questions in the last theme focused on finding out the opinions on the future of BIM based on the experiences from the pilot project.