Department of Real Estate, Planning and Geoinformatics

Clients' role in construction innovation management process

Matti Sivunen

Aalto University

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Abstract

Previous literature has suggested that investments in innovation within the construction sector can increase a company's profitability and competitive advantages. Paradoxically, in practice it has often been noted that the construction sector is quite inefficient in producing innovations. Clients are in essential role in the management and decision-making of construction projects - especially in the early-stages of the project. However, clients' role in construction innovation management process and especially in implementation process has not been extensively studied. Therefore, this dissertation assesses, first, the clients' role in construction innovation projects, and second, how the clients can manage innovation process during the construction design phase.

The research employs a mixed-method research strategy using both quantitative and qualitative data. The mixed-method strategy adopts a diversity of research approaches in order to understand the complex network of relationships present within the construction sector.

The dissertation finds that the client is a driver for innovation in the construction sector and it proposes the following: (i) Companies should involve clients in the construction innovation process because clients can help companies in identifying and reaching innovation targets; and (ii) Clients can use the desired value-in-use for building users, project risk analysis and milestone targets to specify their demands for innovation and manage construction innovation process. The dissertation presents and tests three new tools that clients can use to manage innovation process during the construction design phase. The project where the proposed tools were tested successfully implemented several construction innovations.

As a whole, this research contributes to the existing body of knowledge on the construction innovation field by studying empirically the client's role in construction markets. It supports the view that construction innovations are not typically implemented at the companies themselves, but, rather, at the construction project sites where the companies are engaged. The research highlights the role of the client in the implementation process. The study demonstrates that by applying proper tools, clients can manage the innovation and improve the requirements for construction project stakeholders to successfully implement innovative changes during a construction project. As a mixed method study, the dissertation generates expected methodological pluralism in the field of research on the construction sector.

The dissertation suggests that in the future it would be highly interesting to both deepen and wider the construction innovation process by client's perspective and study further how the construction innovation process influences to construction markets effectiveness.

Keywords Briefing, Construction innovation, Construction management, Design management, Procurement

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Tekijä
Matti Sivunen

Väitöskirjan nimi
Asiakkaan rooli rakennusalan innovaatioprosesseissa ja -johtamisessa

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Tiivistelmä

Innovaatioihin investoiminen voi nostaa rakennusalan yritysten kannattavuutta ja parantaa niiden kilpailuetua. Valitettavasti rakennusala on tehoton innovaatioiden tuottamisessa. Rakennushankkeessa kiinteistön omistaja eli asiakas on keskeisessä roolissa innovaatioihin liittyvissä päätöksissä. Kirjallisuudessa on kuitenkin tutkittu verrattain vähän asiakkaan roolia rakennusalan innovaatioprosessissa. Tämä väitöskirja tutkii rakennushankkeen asiakkaan roolia rakennusalan innovaatioprojekteissa ja kuinka asiakas voi hallita innovaatioprosessia rakennushankkeen hankesuunnittelu- ja suunnitteluvaiheessa.

Tutkimuksessa käytetään sekä numeerista että laadullistat aineistoa. Tutkimuksessa käytetään mixed method –tutkimusstrategiaa ja useita eri tutkimusmenetelmiä aineiston keräämiseen ja analysointiin. Eri tutkimusmenetelmiä on käytetty, jotta voidaan paremmin ymmärtää rakennusalan verkostoja ja toimijoiden välisiä monimutkaisia suhteita.

Tutkimuksen päätuloksena on se, että kiinteistön omistajalla on merkittävä rooli rakennusalan innovaatiotoiminnassa. Tutkimuksen tuloksena väitetään, että i) yritysten kannattaa ottaa asiakas aktiivisesti mukaan innovaatioprojekteihin, koska se tukee yrityksiä pääsemään innovaatioprojektin tavoitteisiin; ja ii) asiakkaat voivat tarkentaa innovaatioiden tarvettaan ja johtaa innovaatiotoimintaa rakennuksen käyttöarvotavoitteen, rakennusprojektiin liittyvien riskien ja välitavoitteiden määrittämisen avulla. Tutkimus esittelee ja testaa kolmea uutta työkalua, joilla asiakas voi hallita innovaatioprosessia rakennushankkeen suunnitteluvaiheessa. Useita innovaatioita otettiin käyttöön rakennushankkeessa, jossa työkaluja testattiin.

Tutkimus edistää rakennusalan innovaatiotoiminnan tieteenalan tietämystä tutkimalla empiirisesti asiakkaan roolia rakennusmarkkinoilla. Tutkimus tukee näkemystä, jonka mukaan rakennusalan innovaatiota ei tyypillisesti implementoida pelkästään rakennusalan yrityksiin vaan yksittäisiin rakennushankkeisiin. Tutkimus korostaa asiakkaan roolia implementointiprosessissa. Tutkimus näyttää esimerkinomaisesti, että hyödyntämällä sopivia työkaluja tilaaja voi hallita innovaatioihin liittyvää riskiä ja vaatia rakennushankkeen osapuolia hallitsemaan ja implementoimaan muutoksia rakennushankkeen aikana. Mixed method –tutkimuksena tutkimus lisää odotettua tutkimuksellista monimuotoisuutta rakennusalan tieteenalalla.

Tutkimus suosittelee, että jatkossa on erittäin kiinnostavaa sekä syventää että laajentaa rakennusalan innovaatioviitekehystä asiakkaan näkökulmalla ja tutkia tarkemmin kuinka rakennusalan innovaatiotoiminta vaikuttaa koko rakennusmarkkinoiden toimintaan.

Avainsanat Hankesuunnittelu, Hankinnat, Rakennuttaminen, Rakennusalan innovaatiotoiminta, Suunnittelun johtaminen

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Dedicated to my Father – Senior Engineer Eero Sivunen
For lifetime passion to develop construction

"There is a way to do it better – find it"
Thomas Edison

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Finally, Akseli and Aatos, If you haven't found it yet, keep looking. Don't settle. Because: only later You can connect the dots.

Helsinki, 15 September 2015
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Papers included in the dissertation

This doctoral dissertation consists of a summary and of the following six scientific publications, which are referred to in the text by their Roman numerals.

Paper I
Sivunen, M., Kajander, J.-K., Heinonen, J., & Junnila, S., 2011. Global challenges of sustainability business innovations in built environment. *In the Proceedings of P. Huovila* (Ed.), *SB11 Helsinki - World Sustainable Building Conference*, October 18th - 21st 2011, Helsinki.

Paper II
Sivunen, M., Kajander-, J.-K., Väänänen, H., Siltaloppi, J., & Junnila, S., 2011. Innovation case study of a life cycle management company. *In the proceedings of M. Finkbeiner* (Ed.), *LCM 2011 - Towards Life Cycle Sustainability Management*, August 28th – 31st 2011, Berlin.

Paper III
Sivunen, M., Pulkka, L., Heinonen, J., Kajander, J.-K., & Junnila, S., 2013. Service-dominant innovation in the built environment, *Construction Innovation: Information, Process, Management* 13(2), pp. 146–164. ISSN 1471-4175

Paper IV
Kajander, J.-K., Sivunen, M., Vimpari, J., Pulkka, L., & Junnila, S., 2012. Market value of sustainability business innovations in the construction sector, *Building Research & Information* 40(6), pp. 665–678. ISSN 0961-3218

Paper V
Sivunen, M., Viljanen, J., Nenonen, S., & Kajander, J.-K., 2014a. Evidence-Based Design in Learning Environments: A Practical framework for project briefing, *International Journal of Facilities Management* pp. 162–174. ISSN 2211-4467.67

Paper VI
Sivunen, M., Kajander, J. K., Kiiras, J., & Toivo, J., 2014b. Managing Risks Related to Functional Changes by Design Alliance, *Procedia Engineering* 85, pp. 473–481. ISSN 1877-7058. Originally published in the proceedings of M. Hadju & M. Skibniewski (Ed.), Creative Construction Conference 2014 June 21st–24th 2014, Prague

Author's contributions to the papers

The contributions of the author of this dissertation to the appended research papers I–VI is outlined below.

Paper I
The author of this dissertation was responsible for initiating and writing the paper. The author shared responsibility for completing the paper with Juho-Kusti Kajander. Other co-authors provided valuable comments and suggestions to make the paper better.

Paper II
The author was responsible for initiating, doing the research for and writing the paper. The co-authors provided valuable comments and suggestions to make the paper better.

Paper III
The author shared the responsibility for initiating the paper, data collection, data analysis and writing of the paper with Juho-Kusti Kajander and Lauri Pulkka. The author was the main person responsible for completing the paper. Juho-Kusti Kajander was responsible for developing the theoretical framework. Lauri Pulkka was responsible for data analysis. Other co-authors provided valuable comments and suggestions to make the paper better.

Paper IV
The author shared the responsibility for initiating the paper, data collection and data analysis with Juho-Kusti Kajander and Jussi Vimpari. Juho-Kusti Kajander was the main person responsible for organising and writing the paper.

Paper V
The author was responsible for initiating, doing the research for and writing the paper. The author shared the responsibility for data collection with Jere Viljanen. Other co-authors provided valuable comments and suggestions to make the paper better.

Paper VI
The author was responsible for initiating, doing the research for and writing the paper. The co-authors provided valuable comments and suggestions to make the paper better.

Table of contents

1 Introduction

1.1 Motivation and background

For hundreds of years construction companies have been responsible for delivering and maintaining various types of construction, such as houses, offices and hospitals, which benefit the needs of clients. However, the clients' needs and the demand for construction companies' services, products and processes have always been changing. For example, in Finland clients have recently begun to demand user-oriented design processes, more ecologically friendly buildings and construction delivery methods that include financial solutions such as funding for the construction project. Paradoxically, in practice it has often been noted that the construction sector is quite inefficient at producing new services and products, or in other words, innovations that meet clients' changing needs (e.g. Winch, 1998; Barlow, 2000; Seaden et al., 2003; Kajander et al., 2010; Bygdalle & Ingemansson, 2014; Pekuri et al., 2014). The client is the person or firm responsible for commissioning and paying for the construction project, i.e. the building owner (Anumba et al., 1996; Barlow, 2000).

Innovation is essential for companies to develop their business and for the markets and companies to allocate resources effectively. The foundation of innovation research is usually traced to the works of Joseph Schumpeter (1942), and especially to his notion of creative destruction. Creative destruction seeks to explain economic growth and effectively resource allocation of the markets as an evolutionary process in which new innovations continuously replace old practices. Classical economics literature (Schumpeter, 1942; Schmookler, 1966; Freeman, 1974; Porter, 1998) has identified a positive relationship between innovation and the financial performance of companies. The competitive advantage of companies is based on generating a more productive use-of-resources, which requires continuous innovation (Porter, 1998). Moreover, Arrow (1962) argues that companies need innovation to manage uncertainty related to business. The innovations and inventions enable companies to allocating resources more efficiently in changing business conditions and thus decrease the risks related to transac-

tions, contracts and changes in market conditions. Within the construction sector, investments in innovations that are based, for example, on information technology (IT) technology, lean thinking and partnering can increase a company's profitability and help it maintain market share and improve its competitive advantages by decreasing project costs and improving its performance (Barlow, 2000; Seaden et al., 2003; Thomas et al., 2004; El-Mashaleh et al., 2006; Gambatese & Hallowell, 2011; Zimina et al., 2012). Lean thinking is a management philosophy that emphasises value creation for customers and reducing waste from the value creation process (Koskela, 2000: Jylhä, 2013). Partnering is the cooperative relationships among the supply chain actors (Eriksson, 2010).

The construction sector has features that affect the construction innovation process (Bygballe & Ingemansson, 2014). For example, construction is a project-based business with project organisations (Winch, 1998; Slaughter, 2000;), and projects involve many actors with different earning logics (Bygballe & Jahre, 2009; Aho, 2013). Differencies in earning logics may generate tension between actors. Different earning logics have different cost and value drivers according to the type of activities involved in project contracts and the interdependencies between them (Bygballe & Jahre, 2009). The construction sector comprises the functions of continuous asset, property and facilities management as well as transaction services, short-lived project management and on-site production activities, manufacturing, distributions and regulation (Carassus, 2004).

Clients are able to enhance innovation in construction in many ways (Blayse & Manley, 2004). Clients can identify specific novel requirements for construction project features to be supplied by developers, building product suppliers, contractors and operators (Seaden & Manseau, 2001), they can integrate knowledge across organisations (Barlow, 2000) and they can influence the way in which a construction project is carried out (Rose & Manley, 2011; Pekuri et al., 2014). Moreover, clients can exert pressure on project participants to improve the lifecycle performance of buildings and their overall characteristics and encourage project flexibility to meet any unforeseen changes in the markets (Gann & Salter, 2000). Finally, clients are key players that enable innovation by generating collaboration and trust between parties (Bygballe & Ingemansson, 2014).

However, not all clients are potential advocates of a construction innovation. The sector serves many small clients who have no interest in developing construction practises or they do not have technical competences to support construction innovation processes (Winch, 1998; Ivory, 2005). Therefore, it is argued that the experientially educated clients are the most potential to enhance the construction innovation (Winch, 1998).

Even thought that the client's key role in innovation has long been known, innovative co-creation between clients and construction companies has not increased significantly. In co-creation process the value of the innovation is defined by and co-created with the client during the innovation process (Michel et al., 2008). It is argued that the construction sector is not generating the types of innovations that clients expect (Kajander et al., 2010), that the need for innovation has been overlooked and undervalued within the sector (Loikkanen & Hyvönen, 2011), and that construction companies should emphasise innovation as one of the primary goals of the client (Toole et al., 2013). There seems to be lack of knowledge about how clients actually should be involved in innovation projects and how they might be able to manage the innovation in construction projects (Ivory, 2005). According to a comprehensive construction innovation literature review done by Xue et al. (2014), only a minority of construction innovation research has analysed the construction innovation process at the construction project level. Furthermore, the construction innovation research at the construction project level focuses on improving companies' ability to generate a push for innovations, e.g. developing new innovations, instead of understanding clients' role in generating demand for innovation.

In this context, this dissertation assesses, first, the clients' role in innovation projects, and second, how the clients can manage innovation process during the construction design phase. The dissertation contributes to the literature clusters of construction innovation and construction management.

1.2 Research problem

The aim of the research is to understand the client's role in the construction innovation process. The dissertation contributes to the body of knowledge on successful innovation management in the construction sector and provides a means to manage the construction innovation process. The research problem is that construction companies are inefficient at generating new services and products — innovations — which clients expect (Loikkanen & Hyvönen, 2011).

The dissertation has two research questions pertaining to the client's role in innovation management in the construction sector from different viewpoints. The research recognises the construction innovation process as presented by Winch (1998). He states that the construction innovation process has three main phases: the *adoption* of new ideas by companies, *implementing* innovations as a part of individual projects and *problem solving and learning* during projects as input for both new innovations for companies and knowledge to diffuse innovations within the construction market. The reasons to utilise Winch's framework are given in Chapter 2.

With the first research question, the focus is on understanding the client's role in the innovation process and management. In the context of the construction innovation process, the first research question is related to the innovation adoption process of companies.

RQ1: What is the role of client in construction innovation process and management?

With the second research question, the focus shifts from the role of the client in the construction innovation process to actual innovation implementation at a construction design process level. The focus is limited to construction design process as other researchers have noted that the briefing and design phases of a construction project is problematic and needs to be more fully developed (e.g. Koskela et al., 2002; Lindahl and Ryd, 2007; Elf & Malmqvist, 2009; Elf et al. 2012). Briefing is the phase when clients define the requirements for their construction project (Ryd, 2004). The design is the phase when designers, project managers and the client produce design solutions that fulfill the requirements set in the brief (Pennanen and Koskela, 2005). Moreover, the ability of the client to influence the final characteristics of a building, the potential value the building generates for the users, and the final cost of the project are the highest at the start of the project's design phase and progressively diminish as the project continues (PMBOK Guide, 2004; Henriksen et al., 2007). Regarding the

second research question, the focus of the research changes from understanding and explaining the current practices to making suggestions on how to improve the situation. In the context of the construction innovation process, the second research question is related to innovation implementation and learning during construction projects.

RQ2: How can the client manage the probability of success in implementing innovation during the construction design process?

Figure 1 illustrates the connection between research questions and the construction innovation process.

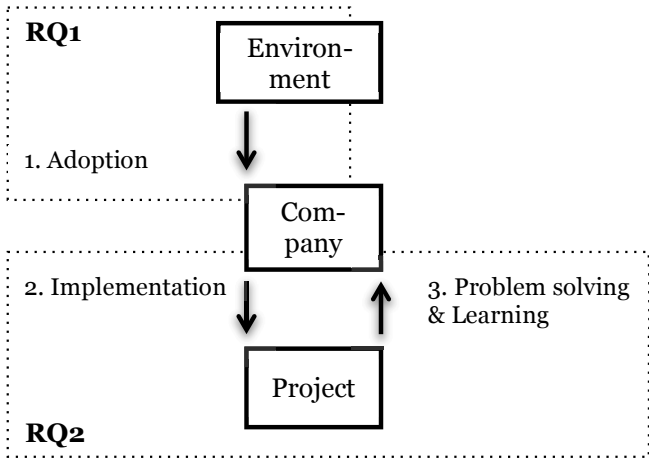

Figure 1 Connection between research questions and the construction innovation process (adopted from Winch, 1998).

1.3 Structure

The research structure is presented in Figure 2. It illustrates how the research aim, questions, papers and summary are all linked together.

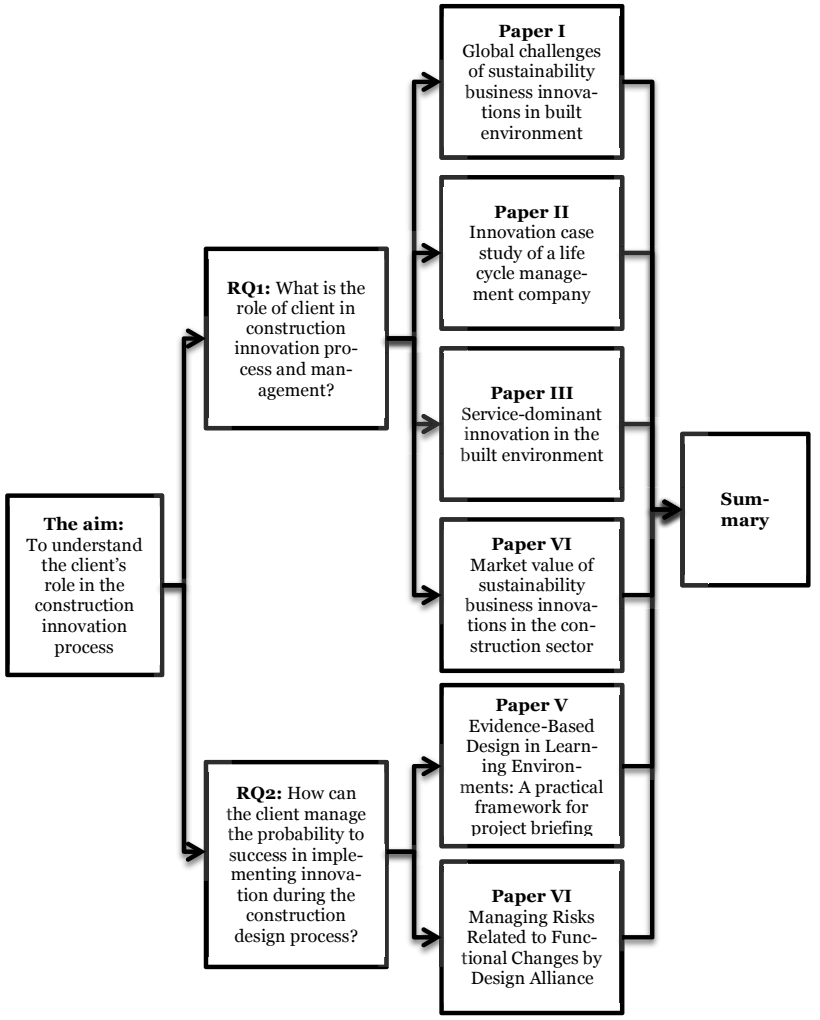

Figure 2 Research structure.

The dissertation consists of three appended articles that have been reviewed and published in academic journals; it also consists of three appended articles that have been reviewed and published in scientific conference publications. All of the study data in the articles are related to innovation projects. The data are described in section 1.4 and in Chapter 3.

Paper I investigates innovative challenges in the construction sector. The purpose of Paper I was to provide an overview of the current barriers to innovation in the construction sector and investigate the potential role the

client has in the innovation process within the construction sector. Paper II studies one interesting case identified in Paper I to further investigate the role of proper management and leadership in generating successful innovations in the construction sector. The innovation practices and client's role in a successful innovation case are analysed, and the results are compared to the findings presented in other innovation literature.

Paper III examines how commercial innovation projects in the construction sector utilise the contemporary market and client-oriented innovation models based on the Service-Dominant logic (S-D Logic). A survey of a large set of innovation projects was conducted and analysed.

Paper IV tests statistically the connection between innovations and the market value of companies in the construction sector. An event study model was used to analyse the innovation announcements and financial information of large construction sector companies in a number of countries.

Paper V and Paper VI suggest and evaluate tools for implementing innovations as a part of the construction design process. Papers V and VI tested the feasibility of the idea that a client can actually manage innovation during a construction project. The papers operate within a very narrow scope, using specific tools during specific construction design phases, to allow for sufficient control over the studied phenomena. However, the main purpose of the study was to show that the innovation can be managed in practice and not to suggest that the actual tools used can always be implemented by the client to manage innovation. Paper V constructs an evidence matrix and framework for project briefing that can be used to evaluate the positive outcomes that innovative design solutions have had in previous construction projects. The evidence matrix presents the correlations between a user's functional outcomes and innovative design strategies within the context of educational buildings. Paper VI presents and analyses two tools that can help implement and manage innovations during construction projects: a risk management approach and milestone analyses. In this context the risk refers to negative and positive possibilities that the project targets generate for the project. Risk management refers to the process that aims to manage these risks.

The summary integrates the findings of the papers.

1.4 Research methodology and data sources

The dissertation employs a mixed-method research strategy using both quantitative and qualitative data (Creswell, 2009). The mixed-method strategy adopts a diversity of research approaches in order to better understand the complex network of relationships present within the construction sector (Dainty, 2008). The use of mixed-method research was suitable for the problem at hand because it makes possible to study different aspects of a phenomenon (Bryman & Bell, 2007) and to identify similarities and differences between the different data sources (Creswell, 2009). Mixed-method and multi-method strategies are gaining recognition in research related to the construction sector because they make the research more complex and realistic (Fellows, 2010). Though there are an increasing number of mixed-method studies in the field of construction innovation literature (e.g. Panuwatwanich et al., 2009; Holt & Edwards, 2012; Hughes et al., 2012; Bygballe & Ingemansson, 2014), the overall number of studies is still few.

The research design is based on convergent design, initially conceptualized as a "triangulation" design in previous literature (Creswell & Plano Clark, 2011). A convergent design uses concurrent timing to implement the quantitative and qualitative strands of the data during the same phase of the research process, it prioritises the methods equally and it keeps the strands independent during analysis and then mixes the results during the overall interpretation phase (Creswell & Plano Clark, 2011). The purpose of convergent design is to obtain different but complementary data on the same topic to best understand the research problem (Morse, 1991).

Convergent research design has four main steps (Creswell & Plano Clark, 2011). First, both quantitative data and qualitative data are collected on the topic of interest. These two methods for collecting data are used concurrently but kept separate. They have equal importance in addressing the study's research questions. Second, the two data sets are analysed separately and independently from each other using typical quantitative and qualitative analytic procedures. Once the two sets of initial results are in hand, the research reaches the point of interface and works to merge the results of the two data sets in the third step. This merging step includes directly comparing the separate results. In the final step, the study interprets the extent to which and the ways in which the two sets of results converge and combine to create a better understanding in response to the study's overall purpose. Steps one and two are presented in each research paper and steps three and four are presented in the summary part of the dissertation.

The convergent design is selected based on its strengths. First, within the context of the research the method makes intuitive sense and it is the first research design using a mixed method discussed in the literature (Jick, 1979). Second, it is an efficient design in which both types of data are collected at roughly the same time. Finally, each type of data can be collected and analysed separately and independently using the techniques traditionally associated with them (Creswell & Plano Clark, 2011).

The convergent method also has challenges (Creswell & Plano Clark, 2011). Fist, much effort and expertise are required to carry out the research. To overcome this challenge, the research was conducted together with several co-authors who have a deep understanding and body of knowledge related to construction industry, used comprehensive data, analysis tools and innovation management practices. Second, the researchers needed to consider the consequences of having different samples and different sample sizes when converging the data sets. This challenge was managed by designing the data collection and analyses so that they addressed the same concept and by carefully comparing the results and the weighting of the results during the interpretation phase.

The research approaches were selected based on the nature of the research problems in each paper (Creswell & Plano Clark, 2011). Semi-structured interviews were used in Paper I to uncover the interviewees' meanings with respect to the construction innovation process and to give freedom in the sequencing and wording of questions as a result of the interviewees' responses (Robson, 2002). According to Yin (2014), single case design is appropriate when analysing a longitudinal case. In Paper II, a single case design was appropriate for analysing the case company's innovation practices. To deepen our understanding of the findings and obtain quantitative evidence to comparing the findings in the qualitative studies, a survey was used in Paper III (Robson, 2002). In Paper IV, the event study method was selected since the aim of the study was to measure the market capitalisation impact of a specific event (Fama, 1998). Paper V utilised the single case study method to test the tool developed for project briefing (Yin, 2014). Paper VI utilised action research to test new tools for addressing clients' design management problems (Coghlan & Brannick, 2014).

The main data sources vary depending on each paper. In Paper I, 11 semi-structured interviews were conducted and analysed. In Paper II, the empirical data were collected in two workshops and from secondary case data, such as peer-company and customer interviews, company documents and presentations, and articles from the media. In Paper III, 44 construction innovation projects were analysed. Paper VI evaluated data from 30 innovation announcements and related market data and from four workshops.

Paper V made use of project briefing documentation and workshop data from an educational case project. In Paper VI, project documentation and evaluation data from a healthcare building project's briefing and design phase and data from 2 workshops were used.

The context of the innovations is mainly related to sustainability. The context was selected because climate change mitigation is one of the largest challenges facing society today (UNEP, 2007; IPCC, 2014). Inside the climate mitigation market the construction sectors are assessed to offer a wide scope of opportunities (McKinsey & Co., 2009) for sustainability business innovations (SBI) – innovations that bridge the gap between business and environment actors to achieve sustainability. Therefore, the clients of the construction companies have increasingly demanded new sustainability innovations.

The framework of SBI was created to structure the empirical analysis of the innovation projects. The framework was called the SBI framework to underline the centrality of commercially viable solutions as a response to the sustainability challenge. The framework was originally presented by Kajander et al. (2010). The SBI framework consisted of three components: discontinuity of innovation, active client participation and value network involvement. The discontinuity of innovation is one of the components because, instead of incremental steps, businesses should strive to make radical leaps in new product and service design. This entails a twofold benefit of creating new business opportunities as well as having a potentially greater impact on reducing the environmental burden. A central theme behind innovation is active client participation, which helps companies target development efforts at the things valued most by the client. Value network involvement lessens the need for in-house technological and business expertise and ensures that external ideas and resources are used in the development project. In addition to these components, a rapid commercialisation process with built-in feedback loops is needed for two reasons. First, with regard to the environmental benefits of sustainability innovations, sooner is considered better. Second, entirely new products and services entail great risks. Therefore, development projects aiming at radical innovation should attempt to enter the market at the earliest possible moment. In the framework provided, sustainability is understood as a value that penetrates the entire innovation process, including all of its decision points. A compilation of the components involved in the sustainability innovation framework is presented in Table 1. The SBI framework and concept is comprehensively discussed in Paper III.

Table 1 Sustainability business innovation framework (Sivunen et al., 2013)

Primary SBI components	Description
Discontinuity of innovation	Projects should strive to make radical innovations instead of incremental improvements.
Active client participation	The client must be seen as a co-creator of value and thus should participate actively in the entire project.
Value network involvement	The value network consists of actors other than the client, such as regulatory bodies, competitors and universities. Its involvement heightens an organisation's sensitivity to external ideas and enables ideas to be exploited more efficiently.

The increasing demand for SBIs made the sustainability context interesting for this research project. In Papers I, II, III and IV the research focus is on studying clients' role in company driven sustainability innovation projects. Papers V and VI discuss how client can support the implementation of innovations in construction projects that increase sustainability through low carbon production and flexible design by setting requirements for sustainability innovations and managing the innovation process. The sustainability requirements tested in the Paper V and VI include LEED certificate, service flexibility, modifiability, maintenance costs and value-in-use. Service flexibility, also known as adaptability, refers to the capacity of the facilities to be operated and used in different ways. Modifiability refers to the capacity of the building to be adapted to changes occurring in the future, such as changes of user organizations. The value-in-use refers to the fit between the facilities and user's functions (Saari et al., 2007).

The research papers, research method, research approach and data are summarised in Table 2.

Table 2 Research methods, research approaches and main data sources used in the papers

Paper	Research method	Research approach	Main data Sources
Paper I	Qualitative	Semi-structured interview study	11 interviews with Finnish and international innovation professionals
Paper II	Qualitative	Single case study	Workshops, peer-company and customer interviews
Paper III	Quantitative	Survey study	A survey of 44 innovation projects, workshops
Paper IV	Quantitative	Event study	30 innovation announcements and related market data, workshops
Paper V	Qualitative	Single case study	Project briefing documentation, workshops
Paper VI	Qualitative	Action research study	Investment case, procurement decision, milestone analyses, workshops

The perspective of the research's paradigm is mainly pragmatism. According to Creswell & Plano Clark (2011), a study of this nature includes several characteristics related to pragmatism. For example, the research is a problem-centred study and oriented towards real-world practice.

Even though that the study was carefully predetermined and planned at the start of the research process, the research includes emergent elements because the data and results affected the design of the research (Creswell & Plano Clark, 2011). People are at the centre of innovation — individuals who aim to develop new technologies for new products, better services and more efficient processes. For this reason, the core information source for the research project included watching people making successful and failed innovations, talking to them and understanding their motivations and actions and the results of their actions. A large part of this information was used to modify the author's understanding with respect to, e.g. formulating research questions, selecting cases and analysing data (Robson, 2002).

2 Theoretical foundation

This chapter describes the theoretical foundation of the research. The purpose of this chapter is not to fully review the literature related to construction innovation, but rather to briefly describe the main theoretical principles that have inspired and led the research process and, moreover, to identify the contribution of the research to the existing literature. Additional information can be found in individual articles. The chapter addresses the theoretical foundation of the study from the following perspectives: innovation research, innovation management, construction innovation, innovation challenges, and the client's role in the construction innovation process. Finally, the theoretical foundation of the research is summarised.

2.1 Innovation research

The foundation for innovation research can be found in the works of the Austrian-American social scientist Joseph Schumpeter, and especially in his notion of creative destruction. Creative destruction seeks to explain economic growth as an evolutionary process in which new innovations continuously replace older processes (Schumpeter, 1942).

Innovation can be seen as being pushed by technology, pulled by demand and pushed or pulled by regulations (Rennings, 2000). Schumpeter (1942) studied economic and social change in the long term, focusing in particular on the essential role of innovation and the factors influencing it. The main factor that Schumpeter discussed was the way in which technology drives innovations such as organisational research and development (R&D). Schmookler (1966) demonstrated that the demand-pull influence is also an important factor. The more intense the demand, the more creative groups and individuals are willing to work on an unsolved problem and generate more patentable inventions. Besides the technology push and demand pull, regulations might also have a push or pull effect on innovative actions (Rennings, 2000). Regulations play an important role especially in the innovation context where subsidies or tight ecological requirements exist.

Innovation as a concept and the concepts related to it have been redefined many times since Schumpeter's original work. According Fagerberg and Verspagen (2009), some of the topics that have emerged within innovation

literature pertain to the factors, such as markets' resource allocation and uncertainty, influencing investment in R&D and innovation (Arrow, 1962), the sources of invention and innovation and the role of innovation demand (Schmookler, 1966), the factors affecting the spread of innovations (Griliches, 1957; Rogers, 2003), the tremendous differences across industries and sectors in how innovation operates (Pavitt, 1984), the important role that firm-level capabilities play in innovation and learning (Cohen & Levinthal, 1989), and the concepts 'national systems of innovation' (Lundvall, 1992) and innovation clusters (Porter, 1998). The exponential increase in the amount of innovation research in the last few decades has fostered specialisation and fragmentation within the field. In their study of the innovation research community, Fagerberg and Verspagen (2009) identified different clusters of innovation scholars with distinct interests. The clusters included innovation management, the Schumpeter crowd, geography and policy, the periphery and industrial economics. The *management* cluster consists of a relatively small community, one in which sociologists and management scholars are strongly present. The sources of inspiration are greatly fragmented within the community. The *Schumpeter crowd* consists of a large community of mainly economists who recognise Josef Schumpeter as their main source of inspiration. The *geography and Policy* community is more cross-disciplinary in its orientation than the Schumpeter crowd or the network as a whole. It consists of geographers, sociologists and management scholars. The members greatly esteem Schumpeter's work, but the work of Bengt-Åke Lundvall and Michael Porter carry more weight within the cluster. Scholars with a mainstream economics background dominate the *periphery* cluster. The members of this cluster are less interested in taking part in meetings and publishing their research in other journals than scholars in the other clusters. They like Schumpeter, but what particularly inspires them is the work by Zvi Griliches. The *industrial economics* cluster is like the periphery cluster but it has more ties with the other clusters. Next, the characters of innovation management literature foundation are briefly described.

2.2 Innovation management

Innovation management is examined here in three parts. First, the section addresses the conventional line of research that focuses on the new product development (NPD) process and innovation in closed systems. Second, it focuses on recent studies that examine open innovation. Finally, it explains S-D Logic and how it has affected on the innovation process. These are the main innovation management theories that have inspired the research.

The closed system model of innovation is the conventional industrial approach. With this model, innovation takes the form of a traditional goods-dominant NPD process. According to earlier studies, typical features of the NPD process include detailed planning, relying on in-house technological capabilities and operating under secrecy, i.e. trying to impede competitors and other actors from learning about a new innovation throughout the NPD process (Chesbrough, 2003a, 2003b, 2004; Michel et al., 2008). Such a process functions according to a linear pipeline model (Chesbrough, 2003a). First, a number of product ideas are submitted for technical and market assessment. After a preliminary elimination phase, the surviving ideas are transferred to the R&D pipeline as projects. Finally, only a few of the original product ideas are actually converted into products and introduced to the market. It is important to note that in presenting the above generalisation, the current study in no way means to imply that there is only one type of closed innovation process. A common way to conceptualise the traditional NPD process is via the stage-gate model originally developed by Cooper (1990), and later elaborated on by the same scholar (Cooper, 2005, 2007) as well as others (e.g. O'Connor, 2002). With stage-gate systems, methods similar to product manufacturing processes are used to manage the innovation process. The development process is divided into sequential stages with decision gates between them, with the gates acting as quality control checkpoints (Phillips et al., 1999; Ettlie & Elsenbach, 2007).

According to the open innovation paradigm, innovation is based on both internal and external ideas (Chesbrough, 2003b). During the last few decades, the foundation for a successful innovation process has increasingly shifted away from the capability to develop in-house technologies towards the capability to monitor the external environment, set up relationships with different actors — suppliers, competitors, other non-competitive companies, research institutes and end-users — and integrate several knowledge components (Chesbrough, 2007, 2008). Moreover, the concept of successful innovation has evolved to recognise the proactive role of intellectual property management, which utilises the market to exchange valuable knowledge and enables alternative commercialisation routes for the results of innovation projects (Chesbrough, 2003a).

The S-D logic approach provides a highly client-centric view for analysing, managing and developing innovation processes. According to Vargo and Lusch (2004), innovation development should always be strategically targeted at a specific client's need. In fact, the value of the innovation is defined by and co-created with the client during the innovation process. Furthermore, Lusch et al. (2010) argue that integrating the innovator's value network is an imperative asset in the innovation process with respect to

tackling several key questions related to the development of innovation, such as what is the most effective way to involve suppliers and clients in the design process of services and how to reframe the value network to speed up the innovation process. In summary, the S-D logic approach highlights the importance of strong client participation and value network involvement in a successful innovation process.

As mentioned by Pavitt (1984), the sector's special features affect the innovation processes. Next, the type of innovation management related to the construction sector is examined.

2.3 Construction innovation

The construction sector has unique features that require special attention when comparing it to other industries. Value chains in the sector are usually long and complex by nature, activities are project based, the regulatory influence on the sector is substantial and the industry is often considered to be conservative (e.g. Winch, 1998; Toole et al., 2013; Bygballe & Ingemansson, 2014). Therefore, innovation research related to the construction sector comprises a literature area separate from general innovation research.

In the context of the construction sector, the definitions for innovation vary widely. In this research, construction innovation is understood, in line with Seaden et al. (2003), as the implementation of significantly new processes, products or management approaches by a company in order to increase its efficiency (i.e. improved quality, lower production costs) and/or effectiveness (i.e. greater market share, client satisfaction). This definition differs from numerous other ways in which construction innovation is defined. For example, Slaughter (1998) or Toole (1998) define construction innovation as the design solution for a building, not business related factor.

Xue et al. (2014) divides the literature related to construction innovation into the following categories: collaboration, culture, innovation input, innovation processes and innovation outcomes. The collaboration category has gained the most attention within the field of construction innovation literature, while only a small minority of researchers have analysed construction innovation processes at the project level (Xue et al., 2014). With the literature focusing on the construction innovation process, a number of studies are based on the research done by Winch (1998).

Winch (1998) has presented a comprehensive model of the construction innovation process. The model highlights two distinctive moments: a top-down moment of adoption and implementation and a bottom-up moment of problem solving and learning. The first moment is based on the notion that, unlike in many other industries, innovations in the construction in-

dustry are typically not implemented within the company itself, but as part of the projects that a particular company is engaged in at the time. Therefore, companies must first make a decision to adopt new innovation and also be able to implement it during the projects. The projects typically involve other companies within the project coalition, and so almost all innovations in the construction sector have to be negotiated with one or more actors within the project coalition. The second moment is based on Cohen and Levinthal's (1989) findings as well as Slaughter's (1993) findings that projects should be viewed as innovation and learning sources. The projects in which companies are engaged offer another, internal, source for new ideas: problem-solving during projects. Construction projects include considerable amounts of problem-solving as the general repertoire of technologies and techniques is adapted and applied to meet the specific client's needs in interaction with the constraints of the site. After deploying the model, many scholars have participated in the discussion related to the nature of the construction innovation process, and it seems that the link between a construction company's internal innovation process and the implementation process at project sites is highly important for successful construction innovation (e.g. Gann & Salter, 2000; Slaughter, 2000; Ling, 2003; Winch, 2003; Manley, 2008; Lloyd-Walker et al., 2014). Next, some key challenges related to innovation are described.

2.4 Innovation challenges

Challenges that prevent companies to produce innovations have been widely studied in last decades. Challenges to innovation are related to, for example, innovation strategy and processes, and organizational culture. Several studies (Vargo & Lusch, 2004; Michel et al., 2008; Lusch et al., 2010) have investigated innovation processes and strategies and suggest that a low level of client integration into the innovation process represents a challenge to innovation. Instead a low level of client integration, the client should be a co-creator of the innovation. In co-creation concept the client does not receive value created by the company but is a co-creator of that value. Holmström (1989) argues that large size of the organization per se is a great challenge to innovations as it often leads to bureaucratic internal organization of the company and myopic management behavior due to concerns for reputation in the capital market. Therefore, small companies innovate disproportionately compare to large companies, and contrary incumbents often fail to innovate due to their bureaucratic organizations that compromise innovation incentives. Moreover, Chesbrough and Crowther (2006) have identified not-invented-here (NIH) syndrome and lack of in-

ternal commitment for innovation processes as main hampering factors of innovations.

Several studies suggest that there are various industry specific challenges to innovation in construction sector (Nam and Tatum, 1997; Manley 2008; Lim et al., 2010). Innovation in the construction sector is often classified as a cost-intensive investment with very indefinite returns due to the risks associated with R&D and great variations in both demand and profits In addition, the lack of innovation management competencies and tools – especially related to promoting new ideas and making conscious strategic decisions about the direction of the company's innovation activity – present a challenge to innovation in construction sector. It is argued that the client has a role in enabling construction sector to overcome some of these innovation challenges (Nam and Tatum, 1997; Winch, 1998; Michel et al., 2008) Next, the role of the client in construction innovation management is studied.

2.5 Client's role in construction innovation

The end customer of the construction company, i.e. the client, is the person or firm responsible for commissioning and paying for the construction project (Anumba et al., 1996). In general, there are two types of clients: investors and user-owners. Barlow (2000) argues that investors are usually seeking short-term returns, whereas user-owners usually have a long-term view. There is considerable diversity between and within the clients involved in a construction project. The nature of the interactions between contractual parties will be partly influenced by a client's previous experience with and knowledge about how to procure construction work. Clients range from the very experienced and talented to those who are infrequent purchasers of construction services with little incentive to become experts in the procurement process (Barlow, 2000). Nam and Tatum (1997) suggest that there might be a close relationship between the clients' technical competence and their active participation in a project. For example, in the United Kingdom experienced clients — who include many government bodies — have become increasingly concerned with the need for innovations and have exerted considerable influence on the construction sector (Barlow, 2000).

For a long time, many scholars argued that the client is a key factor influencing innovations in the construction sector (e.g. Nam & Tatum, 1997; Slaughter, 2000; Blayse & Manley, 2004). More recently, Gambatese and Hallowell (2011) found that a very strong, positive relationship exists between client influence and innovation in construction projects. Bygballe

and Ingemansson (2014) argue that the client is an important driver of innovation, but that traditionally the connections between construction companies and clients have been weak. Moreover, Fearne and Fowler (2006) argue that in order to improve performance in the construction sector, a fundamental change in the management of relationships between clients, contractors and sub-contractors is required.

Clients are able to enhance innovation in the construction sector in many ways. Clients can identify specific novel requirements to be supplied by developers, building product suppliers, contractors and operators (Seaden & Manseau, 2001), and they can integrate knowledge across various organisations (Barlow, 2000). Moreover, clients can exert pressure on project participants to improve the lifecycle performance of buildings and their overall characteristics and encourage project flexibility to cope with any unforeseen changes in the markets (Gann & Salter, 2000). Lloyd-walker et al. (2014) argue that the way in which innovations are implemented depends on the level of collaboration on construction projects, and true collaboration is inextricably linked with behavioural drivers. The foremost of these drivers is a culture of openness and a willingness to share the pain and gain that are a part of experimentation; such a culture requires that collaborators be protected from the threat of being blamed and held accountable for experimental failure. In line with Lloyd-Walker et al., Bygballe and Ingemansson (2014) argue that clients are key players who enable innovation by generating collaboration and trust between parties.

One reason behind the clients' key role in the construction innovation process is that clients often share a high proportion of the risks associated with the innovations (Nam & Tatum, 1997). In contrast to other capital good products, the lifecycle of buildings is quite long. It is common that the compensation defined in the contracts is in effect for a shorter period of time than the reimbursement on the investment or the lifecycle of the building.

However, despite the fact that a number of studies underline the importance of the client in implementing innovations as a part of construction projects, the client's effect on the implementation process might also be negative for four reasons. First, architects and engineers act as gatekeepers, or 'honest brokers', for the technologies desired by clients (Winch, 2000), and it is often a question of how they sell or offer the innovations to clients and not a question of how good or valuable the innovations actually are. Second, the lack of technological expertise by clients might actually hinder the innovation process (Nam & Tatum, 1997). Third, based on three construction case studies, Ivory (2005) argues that strong client leadership may have negative consequences for innovation in terms suppressing par-

ticular innovations and putting an overly narrow focus on particular types of innovation. Given that innovation will play a key role in the future competitiveness in the construction sector, he argues that the role of the client in the construction innovation process requires more careful examination than it has thus far been afforded. Finally, the organisations that have fully separate requirement setting and design the product in different units usually fail to generate competitive products, as there is no learning between the design and requirement setting and the requirements are set by thinking of already existing solutions (Suh, 2005). Suh (1990) proposes that utilising axiomatic design principles is a potential solution to tackle the problem. However, careful consideration needs to be given to the amount and nature of influence that the client has over a particular innovation during a construction project.

2.6 Summary of the theoretical foundation

This study is based on innovation research (e.g. Schumpeter, 1942; Arrow 1962; Schmookler, 1966; Pavitt, 1984), innovation management (e.g. Chesbrough, 2003a; Vargo & Lusch, 2004; Cooper, 2005), construction innovation (e.g. Winch, 1998; Seaden et al., 2003) and the client's role in the construction innovation process (Nam & Tatum, 1997; Barlow, 2000; Ivory, 2005; Bygballe & Ingemansson, 2014). The construction sector has unique features that demand special attention when comparing it to other industries. Unlike many other industries, innovations in the construction sector are not typically implemented within a company, but at the project sites where the company is engaged (Winch, 1998). While the adaption process for innovation seems to be explained by general innovation research and innovation management research, the implementation process itself causes construction innovation literature to be different from that of other innovation literature clusters. Construction innovation literature argues that the client is a key factor influencing innovations in the construction sector and that clients are able to enhance innovation in construction in many ways. One reason behind clients' key role in the construction innovation process is that clients often share a high proportion of the risks associated with the innovations. Paradoxically, clients' effect on innovation can also be negative. The role of the client in construction innovation requires more careful examination than it has thus far received (Ivory, 2005). Therefore, there is a need for empirical studies that investigate construction innovation cases in reality.

3 Summaries of the papers

This chapter presents a summary of the papers. The summaries briefly highlight the purpose, research methodology, findings and contribution of each paper. The full papers are appended to the dissertation.

3.1 Paper I: Global challenges of sustainability business innovations in built environment

The first paper investigated the challenges facing the construction sector in terms of producing innovations and the potential solutions to these challenges. The paper focused mainly on innovations related to sustainability.

In the paper, two company groups were analysed via semi-structured interviews. The challenges identified in previous studies were used as background material for the semi-structured interviews. After the analyses, three construction innovation experts were interviewed to evaluate the results and suggest potential solutions to overcome the challenges.

The aim of the analysis regarding the first group was to identify the key challenges facing the construction sector in terms of producing innovations from the perspective of venture financing (VC) companies. Three VC companies were analysed. The companies were VC organisations based in Finland that have altogether invested more than 480 million euros in sustainability oriented and innovative construction companies, especially in renewable energies and energy saving technology companies in Finland and elsewhere in Europe.

The aim of the analysis regarding the second group was to discover the key challenges in terms of producing innovations from the perspective of innovators. Five construction companies were analysed. The companies specialised in engineering projects, developing and manufacturing steel structures, developing and manufacturing products for indoor environments, developing and manufacturing modular products, and producing lifecycle cost analyse services. Four of the companies were based in Finland and one was based in Sweden.

The collected data was analysed by utilizing content analyses method (Robson, 2002). First, the interviews were transcript. Second, the use of

word and phrase frequencies and inter-correlations were analysed and used to generate main themes. Following that, relative importance of the themes was determined by evaluating how large portion of the interviewees had mentioned it. Finally, the results were summarized and discussed.

The results from all of the companies imply that a *complex value network* and *team building* are the key challenges to innovation. Introducing innovations, especially radical ones, to the market is difficult due to the fragmented nature of the construction sector value network, as commitment and acceptance by multiple stakeholders are required to proceed further in the innovation process. Every company also raised the issue of *team building*, as there are a lack of multidisciplinary entrepreneurial teams capable of managing complex value networks and innovations. Moreover, nearly all companies viewed pending regulatory decisions and a lack of R&D and commercialisation management competences as challenges to innovation. Many companies also identified the long-term research and development background for innovation, project-based operations, internationalisation and fundraising as challenges. A summary of the findings is presented in Table 3.

Table 3 Summary of the identified challenges in companies 1–8

Innovation challenge	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Complex value network	X	X	X	X	X	X	X	X
Team building	X	X	X	X	X	X	X	X
Long-term research and development background for innovation	X	X	X					
Pending regulatory decisions	X	X	X	X		X		
R&D and commercialization management				X	X	X	X	X
Project-based operations				X	X	X		
Internationalisation						X	X	
Fundraising							X	X

Project business orientation in the construction sector and the challenges related to fundraising for innovations were present mainly in construction companies. In addition, in contrast to VC investors, the companies did not perceive pending regulatory decisions as such a severe challenge to innovations. Moreover, while VC investors consider the length of time to market and the sunk costs related to innovation as primary issues in the area of R&D management, the companies felt that it is first and foremost a question of developing better tools and processes for innovation management.

After the analyses, three construction innovation experts verified that the findings are also applicable in Switzerland and further suggested that they are key challenges more generally to innovation in Europe. The interviewees argued that client demand is one of the main drivers for overcoming the key challenges. Moreover, they argued that client demand currently plays a relative small role in practice when it comes to innovation management.

3.2 Paper II: Innovation case study of a life cycle management company

The second paper investigated the role of proper management and leadership in generating successful innovations in the construction sector and the client's role in a successful innovation project. The innovation practices of a successful construction company was analysed, and the results were compared to findings presented in the general innovation management literature. The case study was a successful Finnish company that developed construction management methods, software products and related services. The case was identified as longitudinal case because the company in question has been able to maintain its status as a technological leader for more than a decade.

The empirical data in this study were collected in two workshops and from a secondary case data, such as peer-company and customer interviews, company documents and presentations, and articles by the media. In the first workshop, the authors constructed a schematic framework for innovation management and leadership practices in the company case. In the second workshop, the framework was presented and further improved for accuracy. Also, a general hypothesis for successful innovation management and leadership practices in SBI was generated. Finally, the various proposed hypotheses were evaluated by comparing them with principles for successful innovation practices presented in the general innovation literature.

The data analyses consisted three activities: data reduction, data display, and generating conclusion (Robson, 2002). First, the secondary case data was analysed and a summary sheet of the results was generated, and relevance of each document was analysed. Second, the results of the first workshop were coded and the meanings of the data were analysed by using context charts to identify patterns between codes. Finally, the context charts were analysed in the second workshop and general hypothesis for successful innovation management and leadership practices in SBI was generated to improve conceptual coherence.

Innovation management and leadership characteristics pertaining to innovation were identified based on three chronological phases of the innovation process:

1. Starting point: the external and internal innovation environment;
2. Early innovation phase: R&D and commercialisation;
3. Late innovation phase: Diffusion.

The starting point phase was defined as the external and internal company environment for innovation. The early innovation phase was the period during which the invention was developed and commercialised in the form of new products. During the late innovation phase, new products were diffused into national markets and managed based on the company's market-standard position.

The main findings of the paper suggest that a successful innovation management and leadership process in the construction sector actually combines aspects of several innovation management theories, such as open innovation, innovation leadership, the diffusion of innovation and S-D logic. No single theory could explain the success of a company. In addition, some potential innovation management and leadership characteristics, such as influencing industry practises and modifying the owner network to help innovation diffuse to market, were identified; none of these characteristics have been emphasised in the previous innovation literature.

According to the results, the client's role in a successful innovation project is highly important in terms of generating demand for innovation and participating in the innovation project. The external components for successful innovation include client demand, technology push and regulatory acceptance. In addition, the internal components for successful innovation include a motivated team, the incorporated value and owner network, client orientation and a target for radical innovations. A successful early innovation phase needs innovation champions and client-driven product development focusing especially on the innovation's relative advantage, compatibility, complexity, trialability and observability. The effective diffusion of innovation calls for a combination of managerial skills, strong references for credibility, actively participating in the development of industry practices and maintaining technology leader status.

3.3 Paper III: Service-dominant innovation in the built environment

The main aim of the third paper was to examine the ways in which innovation projects in the construction sector utilise the contemporary market and client-oriented innovation models mainly based on the S-D logic and the extent to which clients participate in to the innovation projects. The main context for the 44 innovation projects that were studied was sustainability. The organisations participating in the projects varied in type and size. In addition to privately owned companies, the participants included public utilities, municipalities and research organisations. There were also differences in the total project budgets, which ranged from under € 50,000 to more than € 10,000,000.

The results demonstrated that over a third of the examined projects lack all the necessary innovation components recognised in the literature. The share of projects possessing different numbers of SBI components regardless of their type is displayed in Table 4. An innovation process in accordance with S-D logic presupposes the existence of all three SBI components. This was the situation in only 14 per cent of the projects. Less than half of the projects, 41 per cent, had two or three of the components. No components could be found in 34 per cent of the projects, meaning that the majority of the projects, 66 per cent, contained at least one SBI component.

Table 4 The frequencies at which the different numbers of SBI components occurred (Sivunen et al., 2013)

All three components	13.6% (6)
At least two components	40.9% (18)
At least one component	65.9% (29)
None of the components	34.1% (15)

Note: n = 44

The active customer participation component is deemed to be present only in projects in which the customer participates actively or bears the main responsibility throughout the entire project. The analysis indicates that active client participation is the most common component with a clear margin for discontinuity of innovation and value network involvement, as illustrated in Table 5. The clients participated actively in the projects in 52.3 per cent of the cases. A client's active participation in or main responsibility for the project and close cooperation from the idea to the market stage are found in a somewhat greater proportion of projects, 70.5 and 61.4 per cent, respectively.

Table 5 A comparison of the frequencies at which specific innovation components and subcomponents occurred in the examined projects (Sivunen et al., 2013)

SBI component Subcomponent	Percentage frequency (quantity)
Discontinuity of innovation	36.4% (16)
Change in customer behaviour	65.9% (29)
Change in organisation's value creation	56.8% (25)
Active customer participation	52.3% (23)
Customer is active or bears the main responsibility	70.5% (31)
Close cooperation from the idea to market stage	61.4% (27)
Value network involvement	31.8% (14)
Business-oriented value network	6.8% (3)
Technology-oriented value network	29.5% (13)

Note: n = 44

Very few projects utilised concurrent market feedback in the development phase. The results of three cross tabulations of the commercialisation process according to varying numbers of SBI components are compiled in Table 6. Commercialisation after thorough development and testing was the most common means of commercialisation. The study found this to be true in 36 per cent of the projects, followed by commercialisation as a part of the core product development in 25 per cent of the projects and rapid commercialisation in 23 per cent of the projects. Approximately 13 per cent of the respondents did not know or would not say. Remarkably, none of the projects with all three or at least two of the components attempted quick market entry before the main development phase. Likewise, quick market entry was the least popular process of commercialisation for the group of projects with at least one component, with a share of 9 per cent. Interestingly, development after piloting was the most common type of commercialisation process among the projects with no SBI components.

Table 6 The relationship between the number of SBI components and the organisation's commercialisation process (Sivunen et al., 2013)

Commercialisation process	No SBI components	At least one component	At least two components	All three components
As a part of the core business	7% (3)	18% (8)	14% (6)	9% (4)
After thorough development and testing	9% (4)	27% (12)	20% (9)	5% (2)
The idea is taken to the market quickly	14% (6)	9% (4)	0% (0)	0% (0)
Does not know or say	2% (2)	11% (5)	7% (3)	0% (0)

Note: n = 44

According to the results, half of the studied innovation projects still lacked active participation by the client. The paper suggests that sustainability innovations fail commercially in the built environment because they lack active client participation and value network involvement, and they aim for incremental instead of radical improvements. Organisations striving to make innovations should aim at radical instead of incremental innovations, and they should focus on client participation and value network involvement. The innovation adoption processes practised by construction companies could be organised better by utilising tested S-D Logic models.

3.4 Paper IV: Market value of sustainability business innovations in the construction sector

The fourth paper investigated how shareholders understand the market value of innovations in the construction sector. The paper examines the possible connection between SBI and the market capitalisation of companies in the construction sector. An event study model was used to analyse the sustainability innovation announcements and financial information of large construction sector companies in a number of countries. In the fourth paper, 30 innovation announcement were analysed from 10 construction companies. The companies are based in Germany, France, the United Kingdom, Australia, Sweden and Finland.

Overall, the selected companies operate in the fields of construction sector project development, construction-related services, engineering and infrastructure, and property solutions. Moreover, the companies are very large and operate in several different markets, mostly in Europe though. All the companies claim to have a sustainability agenda that is basically carried out by developing eco-efficient solutions. Surprisingly, most of the more than 80 companies reviewed for the study claimed that they have a sustainability

agenda, even though they did not have any actual press releases on the subject. In terms of innovation, only a few of the companies clearly present their innovation or research and development policy on their webpages.

The role of the client was carefully analysed in each announcement. The tentative innovation announcements were analysed further as to whether they actually contained client involvement. The analysis and classification process for the announcements included four expert group workshops. The workshops focused on a qualitative and quantitative evaluation and ranking of the selected press releases. An announcement was classified as SBI if it was thematically related to sustainability and contained client involvement, discontinuity of innovation and a value network.

The fourth paper suggests that shareholders seem to understand the value of the innovations in construction companies. The main finding as a result of the analysis was that a positive and statistically significant association exists between SBI and the market value of companies in the construction industry. According to the results, SBI announcements explain an increase of 0.82% in the market capitalisation of the studied companies. The findings were in line with those presented in earlier studies (e.g. Turner and Frankel, 2008; Fuerst and McAllister, 2008; Eichholtz et al., 2009), suggesting that the investments of companies in SBI can lead to the creation of economic value.

3.5 Paper V: Evidence-Based Design in Learning Environments: A practical framework for project briefing

The fifth paper examined how clients can support and demand innovations in construction projects by setting innovation-enabling requirements. Moreover, the paper investigated how the design process can improve the benefits a building might have for its users. The paper suggested that clients should set requirements for design solutions in the building brief document, which would enable designers and other stakeholders to innovate potential solutions. The requirements should be based on user vision and Evidence-Based Design (EBD) research results, which support the vision. The EBD approach uses research evidence to forecast the desired outcomes for building users (Ulrich et al., 2008).

The case project for this Paper was a high school-level educational building. The case project was selected because a learning environment design at its best can have a significant positive impact on learning outcomes (e.g. Barrett et al., 2013). The practical motivation behind the paper was that few tools currently exist for clients to systematically manage the building design process as a means of harnessing their productivity benefits and allowing design teams to create better solutions.

The content analysis was used as a main data analyses method (Robson, 2002). First, EBD results were scanned from well-known Evidence-Based Design articles as well as using academic search engines (i.e. Scopus, Web of Science and Proquest) with keywords, such as *"learning outcomes"* and *"Evidence-Based Design"*. Second, the use of word and phrase frequencies and inter-correlations were analysed and used to generate themes. Following that, relative importance of the themes was determined by evaluating how large portion of the authors had found EBD results from the same theme. After the literature was analysed, the themes were summarized in the evidence matrix. Following that, the evidence matrix was tested in a construction project briefing phase. Finally, the results were presented in a workshop. The aim of the workshop was to improve the conceptual coherence of the results

The main finding of the paper was that clients can utilise the presented evidence matrix to make key decisions during the building briefing phase regarding functional requirements and design parameters that support learning in the facilities. Based on the reviewed literature, considerable evidence for correlations between indoor environment elements and specific learning outcomes exists. Table 7 summarises the findings and presents the evidence matrix for learning outcomes. The correlations are presented and analysed by applying the method suggested by Ulrich et al. (2008).

Table 7 Evidence matrix: Relationships between design strategies and outcomes (Sivunen et al., 2014 a)

Indoor environment elements / **Learning outcome**	Air quality and temperature	Noise	Day-lighting	Lighting and colour	Facility condition	Furniture	Arrangement/ layout	Informal areas at school
Attainment	**	**	**	**		*	*	
Wellbeing	**	**				*		
Engagement (Study commitment)		**				*	*	*
Attendance	*		*		*			
Affect		*				*	*	
User satisfaction							*	*
Behaviour	*						*	

* indicates that a relationship between a specific indoor element and a learning outcome was indicated, directly or indirectly, by a single empirical study reviewed in this report.
** indicates that there is strong evidence (converging findings from multiple studies) that a specified indoor element improves a learning outcome.

The evidence matrix can be utilised by building owners as a tool during the building briefing process. Pennanen and Koskela (2005) emphasise the importance of dialogue in briefings between owners, users and other stakeholders. The dialogue should include:

i. User activity description
ii. Workplace requirement description
iii. Performance requirement description
iv. Use-of-resource description.

These four steps can be both broadened and deepened by applying the evidence matrix and EBD process. In addition to the functional requirements needed as part of the user activity description, the functional requirements of the desired value-in-use for the user can also be added to the brief. Likewise, in addition to the design parameters for performance, the brief can include EBD design parameters from the resulting evidence matrix. These two steps also include the starting point for evaluating the outcome, which is not only based on evaluating the performance of the building but also on the evaluation outcomes regarding the performance of the users.

Table 8 provides an example of an EBD application used during the briefing process. Building design is the next phase after briefing. The success of the design solution can be evaluated via the brief. For example, if the presented design solution satisfies the design parameters and constraints, e.g. the requirements of the workplace, performance, EBD and use-of-resources under normal conditions, then the design can be accepted.

Table 8 EBD and brief implementation (Sivunen et al., 2014a)

Briefing phase	**Briefing content in the dialogue**	**Role of Matrix**	**Example of values**
User activity description	User vision User processes	Setting a context for a learning environment project	Classroom for 30 pupils
Desired value-in-use for the user	User goals for the value of the solution	Providing examples and good practices	Improved student attainment by 30% during the first 5 years of operation
Workplace requirement description	User space needs	Providing new insights for the learning environment; for example, use flexibility	Classroom requires 45 m2 and the room must be divisible into 2 small work group spaces
Performance requirement descriptions	Technical solutions	Setting the context for technical solutions	Load 5 kN/m2
Evidence-Based requirements from the resulting evidence matrix	Evidence-based choices	Providing recommendations	• Attainment (requirements): • Air quality level: CO2 level at 600 ppm (Satish et al., 2012) and • Internal temperature level: 23 degrees Celsius (Maula et al., 2012) • Noise: Ambient noise levels under 57 dBa (Haines et al., 2001) • Colour: Bright colours (Warm colour for senior grades and cool colours for junior grades) (Barret et al., 2013) • Lighting: High quality and quantity of the electrical lightings (Barret et al., 2013) • Day-lighting: Classrooms receive natural light from more than one direction (Barret et al., 2013)
Use-of-resource description	Goals for evaluating the learning environments	Basics for long-term and short-term evaluations	The classroom will be in good use (utilisation degree 70%), life-cycle costs of the classroom are 15 € / m2 / year

3.6 Paper VI: Managing risks related to functional changes by Design Alliance

Paper VI investigated how a client can implement and manage innovations at the construction project level. The aim of the paper was to introduce a new procurement model, Design Alliance DA, to manage a client's risks with respect to functional changes by the building user. The paper presents and analyses two tools used to develop the model and to evaluate the model's success: a risk management approach and milestone analyses.

The risk management approach consists of three phases: 1) identifying the risks related to the design flow and value-in-use for the user; 2) planning the management actions; and 3) integrating management actions into the DA model. The risks related to design flow and a decrease in value-in-use were identified by a professional group. The professional group consisted of experts from the academic world, the practical construction sector and healthcare field; they assisted in the areas of construction management, healthcare design, BIM management and procurement law. Moreover, the professional group investigated and implemented innovations and inventions to help manage the risks. In this instance, design flow refers to the perspective of the customer purchasing the design work (client) and to how the client perceives the progress of the design work. Moreover, value-in-use refers to the fit between the facilities and the user's functions. The identified risks and management actions related to design flow are presented in Table 9. The identified risks and risk prevention actions related to value-in-use are collected in Table 10.

Table 9 The identified risks and prevention actions related to design flow

Risk	Risk prevention actions for DA
Changes in user functions delay the design progress	Integrate the users into the design process via a flexible room programme, set milestones for the design process, separate procurements for the infill and base building, and set target costs for the infill and base building.
The design solution does not fulfil the requirements of the brief	Divide the design work of the design alliance into milestones, i.e. functional solution (M1), conceptual solution (M2), construction permit designs (M3), and contracting offers (M4), and verify that the design solution alternatives fulfil the requirements for each milestone using audits and financial incentives.
The users do not have enough motivation to participate in the design process	Users participate in the design alliance procurement process. Utilize a 3D and 1:1 ratio to illustrate the design solutions and their operative impact on the users. Integrate the users only into the design tasks that they consider interesting using an open building approach.

Table 10 The identified risks and preventative actions related to value-in-use

Risk	Risk prevention actions for DA
The user functions change after the design phase	Set measurable requirements for the flexibility of the building in the project brief (e.g. service flexibility and modifiability) and test the flexibility of the design solution in a virtual environment and in separate test sets.
Users cannot fully explain the requirements they have to the designers	Utilise building information modelling (BIM), i.e. use virtual 3D modelling to illustrate the design solutions and simulation to illustrate the user processes in the facilities.
	Build test facilities, i.e. build concept rooms where users can test real functions and improve the design solution and procure the infill construction work so that they are able to test the fit between facilities and functions before the final acceptance of the construction work.

The main innovations that are implemented as part of the case project are an open building design approach, 3D and 1:1 ratio CAVE technology, and intelligent BIM modelling. Moreover, a milestone analyses tool was constructed as a result of the risk management actions.

Internal and external auditors used the milestone analyses tool to assess the results of the innovations and design solution based on four milestones: a functional solution (M1), a conceptual solution (M2), construction permit designs (M3) and building contracting offers (M4). Moreover, the paper discusses the ways in which the innovations were used, and clients were able to give feedback to producers on how to develop the innovations during the next milestones. Financial incentives are an important part of the milestone analyses. In effect, approximately 40% of the compensation paid to designers is based on reaching targets at each milestone. Moreover, the designers and client share the positive and negative risks of the project.

The following key factors are analysed at each milestone:

- Quality: Does the design solution fail to meet, meet or exceed the functional, quality and flexibility requirements set for the infill and base building in the brief?
- Costs: Is the design solution in line with the investment and maintenance budget set out in the brief?
- Time: Have designers generated alternative solutions and are all designs produced on time?
- Collaboration: Are users and owners satisfied with their collaboration with designers?

The paper uses action research to study how the model manages the design phase of the case project. The case project is a new healthcare centre located in the city of Järvenpää, Finland.

The performance of the DA model was evaluated through a milestone analysis of two milestones, i.e. a functional solution (M1) and a conceptual solution (M2). An evaluation group, which that contained experts from the

areas of cost management, BIM and open building, did the evaluation. The main information sources for the evaluation were BIM models, a satisfaction survey for users and building owner and benchmark cost data. The results of the milestone analyses are presented in Table 11. A summary of the success of the milestones is presented using the following scale: comprehensive success (full or nearly full bonuses), good, normal (no bonuses / sanctions), failure, and comprehensive failure (full or nearly full sanctions).

Table 11 Results of M1 and M2 (Sivunen et al., 2014b)

Key factor	M1: functional solution	M2: conceptual solution
Quality	The design solution exceeded functional, quality and flexibility requirements.	The first version was not accepted due to conflicting design documents. However, after an audit and development period of three weeks, the design solution met the functional, quality and flexibility requirements.
Costs	The design solution is within the investment and maintenance budget.	The developed design solution is within the investment and maintenance budget.
Time	Alternative solutions (9) have been generated and all designs have been completed on time and were of good quality.	Alternative solutions (3) have been generated and the developed designs were completed on time and were of good quality.
Collaboration	User and owner are very satisfied with the collaboration.	User and owner are extremely satisfied with the collaboration.
In summary	Comprehensive success performance relative to targets.	Good performance relative to targets.

According to the evaluation results, the DA model worked well during the conceptual design phase. The developed DA model is potentially highly beneficial for the clients in projects where functions change. Moreover, the users and client stated that working cooperatively with and the user orientations of the service provider in the design process exceeded their expectations. The main reasons for the high level of satisfaction had to do with integrating the user in design tasks of their interest using an open building approach, utilising 1:1 and 3D visualisation for design solutions with CAVE technology and the service-oriented design process.

The main conclusion of the paper was that the client can manage the risks related to changing functions with the DA model. With respect to the new, 40-million-euro healthcare centre in the case study, the functional changes did not have a negative effect on the project budget, the schedule, the quality of the project or cooperation between stakeholders. The users and the building owner stated that the experience of working together on the design process exceeded their expectations. Therefore, the results indicate that the client can increase the probability of construction innovation being successfully implemented when using the proposed tools.

4 Conclusions and discussion

4.1 Summary of the results

The aim of the dissertation was to understand the client's role in the construction innovation process. Next, the results of the papers will be interpreted in light of the extent to which extent and the ways in which the results converged and combined to create an understanding with respect to the study's aim.

The findings demonstrate that companies should involve clients in the construction innovation process because the clients can help companies in identifying and reaching innovation targets. From the construction companies' viewpoint, clients can generate demand for innovations, which supports the companies in tackling challenges specific to the construction industry, such as a complex value network (Papers I and II). Active client participation was the most common innovation element in the studied construction innovation projects (Paper III). Moreover, the shareholders in the construction companies assigned positive market value to the companies' innovation announcements that included active client participation (Paper IV). Finally, the clients themselves and the users of the buildings have reported positive outcomes for innovations that have been required by the client (Papers V and VI).

The findings indicate that innovators in the construction sector recognise the essential role that the client has in construction innovation. Paper IV show that it is difficult to find active innovators within the global construction sector. Papers III and IV found that the innovators in the construction sector have recognised the positive role that clients have with respect to construction innovation and that clients are actively involved in innovation projects managed by innovative private and publicity owned construction companies, public utilities and research organisations. The results are supported by the Papers I and II. For example, in the successful construction innovation process analysed in Paper II, clients demanded innovation and actively participated in the development phase for implementing innovations.

The positive role that clients might have in the construction innovation process has been previously recognised by several authors (e.g. Barlow, 2000; Gambatese & Hallowell, 2011; Bygballe & Ingemansson, 2014). However, Nam and Tatum (1997), Winch (1998) and Ivory (2005) have all raised doubts about the clients' ability and technical competence to play a strong role in innovation projects and have even reported the negative consequences that client might have on construction innovation. The S-D Logic theory (Vargo & Lusch, 2004) and qualitative data analyses discussed in Paper V and VI were found to illustrate how clients can manage construction innovation risks during the construction design process and have a positive influence on how innovations are successfully introduced during the process.

A central theme in S-D logic theory is active customer (i.e. client) participation in innovation projects, which helps target development efforts at the things valued by the customer. According to Vargo and Lusch (2004), innovation development should always be strategically targeted at a specific customer need. In fact, the value of the innovation is defined by and co-created with the customer during the innovation process rather than embedded in the output.

The result suggested that clients can use the desired value-in-use for building users, project risks and milestone targets to specify their demands for innovation, implement innovations during the construction design process and manage construction innovation. The analyses presented in Paper V demonstrate that clients can use EBD results, user vision, targets for value-in-use and a constructed framework to set requirements promoting the desired value-in-use for building users and learn from innovation results in previous construction projects. The paper suggested that clients should set requirements for design solutions in the building brief document, which would enable designers and other stakeholders to innovate potential solutions. The requirements should be based on user vision and EBD research results, which support the vision. Paper VI illustrate that clients can specify their innovation needs by identifying project risks and proposing management actions for minimising those risks via a constructed risk management approach. Moreover, Paper VI used a milestone analyses tool to examine how clients can set milestone targets for implementing construction innovations during a construction project. Finally, the data analyses presented in Paper VI demonstrate that several innovations were successfully implemented at the construction project site where the proposed tools were used.

In its entirety, this dissertation found that the client is a driver of innovation in the construction sector and it makes the following proposals:

i. Companies should involve clients in the construction innovation process because clients can help companies in identifying and reaching innovation targets;
ii. Clients can use the desired value-in-use target setting for building users, project risk analysis and milestone targets to specify their demands for innovation and manage construction innovation process;

The results of the dissertation demonstrate that by using proper tools the construction sector can produce successful innovations and implement them in to construction projects. The results of the dissertation give insight how construction sector can tackle innovation challenges and improve effectiveness in producing innovations as the productivity of construction companies innovation strategies could be improved with client oriented innovation processes. Moreover, the client can support the implementation of the innovations in to the construction projects by utilizing presented management methods.

4.2 Contribution of the research

The dissertation contributes to the body of knowledge on successful innovation management in the construction sector and provides a means to manage construction innovation. The contribution of this dissertation can be assessed by first looking at the parts individually and then in their entirety.

The presented theoretical foundation organises the literature related to innovation management and construction innovation research and links market and client-oriented S-D logic literature with construction innovation research. The theoretical foundation is valuable for both researchers and practitioners because it highlights exemplary studies and gaps in the research and it shows how the dissertation relates to previous studies in general.

Paper I was the final publication in a unique series of publications (Kajander et al., 2010; Kajander et al., 2011) that empirically analysed construction innovation challenges at the company level within the context of sustainability. The paper deepens our understanding of the current challenges in construction innovation. The empirical findings of the paper relate to the client's potential role as a driver of innovation and supported the findings from previous studies on construction innovation in the existing literature.

Paper II was the first known study to deeply investigate the efficiency of an innovation process used by a construction company that has maintained

its status as a technological leader for a long time, and it compares the characteristics of the innovation process to those discussed in the innovation management literature. The paper argues that a successful innovation management and leadership process in the construction sector actually combines parts of several innovation theories; no single theory could explain the success of the company. Moreover, the paper empirically identified the role that client-centric elements have in a successful innovation process. The analysis produced in this paper has been perceived as valuable by several construction company managers since it can be used as an innovation benchmark for a construction company.

Paper III was among the first to address innovation elements based on S-D logic when analysing projects aiming at sustainability innovation in the construction sector. The paper was one of only a few studies to empirically analyse the client's role in construction innovation projects.

Paper IV was the first known study to test statistically the connection between sustainability innovations and the market value of companies in the construction sector. The editor of the journal *Building Research & Information* recommended the paper.

Paper V produced a tool, an evidence matrix and framework for project briefing', which was related to how clients can utilise evidence from previous construction projects during the project briefing phase to support innovation implementation, learning and risk management and to specify the client's needs for innovation.

Paper VI generated two tools for managing construction innovation risks: ʿa risk management approach', which relates to a construction project's risk management, and ʿmilestone analyses', which relates to evaluating the progress made in innovation implementation. A 'risk management approach' was used to adapt the theory of open innovation (Chesbrough, 2003a) to fit the context of construction management, as it utilises both internal and external innovations to manage project risks. The Performance Information Procurement System (PIPS) developed by Dean Kashiwagi also inspired the development of the construction. The idea behind the PIPS model is to transfer project risks to the party that has the most talent at managing the risk and thus at decreasing the project costs. The ʿmilestone analyses' tool develops commercial unity for the project alliance (e.g. Lahdenperä, 2012) to manage innovations at the project level with intensive frequency.

In its entirety, this dissertation contributes to the body of knowledge on the construction innovation field by studying empirically the client's role in construction innovation processes and it proposes tools that can be used by construction professionals. The dissertation indicates that the client-centric theory S-D logic explains the client's essential role in construction innova-

tion and that successful construction innovation practices seem to be in line with S-D logic principles. The dissertation builds on the construction innovation process presented by Winch (1998) and it supports his view that construction innovations are not typically implemented at the companies themselves, but, rather, at the construction project sites where the companies are engaged. Therefore, innovations in construction have to be implemented together with the provider(s) and the client at the construction project level. The results of this dissertation highlight the role of the client in generating demand for innovations during these negotiations and suggest new tools that clients can use to support innovation implementation and management. Finally, the dissertation advances construction management research in two ways. First, it suggests tools that clients and construction professionals can utilise to facilitate construction innovations during construction projects. Second, as a mixed-methods study it generated positive methodological pluralism with respect to research on the construction sector. Mixed methods are both legitimate and desirable if established models and understandings are to be questioned and knowledge furthered (Dainty, 2008).

4.3 Evaluation of the research

This section evaluates the research first by evaluating the mixed-method research process, and second, by discussing the quality of the research. Creswell and Plano Clark (2011) suggest that a mixed-method study can be evaluated using the following criteria: the study should

- collect both quantitative and qualitative data;
- employ rigorous procedures in the methods used for data collection and analysis;
- integrate or mix (merge, embed or connect) the two sources of data so that their combined use provides a better understanding of the research problem than just one source or the other;
- use a mixed methods research design and integrate all of the features of the study with the design; and
- convey research terms consistent with those being used in the mixed-method field.

In this study, both quantitative and qualitative data were collected (presented in Table 1). The data were collected and analysed using rigorous procedures, as presented in each paper. The study integrated the data sources and constructed findings that provide a better understanding of the research problem than a single source would. For example, the qualitative data was utilised to suggest new tools for improving the current situation.

This would not have been possible by utilising only quantitative data. In contrast, the quantitative data present new views related to the client's participation practices in construction innovation processes that would not have been possible to generate utilising only qualitative data. The study uses convergent design and integrates all features of the design, as presented by Creswell and Plano Clark (2011), and it conveys the research terms consistent with their study.

The quality of research is usually evaluated by discussing the validity and reliability of the research. Validity refers to whether the research studies what it was supposed to study. Reliability refers to the repetitiveness of the research (Eisenhardt, 1989).

Four tests have commonly been used to test the quality of empirical research (Yin, 2014). These tests establish validity, internal validity, external validity and reliability. Next, the four tests are discussed in more detail.

Construct validity refers to whether or not correct operational measures for the concepts are being studied (Eisenhardt, 1989). Often, this test has been found to be problematic in especially case study research. Yin (2014), however, presents tactics for increasing construct validity, tactics which are used in this dissertation: use multiple sources of evidence, establish a chain of evidence and have key informants review drafts of the case study reports. This research included multiple data sets analysed by different methods, which improves the construct validity of the study. Each paper presents a chain of evidence. Moreover, the findings have been benchmarked against previous research, and in some cases, with key informants.

Internal validity is a concern for causal or explanatory research (Eisenhardt, 1989), where the researcher tries to determine whether or not one event led to another or was a third component affected the process. In this process, first a theoretical statement about the inquiry was made based on earlier literature. After that, the findings were compared to the statement and the statement was revised. This step was repeated three to five times to increase internal validity, as suggested by Yin (2014).

External validity refers to whether or the study's findings can be generalised beyond the scope of the study (Yin, 2014). This mixed-method study utilises both qualitative and quantitative data. Therefore, a generalisation of the results is better than using only one kind of data (Johnson & Onwuegbuzie, 2004; Creswell & Plano Clark, 2011). The main focus groups of the study were innovative construction companies and innovation-oriented clients based in Finland. The applicability of the results to all companies in the construction sector is limited, as most of the organisations in the field in general are not innovation oriented and operate locally. However, the results of the study are primarily applicable to innovative construction com-

panies and innovation-oriented clients, which are, from an innovation diffusion standpoint, often the most interesting organisations. They develop and adapt new practices first, and in so doing lead the way for the less innovative majority of organisations (Rogers, 2003). Thus, it can be said that although the results cannot be generalised to all organisations in the construction sector, they are applicable to a group that is important for the development of the entire sector. Even though the main data was collected in Finland, the data also contain characteristics that indicate that the results are generalizable to other countries. For example Paper I contains interviews and validation data collected in Switzerland, whereas Paper IV contains data from Germany, the United Kingdom and Australia. Moreover, the findings were continuously compared to previous international literature from Western countries.

The objective of reliability is that if other researchers would follow the exact same processes and procedures and conduct the same study again, they would obtain the same results and reach the same conclusions (Yin, 2014). The goal of reliability is to minimise the errors and biases in a study. Yin (2014) suggests two tests to increase the reliability of case study research. Those tests have to do with using a study protocol and developing a study database. A research plan was developed in advance and the findings and results are reflected in the plan. The studies' progress and results were followed regularly by the co-authors of the papers. Documentation and archiving data and evidence were taken care of and the data was securely stored. In this dissertation, a study database was developed, and all data, which consist of transcribed interviews, project data and questionnaires, have been stored. However, some of the data include identifiable information about companies, which are not authorised for viewing by the general public, but which have nevertheless been read by several internal stakeholders. The results have been reviewed by several external reviewers during the academic peer-review and publishing process as well as reported publicly.

4.4 Future research

Based on the results, the dissertation makes two suggestions for future research. The first suggestion is to develop Winch's (1998) innovation process using a client's perspective on innovation. The Winch model assumes that a construction project is a solid project with multiple parties aiming to achieve the same results. According to experiences collected during the research process, this is not necessarily the case. A construction project has multiple parties with different motivations, different knowledge, different business logics and even sometimes a different language. The project parties usually change during different phases of the project. Therefore, the construction innovation process should be divided into phases, each of which needs to separate and successfully implement the innovations implemented during the previous phases. Moreover, it seems to be essential that the handing over of knowledge and innovations from one phase to another is handled properly. In many cases, an innovation is not successfully implemented during a construction project because an innovation is not properly handed over from, for example, the design phase to the construction phase. Moreover, the Winch model does not highlight the market effect that construction pilot projects have on innovations. Market attitudes and practices might change radically after the pilot project. Therefore, the effect of a successfully or unsuccessfully implemented innovation during a construction project should be reflected in the construction innovation process framework. A suggestion for an updated construction innovation model is presented in Figure 3 to inspire future researchers.

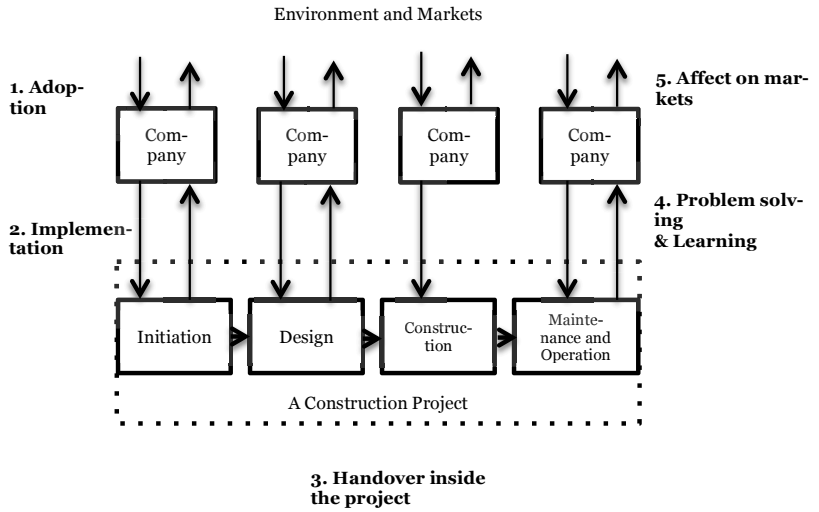

Figure 3 Illustration of next generation's construction innovation process.

The second suggestion is to study further the link between construction innovation management and the effectiveness of construction markets. The early innovation literature (e.g. Schumpeter, 1942; Arrows, 1962) has identified that innovation is a part of key characteristics to efficiently allocate resources inside the markets. The effective resource allocation is an essential part to achieve and maintain competitive markets. As the dissertation finds that the client can improve the innovation performance of construction companies, it could be that the improvement of innovation performance also makes the construction markets more efficient. Arrow (1962) demonstrated that in each contract between buyers and sellers there are assumptions related to environment where the contract will be executed. These assumptions produce uncertainty as the environment continuously changes. The investments in inventions and innovation management to manage the changes during the contract period is potentially the most efficient solution for both parties of the contract – in comparing traditional risk pricing and quarrelling practises. Therefore, could it be that the new knowledge generated in this dissertation actually is a great leap in solving the long term structural problems inside the construction sector such as low labour productivity, low customer satisfaction, project budget overruns, delays in schedule, and the great amount of disagreements?

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In practice it has often been noted that the construction sector is quite inefficient in producing innovations. This dissertation assesses, first, the clients' role in construction innovation projects, and second, how the clients can manage innovation process during the construction design phase. The research employs a mixed-method research strategy using both quantitative and qualitative data. The dissertation finds that the client is a driver for innovation in the construction sector and it proposes the following: (i) Companies should involve clients in the construction innovation process because clients can help companies in identifying and reaching innovation targets; and (ii) Clients can use the desired value-in-use for building users, project risk analysis and milestone targets to specify their demands for innovation and manage construction innovation process. The construction project where the proposes were tested successfully implemented several construction innovations.

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