Collaboration in Discontinuous Innovation in the Construction Industry

Lauri Pulkka
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Abstract

The construction industry holds great societal, environmental and economic importance. Innovation is central to the industry's attempts to simultaneously respond to challenges of increasing urbanization, climate change mitigation and stalling productivity. Construction is inter-organisational by nature, and collaboration is required to successfully introduce and implement new ideas. This is particularly true for more radical change, discontinuous innovation, which is the focus of the dissertation.

The main aim of the research is to develop a better understanding of the inter-organisational dynamics of discontinuous innovation in the construction industry. How should organisations collaborate to spur innovation? The research combines quantitative and qualitative methods; a mixed methods design is employed. The quantitative component consists of a study using survey data. The analysis of the survey is explorative in nature. All inferences are based on descriptive statistics. The qualitative component consist of studies that follow a single, comparative and multiple case study design. The data consists of interviews, documents and participant observation.

Discontinuous innovation requires closer and more active collaboration. Three arguments concerning the nature of collaboration are made. First, successful discontinuous innovation depends on gaining momentum for the innovation process. Adopting an innovation-centric rather than firm centric approach to innovation management is suggested. Second, gaining momentum is also facilitated when innovation is aligned with regulation and the dominant technological trajectory. Third, networks that operate according to the ecosystem principles are more conducive to innovation, possibly because such networks are able to prioritise collective value creation over value appropriation.

The research contributes to the understanding of change in an industry known for its conservativeness and uninnovativeness. It shows that discontinuous innovation does not require re-inventing the wheel but a combination of practices that are already being used in the construction industry. The findings have implications for firms wanting to pursue discontinuous innovation and for construction innovation research, but also for regulators, who do not always understand their major impact on the value creation of construction networks, and for funding agencies, who should consider reallocating some of their funding from individual organisations to networks pursuing innovation.

Keywords Innovation, Collaboration, Construction Industry, Ecosystem

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Tiivistelmä
Rakennusalan yhteiskunnallinen, ympäristöllinen ja taloudellinen merkitys on huomattava. Innovointi eli ideoiden tai keksintojen käytäntöön panemisen prosessi on keskeinen alan yrittäessä samanaikaisesti vastata nopean kaupungitöimisen, ilmastonmuutoksen ja laahtuvan tuottavuuden haasteisiin. Johtuen rakennusalan luontesta, uusien ideoiden viiminen käytäntöön on mahdotonta ilman yhteistyötä. Yhteistyön tarve on erityisen suuri, kun kyse on radikaalista muutoksesta, joka on tämän tutkimuksen keskiössä.


Tutkimus lisää ymmärrystämme muutoksesta alalla, joka on tunnettu konservatiivisuudesta ja epäinnovatiivisuudestaan. Tutkimustuoksisella on merkitsestä innovoiville yrityksille ja rakennusalan innovaatiotutkimukselle. Sen lisäksi tuokset koskettavat julkista sektoria, joka ei tunnu täysin ymmärtävän merkitystä arvon luonnin verkostoinnassa, ja erityisesti rahoittajille, joiden tulisi harkita innovaatiorahoituksen ohjaamista yksittäisiltä yrityksiltä enemmän määriin verkostoille.

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One of the core tenets of this research is that innovation is affected not only by those who actively participate in the process but also by those close to it. It turns out that the exact same thing applies to writing a dissertation. Therefore, I would like to extend my gratitude to all of my colleagues, past and present, at Aalto University; to our department’s students; to the wonderful people I met at UC Berkeley and the EBI; to all organisations and their representatives who have financially or otherwise supported my work; to coffee; to my dear friends and my loving family.

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List of Publications

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


   Paper II is based on


   and


IV. Pulkka, Lauri; Ristimäki, Miro; Rajakallio, Karoliina and Junnila, Seppo (2015). Applicability and benefits of the ecosystem concept in the construction industry. *Construction management and economics*. Accepted for publication.
Author’s contribution

**Publication I:** Service-dominant innovation in the built environment

The author shared responsibility for data analysis and writing the paper. The co-authors initiated the paper, collected the data and shared responsibility for data analysis and writing the paper.

**Publication II:** Gravitational Slingshot Analogy of Discontinuous Sustainability Innovation in the Construction Industry

The author was responsible for initiating the paper, data collection, data analysis and writing the paper. Seppo Junnila provided valuable comments and suggestions to improve the paper.

**Publication III:** How to Succeed in Low-Energy Housing—Path Creation Analysis of Low-Energy Innovation Projects

The author shared responsibility for initiating the paper, data collection, data analysis and writing the paper with Pia Pässilä. Seppo Junnila provided valuable comments and suggestions to improve the paper.

**Publication IV:** Applicability and benefits of the ecosystem concept in the construction industry

The author shared responsibility for initiating the paper, data collection, data analysis and writing the paper with Miro Ristimäki and Karoliina Rajakallio. Seppo Junnila provided valuable comments and suggestions to improve the paper.
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1. Introduction

One problem after another of the supply of commodities to the masses has been successfully solved by being brought within the reach of the methods of capitalist production. The most important one of those that remain, housing, is approaching solution by means of the pre-fabricated house.

Disregarding Schumpeter’s (1994, p. 68) blatant optimism, two observations can be made from the above that are at the core of this dissertation. First, housing in particular, and construction in general, is important. Second, the industry is not a frontrunner when it comes to adopting new ideas. Both points are as valid today as they were in Schumpeter’s time over half century ago.

To start with importance. The construction industry creates the physical surroundings for our lives. People in Helsinki and other Western cities spend approximately 80–90 percent of their time indoors and only a fraction of it in nature (Hussein et al., 2012). The industry is also a major source of economic activity. In 2014, it accounted for 7 percent of total and 29 percent of industrial employment, 9 percent of gross domestic product, and 45 percent of gross fixed capital formation in Europe (FIEC, 2015). Furthermore, the environmental burden created by the construction industry is large. Buildings account for nearly 40 percent of energy use, greenhouse gas emissions, waste generation and materials use (UNEP, 2011).

Given the importance of the industry, it is perhaps alarming that construction is considered one of the least innovative sectors of the economy (Miozzo & Dewick, 2004; Nam & Tatum, 1988; Pries & Janszen, 1995). It is widely acknowledged that there is a need for renewal within the industry, but change has been slow. As a result, the productivity of construction is stalling across Western countries (EIU, 2014), and the industry’s capability of responding to global challenges such as climate change mitigation has been called into question (Pinnegar et al., 2008).

Lack of innovation is most often blamed on the construction industry’s special features: project-based nature, high degree of specialisation, fragmented structure, conservative mindset, and complexity and long life span of constructed products (Bygballe & Ingemansson, 2014; Miozzo & Dewick, 2004; Nam & Tatum, 1988). These features are said to impede industrial renewal by making innovation very difficult. According to an opposing view, the perceived lack of innovation in construction is due to innovation being measured in the wrong way. Traditional metrics of innovativeness such as patents and R&D expenditure do
not capture creative problem-solving in construction projects or the development of new organisational structures (Seaden & Manseau, 2001). The construction industry also makes good use of innovation that takes place in other industries (Winch, 2003).

There is truth to both views. For example, according to a recent survey in Sweden, most construction companies, 61 percent, reported having carried out at least some changes in the last five years, adding value for the client (Håkansson & Ingemansson, 2013). However, only 22 percent of the companies described the changes they had done as considerable, and 39 percent reported having done no changes at all. So there is innovation in the construction industry, possibly more than is often thought, but there is also room for improvement in this respect, particularly when it comes to more substantial change that marks a departure from business as usual. This kind of change, discontinuous innovation, is the focus of the dissertation.

1.1 Research problem

The purpose of this research is to develop a better understanding of the inter-organisational dynamics of discontinuous innovation in the construction industry. More specifically, the following research question is examined:

*How should organisations collaborate to spur discontinuous innovation in the construction industry?*

Innovation is defined as the process of applying an idea or invention into practice (Tidd & Bessant, 2013). There is always an element of newness to innovation, ranging from new to the organisation to new to the world. Innovation can also be classified from incremental to discontinuous. Essentially the difference is in the goal: to do more of the same but better or to do something entirely different. Discontinuous innovation disrupts the pattern of steady development, for example in the form of a new product class or fundamental process improvement (Tushman & Anderson 1986).

Discontinuous innovation is the focus of this dissertation for two reasons. First, the construction industry is already capable of managing incremental innovation: firms make minor improvements to their products and processes and adapt to site-specific conditions and changing user demands all the time (Håkansson & Ingemansson, 2013; Winch, 2003). Discontinuous innovation is therefore analytically more interesting. Second, compared to incremental innovation, discontinuous innovation is riskier and more complex but has potential for greater impact (Slaughter, 1998). If we accept that problems such as climate change mitigation are severe and urgent and that proposed solutions must be radical and swift, then focusing on discontinuous rather than incremental innovation is preferable.

The focus on collaboration arises from the nature of the construction industry. Firms in the industry are specialised, and constructed products are complex,
customised, made up of many components, based on multiple technologies, im-
mobile and produced in one-off projects (Nam & Tatum, 1988). Complex prod-
ucts consist of interconnected parts, and small changes in one part can lead to
large changes in other parts (Miller et al., 1995). This has important implica-
tions for innovation. Because its impacts are not isolated but concern the entire
product system, innovation must always be negotiated with other actors
(Winch, 1998). Collaboration is required to ensure that the inputs are comple-
mentary but also because none of the specialised firms in the construction in-
dustry possess truly game-changing potential on their own.

Construction industry, real estate and construction sector, and built environ-
ment are used somewhat interchangeably throughout the dissertation. A broad,
inclusive definition of the context is useful because actors that influence and
participate in construction innovation are by no means limited to construction
firms (Winch, 1998). Also, innovation in planning or construction can have im-
lications for the use phase of buildings, and demand for innovation often
comes from clients who are outsiders to the construction industry (Blayse &
Manley, 2004)

Most instances of innovation studied in this dissertation are sustainability-
oriented. The term sustainability innovation, which is used interchangeably
with ecoinnovation, refers to innovation with environmental or societal benefits
(Rennings, 2000). The concept is problematic because the true impact of inno-
vation unfolds over time; all of its consequences cannot be foretold. Therefore,
following Hansen et al. (2009), the intention of the innovators is used as a cri-
terion of what qualifies as sustainability innovation.

The research question is examined from multiple theoretical perspectives. The
main concepts that characterise these approaches include open innovation, ser-
vice-dominant logic, change-based momentum, path creation and ecosystem.
Open innovation is a paradigm that emphasises that firms should utilise inter-
internal as well as external ideas and paths to markets (Chesbrough, 2003). Its pop-
ularity reflects the growing importance of collaboration in innovation for firms
across industries (Dahlander & Gann, 2010). Open innovation is used here for
framing innovation as something that happens across rather than within organ-
isational boundaries.

Service-dominant (S-D) logic also highlights the importance of collaboration,
standard particularly on the role of the customer. Its core arguments include that
goods are a distribution mechanism for service provision and that value of ser-
vices is not embedded in the output but defined by the customer (Vargo & Lusch,
2004). S-D logic can therefore be considered as a highly customer-centric per-
spective on innovation, removing the artificial distinction between product and
service innovation. In this dissertation, S-D logic is used to structure the analy-
ysis of innovation activities of individual organisations.

Change-based momentum has been used in organisational strategy research
to examine the energy and enthusiasm associated with pursuing transformative
change (Jansen, 2004). The core idea behind the concept is that after momen-
tum has been established, it becomes a dynamic element that fluctuates in re-
sponse to different events and perceptions and that success in transformative
change requires gaining and maintaining momentum. Here change-based momentum is used in a new way to analyse the inter-organisational dynamics of discontinuous innovation.

The hybrid socio-economic theory of new path creation has previously been used to describe, for example, the development of a new industry (Simmie, 2012). The particular framework used in this dissertation consists of five segments: initial conditions, path creation processes, new path establishment processes, barriers to new path creation and landscape change outcome (Simmie et al., 2014). It is used to analyse the two-way interaction between the network pursuing discontinuous innovation and the environment it is embedded in. This perspective is interesting because of the major influence of regulation and technological trajectories on innovation in construction (Pries & Janszen, 1995).

Problems associated with collaboration among specialised organisations to achieve increasingly complex goals are not unique to construction. Inter-firm collaboration has increased in numerous industries in the last decades (Chesbrough, 2003; Gulati et al., 2012). The ecosystem metaphor has emerged to describe the nature and implications of greater inter-dependency between actors (Thomas & Autio, 2014). There are competing definitions for ecosystem, but commonly agreed features include non-linear value creation, technical and social interdependency of participants, co-evolution of capabilities and reliance on substantial knowledge exchange and non-market governance mechanisms. So far, ecosystem theory has been developed mainly based on evidence from high-tech industries, particularly information technology. In this dissertation, ecosystem theory is applied to the construction industry to gain a deeper understanding of the nature of the inter-organisational setting in which innovation takes place.

1.1.1 Innovation in construction

Innovation in construction is defensibly different from innovation in other industries. This results mainly from the previously listed special features of the industry. Most of the differences are seen to complicate innovation. A simple example is the process of how companies find and make use of new ideas. Winch (1998) illustrates two routes for construction innovation: adoption and problem solving. Ideas from external sources are adopted by the firm, but—and unlike in, for example, manufacturing—the ideas are not implemented within the firm itself but in construction projects, adding another step to the innovation process. The second route is problem solving that takes place in projects and that the firm can learn from. However, since the need for problem solving often arises from site-specific conditions, solutions can have limited applicability in the context of other projects, which hinders inter-project learning. And these are issues at the firm level. Construction innovation is further complicated by the collaborative and inter-organisational nature of the industry.

The construction industry has been categorised as a complex product systems (CoPS) industry (Gann & Salter, 2000; Miozzo & Dewick, 2004; Rutten et al. 2009; Winch, 1998). A defining feature of all CoPS is that they consist of hier-
archically organised interconnected parts, which are provided by specialised organisations, and exhibit non-linear and emerging properties, whereby small changes in one part can lead to large changes in other parts (Miller et al., 1995). The main implication is that innovation is not just up to the firm but must be negotiated with other organisations that are affected by it, including clients, regulators, professional institutions, contractors, consultants and suppliers (Winch, 1998). Mediation of innovation is facilitated by a central actor, whose role is to orchestrate the collaboration (Nam & Tatum, 1997; Slaughter, 1998; Winch, 1998). But orchestration does not equate control. The innovation process is dynamic; organisations have varying and evolving expectations and preferences, and all of them have some power at their disposal (Harty 2005; 2008). Examining the inter-organisational dynamics of discontinuous innovation in construction is at the core of this research.

A peculiarity of the construction industry is that there are two layers of networks. Construction projects can be described as temporary networks within permanent networks (Dubois & Gadde, 2000). A firm is typically involved in multiple projects with different participants simultaneously. The particular constellation of actors collaborating in a project seldom exists before the project, and after the project ends the network is disbanded. But during the project the ties between the participants are strong because the participants are inter-dependent. The project network is thus characterised by strong but temporary relations between actors. The opposite is true for permanent networks, which are characterised by weak but long-term relations.

The limited collaboration outside of projects has earned the construction industry a reputation as a “loosely coupled system” (Dubois & Gadde, 2002). The tightness of couplings refers to the inter-relatedness of organisational entities, loose couplings meaning that organisations have only little interaction and weak influence on one another (Orton & Weick, 1990). The tightness of couplings is argued to affect the rate of innovation (Dorée & Holmen, 2004; Dubois & Gadde, 2002). Dorée and Holmen (2004) argue that tighter couplings on all levels—within projects, with supply chains, between sequential (but not parallel) projects and among construction companies—lead to more innovation. Loose couplings in the permanent network hinder innovation by encouraging short-term market exchanges over relational exchanges, which in turn decreases commitment, collective adaptations and learning (Dubois & Gadde, 2002). In addition to easing uncertainty, long-term relations help overcome the problems of knowledge transfer between projects (Drejer & Vinding, 2006).

Time and cost are dominant constraints in construction projects. Unless it is demanded by the project, they make focusing on innovation more difficult (Tatum, 1989). This is particularly true for discontinuous innovation, which can require substantial investments in terms of both time and money. The permanent network could provide a more stable platform for ambitious development activities. Another way to free innovation from some of the constraints is to organise it across multiple sequential projects; to create and proactively follow purposive development trajectories (Hartmann & Dorée, 2015). Because firms often have limited control over the participants of a project, some benefits of
long-term collaboration such as trust building may be lost in this approach (Dubois & Gadde, 2002), although, on the other hand, changes in project participants expose firms to a wider variety of ideas and knowledge (Dorée & Holmen, 2004).

1.1.2 Discontinuous innovation

A common typology of construction innovation is based on the magnitude of change and linkages between components and systems (Slaughter 1998). The different types from less to more complex are incremental, modular, architectural, system and radical innovation. Incremental innovation refers to small changes and improvements in existing products and processes. Modular innovation means an improvement in a component of a system without affecting linkages to other components. Architectural innovation is the other way around, it affects the linkages but not the components. System innovation integrates multiple new components and linkages to perform new functions or to increase performance as a whole. Radical innovation refers to rare instances of industry-changing breakthroughs that disregard existing linkages and components.

The above typology makes no explicit mention of discontinuous innovation, but the idea of steady incremental change being interrupted and redirected by occasional major advancements is there. More complex types of innovation are less common and have less predictable outcomes. They open new avenues for subsequent incremental development by changing the conception of what is possible and what constitutes an improvement (Dosi, 1982). Discontinuous innovation means noticeable qualitative change that cannot be reached through incremental improvements. As Schumpeter (1934, p. 64) put it: “Add successively as many mail coaches as you will, you will never get a railway thereby”.

Compared to incremental innovation, discontinuous innovation is risky and complex but carries a promise of greater reward in the long term (Assink, 2006; Holt, 2013; Miller, 2006; O’Connor & McDermott, 2004). Discontinuous innovation presents an opportunity for the innovators to gain a competitive advantage, but its implications for others depend on whether it is competence-enhancing or competence-destroying (Tushman and Anderson, 1986). Discontinuities brought by order-of-magnitude improvements over prior products or processes are competence-enhancing if they are based on the industry’s existing know-how. Competence-destroying discontinuities, e.g., major process substitutions and new product classes, are more worrisome for established firms because their skills and knowledge can be rendered largely obsolete, opening the market for new entrants.

Discontinuous innovation is complicated because it requires collaboration. Creating networks to manage discontinuous innovation involves not only finding and forming relationships with the right partners but also building trust and reciprocity across the network (Birkinshaw et al., 2007). This applies to all industries, but in construction the distinction between the temporary and permanent network layer must also be taken into account. It has been argued that more complex types of innovation generally require deeper and earlier commitment from all involved organisations (Slaughter, 1998). That is, more radical
innovation can require agreement from top-level management of all parties well before work starts on any particular project. Therefore, closer collaboration in the permanent network can facilitate discontinuous innovation.

1.1.3 Innovation and sustainability

Humans are overusing Earth’s resources and polluting the atmosphere with climate-changing consequences (IPCC, 2014). It should be obvious that sustainable development necessitates a departure from business as usual. Many argue that the efforts of companies in introducing new products and services to the market and transforming their processes are a large part of the solution (Carrillo-Hermosilla et al., 2009; Hall & Vredenburg, 2003; Huber, 2003; Porter & van der Linde, 1995; Rennings, 2000; Rennings & Rammer, 2011). Such views are often grouped under the heading of “ecological modernisation”, which is an umbrella term for a loosely connected group of theories and approaches that share the following premises: 1) seeing environmental problems as challenges that can be solved with social, technical and economic reforms; 2) emphasising the need to transform science and technology, production and consumption, politics and governance, and markets and other institutions; and 3) differentiating from approaches that see dismantling the capitalist system as the only way to solve environmental problems (Mol & Sonnenfeld, 2000).

Innovation with environmental benefits is termed sustainability innovation. In addition to technology push and demand pull, two drivers are linked specifically to sustainability innovation: regulatory push and vision pull (Hansen et al., 2009). Regulatory push refers to subsidies, self-regulation, laws, policies and other similar sticks and carrots that are meant to induce sustainability innovation (Rennings, 2000). For example, the European Union has set increasingly ambitious targets for 2020 and 2030 for reducing greenhouse gas emission, increasing the share of renewable energy and improving energy efficiency (European Commission, 2014). Interestingly, innovation driven by environmental regulation may lead to similar or even better results than regular innovation, due to an increase in demand and lower uncertainty (Porter and van der Linde, 1995; Rennings and Rammer, 2011). However, it has also been argued that regulation may benefit only some companies and that the short-term effects in particular are often negative (Palmer et al., 1995; Wubben, 1999). Moreover, the construction industry has a long history of extensive regulation (Nam and Tatum, 1988), environmental regulation being only one manifestation of the regulatory push mechanism. The second driver, vision pull, means that sustainability generates ideas leading to new business opportunities (Hansen et al., 2009). The moral side of vision pull is that firms have the capacity and therefore the responsibility to advance sustainability (Hart, 1997). Its business side is that sustainability offers terrific business opportunities (Wagner and Schaltegger, 2003).

Supporters of ecological modernisation have been criticised for their faith in innovation despite innovation having been the engine of increasing environmental degradation in the first place (York & Rosa, 2003). The main problem with the concept of sustainability innovation is that a reliable assessment of the
environmental and societal impacts of innovation is not possible \textit{a priori}. Therefore, and in line with Hansen \textit{et al.} (2009), a declaration of intent on behalf of the innovator is used in this research as the main criterion for identifying sustainability innovation. The problem is particularly significant in the construction industry, due to the exceptionally long life-span of constructed products. Moreover, the impacts of innovation are not unequivocally good or bad: “Whether a given entrepreneurial success benefits or injures society or a particular group within society is a question that must be decided on the merits of each case” (Schumpeter, 1947, p. 153). For these reasons, it is good to maintain a healthy scepticism towards sustainability in sustainability innovation.

### 1.2 Research structure

<table>
<thead>
<tr>
<th>Research question</th>
<th>How should organisations collaborate to spur discontinuous innovation in the construction industry?</th>
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<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Paper I: Service-Dominant Innovation in the Built Environment</td>
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<td></td>
<td>Paper II: Gravitational Sling-shot Analogy of Discontinuous Sustainability Innovation in the Construction Industry</td>
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<td></td>
<td>Paper IV: Applicability and benefits of the ecosystem concept in the construction industry</td>
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<tr>
<td><strong>Theme</strong></td>
<td>Collaboration in sustainability-oriented innovation projects</td>
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<td>Dynamics of discontinuous innovation on the network level</td>
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<td>Interaction between the innovating network and its environment</td>
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<td>Influence of the industry’s special features on the applicability of ecosystem theory</td>
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<td><strong>Core concepts</strong></td>
<td>Open innovation; Service-dominant logic</td>
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<td></td>
<td>Change-based momentum</td>
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<td>Path creation</td>
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<td>Ecosystem</td>
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<td><strong>Research design</strong></td>
<td>Survey to managers of innovation projects</td>
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<td>Single case study</td>
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<td>Comparative case study</td>
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<td>Multiple case study following replication logic</td>
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<tr>
<td><strong>Findings</strong></td>
<td>Client participation is active compared to collaboration with value network, and project aims are incremental rather than discontinuous</td>
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<td>Contextual models of innovation do not capture the dynamics of discontinuous innovation; an innovation-centric approach should be adopted</td>
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<td>Regulatory support and compatibility with the dominant technological trajectory facilitate discontinuous innovation</td>
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<td></td>
<td>Operating according to the ecosystem principles is positively connected to value creation, including innovation, in construction networks</td>
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**Figure 1.** The research structure.
The dissertation consists of four research papers and this compiling part (Figure 1). Collaboration in publicly supported innovation projects is examined in Paper I. In addition to establishing how prevalent collaboration—or lack thereof—is in the construction industry, the paper assesses whether organisations are aiming at incremental or discontinuous innovation. Paper II moves away from the frequency of collaboration to examine the quality of the interactions between organisations. How organisations interact with each other and how they impact the momentum of the innovation process is explored in a detailed single case study. Paper III follows a similar line of inquiry, but with a particular focus on interaction between the innovating network and its environment. Paper IV complements the other papers by exploring characteristics that support value creation, including innovation, in construction networks.

Papers I–IV have been published as articles in academic journals. The compiling part of the dissertation continues with a description of the methodology, summaries of the four research papers and a discussion of the findings, together with an evaluation of the research and suggestions for future research.
2. Research methodology

The research combines quantitative and qualitative methods. These are combined in a holistic way, meaning that different methods are used mainly to tease out new dimensions of the same phenomenon, not to validate the same findings multiple times (Jick, 1979). In other terms, a mixed methods design consisting of a quantitative and qualitative component is employed. More specifically, the design is what Creswell (2009) terms “sequential mixed methods”, in which one method elaborates on or expands the findings of another.

One of the main advantages of mixed methods research is said to be the ability to disregard traditional philosophical underpinnings of monomethod research in favour of combining approaches more freely to provide the best understanding of the research problem (Creswell, 2009). Greene et al. (1989) have outlined purposes of mixed methods research as follows: 1) triangulation (seeking convergence of results from different methods), 2) complementarity (elaboration or clarification of results), 3) development (using the results from one method to inform the other), 4) initiation (finding contradictions and explanations for them) and 5) expansion (extending the breadth and range of inquiry). Due to this kind of openness towards different research techniques and designs, mixed methods research is associated with pragmatism, a philosophical position that emphasises the role of research as an instrument of practical problem solving.

A pragmatic researcher recognises that quantitative methods need not be positivist or that qualitative methods need not be hermeneutic and that both methods can be used for confirmation and exploration; the selection of the appropriate technique or techniques is guided by the research problem (Onwuegbuzie & Leech, 2005).

The idea of using all available methods to come up with the best possible solution to a real-world problem is attractive, but applications of mixed methods research have received much criticism in this respect. Serious pitfalls include 1) the failure to form a research design that is conducive to both qualitative and quantitative methods, 2) falsely assuming that mixing methods would cancel out their individual shortcomings, 3) including a superficial, unnecessary quantitative or qualitative component and 4) using mixed methods as an excuse not to apply all methods rigorously (Bergman, 2011). Because the quantitative and qualitative methods are applied in separate papers that have gone through peer review, it is argued that points three and four pose a minuscule threat to this dissertation; methodologically the papers have already been deemed rigorous and significant enough to merit their publication. Moreover, the shortcomings
of different methods have not been overlooked, their weaknesses have been dis-
cussed in the papers. This leaves the question of the justification and usefulness
of both components in the same research design.

The quantitative part of the research consists of Paper I. The qualitative part
consists of Papers II, III and IV. In short, the quantitative and qualitative com-
ponents of the mixed methods research design complement each other in the
following way. The qualitative studies examine collaboration and innovation in
detail at multiple levels of analysis from interactions to the network. These stud-
ies offer explanations to the potential reasons behind the low level of collabora-
tion, as well as to other patterns, observed in the quantitative part of the re-
search. As a whole, the research design, which, in addition to sequential, can be
labelled “qualitative dominant mixed methods research” (Johnson et al., 2007,
p. 124), allows for a thorough examination of the inter-organisational dynamics
of discontinuous innovation in the construction industry. Next, an overview of
data collection and data analysis strategies are provided for both parts in rela-
tion to the research problem. Because the details of what was actually done are
already described in the individual papers, in the following sub-chapters I also
expand on the context and restrictions that affected the methodological choices.

2.1 The quantitative component: survey method

Paper I is based on survey data. The online survey was sent out to the managers
of publicly supported innovation projects that were part of two sustainability-
oriented research programmes in Finland. The unit of analysis in the study is
the organisation. The survey was conducted to understand how rapid, market-
oriented innovation methods are utilised in sustainability-oriented innovation
projects in the built environment: How prevalent is collaboration in innovation,
who do organisations collaborate with and are they aiming at incremental or
radical innovation?

The data was collected through a survey because the ease of reaching a large
number of respondents makes it an efficient tool for examining the prevalence
of a phenomenon. Although the surveyed population was relatively small, 189
managers, the survey would still have been cumbersome to replace with, for ex-
ample, interviews. Despite being based on quantitative data, the study is explor-
atory rather than confirmatory in nature. There are no hypotheses tested, and
all inferences are based on descriptive rather than inferential statistics, mainly
on cross-tabulations of different variables.

The research design was affected by the context in which the study was con-
ceived and by some practical limitations. The study was a part of a larger re-
search project, which as a whole tried to explain the seeming disparity between
the large sustainable business potential and low-rate of innovation in the built
environment. The survey was informed particularly by an earlier review of 93
publicly available innovation project summaries (Kajander et al., 2010). That
review suggested that the problem does not necessarily have to do with the or-
ganisations’ attitudes towards sustainability but with the ways they pursue in-
novation. This idea guided the creation of the questionnaire.
In retrospect, the survey suffers from some shortcomings. The failure to include questions measuring project success, which could have been used as dependent variables in order to test the theoretical framework, is perhaps the most significant one. On the other hand, the sample is relatively small and non-random, so the dataset would have lent itself poorly to statistical testing anyway. Before the survey was sent out, an alternative dataset was considered: the project plan documents. However, the agency running the research programmes could not disclose the full plans due to their business sensitive information.

2.2 The qualitative component: case study strategy

The survey left open questions concerning the dynamics of collaboration in innovation: How does collaboration affect innovation, how does it start and how does it change over time? A more detailed investigation of the innovation process and the nature of collaboration was required. Pettigrew states (1990, 268) that “practically useful research on change should explore the contexts, content, and process of change together with their interconnections through time”. The same requirement arguably applies to the study of innovation processes, which involve multiple social actors and levels of analysis and unfold over time and within contextualised settings (Garud et al., 2013; Shibeika & Harty, 2015). Therefore, for Papers II–IV a case study strategy was used. Case study is an appropriate research strategy for asking “how” and “why” questions about a contemporary phenomenon within its real-life context (Yin, 1994). Contextual conditions are highly pertinent to all three studies, which examine innovation and value creation in the context of the construction industry specifically.

Paper II presents the results of a longitudinal detailed single case study. The case is an innovation project, more specifically an attempt at developing and commercialising a concept for sustainable detached houses. The unit of analysis is the interaction of organisations. Paper III is based on a comparative case study of two networks aiming at discontinuous innovation. One of the cases is the same as in the previous paper. The comparative approach is apt, because both networks had similar aims, started at approximately the same time and operated in the same industrial and national context—only one of them succeeded, and the other failed. The unit of analysis is the network. The data for both studies consists of interviews and confidential and publicly available documents.

Paper IV employs a multiple-case design. The cases were selected by following the logic of literal replication, meaning that each case predicts similar results (Yin, 1994). Replication logic, analogously to multiple experiments, is not used to assess the incidence of a phenomenon but to seek empirical support for theoretical propositions across cases. The unit of analysis is the network. The data consists of interviews, documents and participant observation, which were used to establish converging lines of inquiry, rather than to examine different sides of the same case.

For all the cases presented in Papers II–IV, data have been collected with the goal in mind of understanding the activities of the network from its conception.
Again, in retrospect it can be argued that the datasets would have been stronger if more repeat interviews had been conducted at different time points instead of relying on interviewees’ recollections and documents for completing the timelines. Although all three papers use the case study strategies, the specific applications of the strategy within the papers are somewhat different. The main difference is that, whereas Paper II and III are clearly explorative, Paper IV with its theoretical propositions and the use of replication logic approaches what Onwuegbuzie and Leech (2005) term confirmatory use of qualitative methods.
3. Summaries of the papers

Papers included in the dissertation are summarized in this section. The summaries include an overview of the theme, method, findings and contribution of each paper.

3.1 Paper I: Service-Dominant Innovation in the Built Environment

Companies in the real estate and construction industries hold great potential for mitigating anthropogenic climate change. Exploiting that potential requires innovation, but success has been limited. There is much room for improvement in commercialization of innovation as well as in reducing the environmental impact of the industry. It is not clear why the results remain meagre despite growing investment in environmentally-oriented R&D (National Audit Office of Finland, 2011). Innovation theory suggests rapid, market-oriented innovation methods to increase chances of success. How are they utilized in sustainability-oriented innovation projects?

Table 1. Sustainability Business Innovation framework (adapted from Paper I).

<table>
<thead>
<tr>
<th>Primary SBI components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontinuity of innovation</td>
<td>Projects should strive for radical innovation instead of incremental improvements</td>
</tr>
<tr>
<td>Active customer participation</td>
<td>The customer must be seen as a co-creator of value and thus should participate actively in the entire project</td>
</tr>
<tr>
<td>Value network involvement</td>
<td>The value network comprises actors other than the customer, such as regulatory bodies, competitors and universities. Its involvement heightens the organization's sensitivity to external ideas and enables ideas to be exploited more efficiently</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary SBI components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>A value that is present throughout the innovation project from the idea to the market stage. The sustainability component of the projects studied in this paper was assessed by the funding organization before the funding resolution</td>
</tr>
<tr>
<td>Spiral commercialization process</td>
<td>The concurrent development and commercialization of the idea enables the utilization of market feedback in the main development phase</td>
</tr>
</tbody>
</table>

A framework is created to structure the empirical analysis. The Sustainability Business Innovation framework, presented in Table 1, is inspired by service-dominant (S-D) logic (Vargo & Lusch, 2004). According to S-D logic, goods are merely a distribution mechanism for service provision. Value of innovation is
defined by and co-created with the customer during the process rather than embedded in the output. Active customer participation is therefore essential. Involvement of the value network is important for speeding up the innovation process and benefiting from external ideas. Projects should also strive for discontinuous rather than incremental innovation to maximize the commercial and sustainability impact (Michel et al., 2008). Concurrent development and commercialization enables the utilization of market feedback in the main development phase (Miller, 2006).

The findings are based on a survey to managers of sustainability innovation projects. The projects are partly funded by Tekes, the Finnish Funding Agency for Innovation, through two programmes: the Sustainable Community and the Built Environment. Invitations to the survey were sent out to 189 project managers; 50 managers completed the survey, giving a response rate of 27 percent. The variables that measure the primary components of the SBI framework were operationalized by combining multiple questions. Sustainability of the projects was assessed and approved by Tekes before it funded the projects. The commercialization process was measured by one direct question. Due to some missing answers to questions used in the operationalization, the number of valid responses used in the analysis is 44.

Table 2. Frequency of SBI components in innovation projects (adapted from Paper I).

<table>
<thead>
<tr>
<th>SBI component</th>
<th>Frequency (N=44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontinuity of innovation</td>
<td>16</td>
</tr>
<tr>
<td>Change in customer behaviour</td>
<td>29</td>
</tr>
<tr>
<td>Change in organization’s value creation</td>
<td>25</td>
</tr>
<tr>
<td>Active customer participation</td>
<td>23</td>
</tr>
<tr>
<td>Customer is active or bears main responsibility</td>
<td>31</td>
</tr>
<tr>
<td>Tight cooperation from idea to market stage</td>
<td>27</td>
</tr>
<tr>
<td>Value network involvement</td>
<td>14</td>
</tr>
<tr>
<td>Business-oriented value network</td>
<td>3</td>
</tr>
<tr>
<td>Technology-oriented value network</td>
<td>13</td>
</tr>
</tbody>
</table>

Most of the innovation projects do not utilize rapid, market-oriented innovation methods as measured by the SBI framework. The main result is presented in Table 2. Customer participation is active in approximately half of the projects. The value network is utilized and the aim is discontinuous in approximately one third of the projects. All three primary components were found in 6 projects, whereas none of the components could be found in 15 projects. Also, only 10 projects reported taking the idea to the market quickly, that is, utilizing market feedback in the main development phase.

The finding is in line with earlier studies that have found a discrepancy between sustainability-innovation projects and the creation of new business. To test the reliability of the finding, another study was conducted (see Pulkka et al. 2013). The study was replicated in the context of regular development activities of organizations. A survey was sent to the shareholder organizations of RYM, the Strategic centre for Science, Technology and Innovation of the built envi-
ronment in Finland. It is a public-private partnership whose main aim is to thoroughly renew the real estate and construction sector. RYM is organized as a limited company, whose shareholders are primarily firms, research organizations and municipalities. Invitations to the survey were sent out to all 53 shareholder organizations. The survey was completed by 26 organizations, giving a response rate of 49 percent. The majority of shareholders of RYM do not utilize modern innovation methods, as measured by the SBI framework, in their development activities. Active customer participation and discontinuity of innovation components were found in approximately one-third and value network involvement in one-quarter of the respondents’ development activities. All three components were identified in one organization. That is, in line with the findings of Paper I, collaboration in innovation was found to be lacking in the construction industry.

Innovation theory suggests methods to improve the prospects of success of innovation, but they are not fully utilized in sustainability-oriented innovation projects in the construction industry. While the results suggest that there is much room for improvement, it would be naïve to simply advise firms to collaborate more. Given how pervasive the theme of collaboration is in construction innovation literature, it is perhaps safer to assume that firms are in fact aware of the potential benefits of working together but that they are, for reasons beyond the scope of this paper, unable or unwilling to commit to greater collaboration in innovation projects. The problem domain framed in this paper is examined in greater depth in other papers of the dissertation.

3.2 Paper II: Gravitational Slingshot Analogy of Discontinuous Sustainability Innovation in the Construction Industry

Paper I found that collaboration with other actors in innovation is lacking—perhaps surprisingly, given the inter-organisational nature of the industry. Questions regarding different qualities of collaboration and their implications were left unexplored. This study arose from the need to understand how different actors and their interactions influence innovation: how does discontinuous innovation actually happen in the construction industry? A detailed description of an attempt at discontinuous innovation is presented, focusing on the roles and dynamics of different institutional actors.

The findings are based on a longitudinal single-case study. The case is the K3 initiative of the Finnish Cultural Foundation. The aims of the initiative were to create designs for sustainable and affordable detached houses, to make the designs freely available for private and commercial use and to build the first K3 houses. The designs were published, but industrially manufactured K3 houses have not been produced. The empirical data consist of six interviews with key informants and extensive archival data. The presentation of the case proceeds in two steps. First, a visual mapping strategy (Langley & Truax, 1994) is used to produce a timeline of the main events of the innovation process. Second, the events are described in a narrative that is organized by relevant actor categories. Using the concept of change-based momentum (Jansen, 2004), the impact of different institutional actors on the momentum of the initiative is analysed.
The overall impact of different actors on the momentum of the initiative varied from positive to negative, as shown in Table 3. The results do not indicate a single best reason for why no houses were built. The issues that were not solved, such as house manufacturers not offering the houses for a fixed price or lack of support from regulators, are not impassable on their own. A more plausible explanation for the failure is that the consortium did not gain enough momentum to sustain the initiative, especially after the systems integrator, the Finnish Cultural Foundation, began to withdraw from it.

Based on the results, it is suggested that there are at least five reasons why an innovation-centric approach to innovation is more beneficial for analysing discontinuous innovation than a firm-centric approach is. First, discontinuous innovation in the construction industry is inter-organizational by nature, actors cannot pursue it alone. Second, an innovation-centric perspective takes into account different goals of participants and the consequences of such differences. Third, the composition of the network often changes during innovation. Fourth, other actors besides collaborators influence the momentum of innovation. Fifth, from the perspective of sustainability, the implementation of new ideas is important regardless of their initiator.

**Table 3. Impact of different institutional actors on the momentum of the K3 houses initiative (adapted from Paper II).**

<table>
<thead>
<tr>
<th>Institutional actor</th>
<th>Impact</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems integrator</td>
<td>++</td>
<td>Provided ample resources for the initiative (+); Actively coordinated the project network (+); Skilfully managed public relations (+); Forcefully imposed its own view on the desired outcome on others (–)</td>
</tr>
<tr>
<td>Clients</td>
<td>+</td>
<td>The primary client was active and committed (+); Potential home buyers voiced demand for the houses (+); The primary client withdrew from its role as developer (–)</td>
</tr>
<tr>
<td>Regulators</td>
<td>– –</td>
<td>Regulators were explicit that natural ventilation will remain an option for new construction (+); Regulators prefer mechanical ventilation (–); Energy efficiency is prioritized over other aspects of sustainability in national building regulations (–); Municipal building officials are seen to be able to discriminate against natural ventilation too easily (–)</td>
</tr>
<tr>
<td>Professional institutions</td>
<td>0</td>
<td>Professional institutions were not directly involved in the project; Typical architectural competition by the Finnish Association of Architects was bypassed, but its impact on the project was indeterminate</td>
</tr>
<tr>
<td>Architects</td>
<td>+</td>
<td>Most designs met the strict requirements (+); Some included house manufacturers in the design process (+); Gave only limited consideration for mass manufacturing (–)</td>
</tr>
<tr>
<td>House manufacturers</td>
<td>–</td>
<td>Unwilling to invest in necessary development activities to take the designs into production (–)</td>
</tr>
<tr>
<td>Consultants and experts</td>
<td>++</td>
<td>Compensated for system integrator’s lack of experience in the construction industry (+); Demonstrated the viability of natural ventilation with new building regulations in theory (+)</td>
</tr>
<tr>
<td>Component suppliers</td>
<td>0</td>
<td>Component suppliers were not included, although use of prefabricated elements could have improved manufacturability and decreased production costs of at least two of the house designs.</td>
</tr>
</tbody>
</table>

The concept of change-based momentum adds a dynamic element to the otherwise static contextual models of innovation in the construction industry. An innovation-centric and dynamic approach to innovation is presented through a
gravitational slingshot analogy illustrated in Figure 2. In inter-planetary travel, the gravity and motion of planets is used to change, without propellant, the speed and direction of a spacecraft. Similarly in innovation, interactions with institutional actors (planets) affect the path and momentum of innovation (the spacecraft). Interactions with supportive actors (travelling with orbital motion of planets) gain momentum, while interactions with non-supportive actors (travelling against orbital motion of planets) lose momentum. The K3 initiative did not become a market success (reach escape velocity). Due to a lack of momentum, it plummeted back to the centre of the system to either gather new momentum or wither away. The analogy highlights that discontinuous innovation in the construction industry depends on collaboration with supportive actors and skilful management of interactions with non-supportive actors who cannot be disregarded. Also, companies must not settle for their existing networks but remain open to the requirements that discontinuous innovation imposes on the capabilities of collaborators.

Figure 2. Gravitational slingshot analogy of discontinuous innovation (adapted from Paper II).

### 3.3 Paper III: How to Succeed in Low-Energy Housing—Path Creation Analysis of Low-Energy Innovation Projects

Paper II examined how interactions between various actors affect discontinuous innovation and found, among other things, that regulators had a substantial negative impact on the momentum of the studied innovation process despite not being members of the innovating consortium. This study expands on that
notion by focusing on the environment in which innovation takes place and the possibility of the innovators to actively shape that environment to their advantage.

The findings are based on a comparison of two cases: the K3 houses initiative, which was introduced in Paper II, and MeraReponen, a development project for energy-efficient apartment buildings that has turned into a permanent consortium. The hybrid socio-economic theory of new path creation (Simmie, 2012; Simmie et al., 2014), presented in Table 4, is used to structure the analysis. The cases are first examined separately and then a cross-case analysis is conducted. Many similarities between the cases make the comparative approach particularly useful. Both had ambitious targets concerning energy efficiency in housing, and both took place at the same time in the same institutional context. In terms of the hybrid socio-economic theory of new path creation, the cases share the same initial conditions and landscape change outcomes. However, MeraReponen has been a great success, while the K3 initiative has not.

<table>
<thead>
<tr>
<th>Initial conditions</th>
<th>Path creation processes</th>
<th>New path establishment processes</th>
<th>Barriers to new path creation</th>
<th>Landscape change outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previously formed, existing path-dependent technological development trajectories</td>
<td>The creation of a new invention</td>
<td>The innovation phase where the invention is taken into practice by the niche agents</td>
<td>Economic, cognitive, institutional, and/or socio-political factors that hinder the success of the innovation</td>
<td>Process outcome of either creation of a new industrial pathway, de-locking of the existing one or failure of the new innovation path</td>
</tr>
</tbody>
</table>

Why the outcome of the two cases was so different is made evident in Table 5. When the path establishment processes of MeraReponen are examined side-by-side with the barriers to new path creation in K3, it can be seen that the same elements that created an advantage to MeraReponen were disadvantageous to K3. What is important to note is that most of the elements were well within reach of the innovators. The capacity of either consortium to directly influence for example environmental policy was surely limited, but the construction of a demonstration house, establishment of a production line for elements and, to some extent, framing their approach as a viable alternative to climate change mitigation could have also been done in K3. The demonstration house proved to be particularly important for MeraReponen in gaining support for their concept from regulators and the market—and it was the lack of one that was seen to prevent the dismantling of many cognitive and normative barriers that stood in the way of K3’s success.

The main contribution of this study is two-fold. First, it shows that innovation is possible and its outcome can be successful despite initially unfavourable or outright hostile environment. Second, instead of passive subjects, innovators can be active agents and successfully steer changes in their institutional context to their benefit. In other words, discontinuous innovation whose planned out-
come is against current market expectations, regulation or technological trajectory can still succeed because innovation influences its environment. This holds particular importance for sustainability: if we agree that many of our current practices are unsustainable, then it is good that innovators who look for solutions more broadly can actively improve their prospects.

Table 5. Comparison of path establishment in the MeraReponen case with path creation barriers in the K3 case (adapted from Paper III).

<table>
<thead>
<tr>
<th>Path establishment in MeraReponen</th>
<th>Path creation barriers in K3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demo house</td>
<td>No demo house</td>
</tr>
<tr>
<td>− Proving the economic and technical soundness of low-energy buildings</td>
<td>− Untested technical solutions</td>
</tr>
<tr>
<td>− Creation of market interest</td>
<td>− Failure to create market interest</td>
</tr>
<tr>
<td>Production lines established for elements</td>
<td>No production lines established</td>
</tr>
<tr>
<td>− Simpler and more economic construction</td>
<td>− House manufacturers hesitate to invest in development activities</td>
</tr>
<tr>
<td>Environmental policies support urban density</td>
<td>Environmental policies support urban density</td>
</tr>
<tr>
<td>− Favours apartment buildings</td>
<td>− Disfavours detached houses</td>
</tr>
<tr>
<td>Requirements for energy performance and indoor air quality are easier to demonstrate with mechanical design</td>
<td>Requirements for energy performance and indoor air quality are easier to demonstrate with mechanical design</td>
</tr>
<tr>
<td>− Increased predictability of the building permit process</td>
<td>− Autonomy, responsibility, and tendency for risk avoidance of municipal building officials decreased the predictability of the building permit process</td>
</tr>
<tr>
<td>Timing: increasing attention to climate change makes energy efficiency a priority</td>
<td>Timing: increasing attention to climate change makes energy efficiency a priority</td>
</tr>
<tr>
<td>− Success in framing the “high-tech” pathway as the solution</td>
<td>− Failure in framing the “low-tech” pathway as a solution</td>
</tr>
<tr>
<td>− Followers enter the market</td>
<td></td>
</tr>
</tbody>
</table>

3.4 Paper IV: Applicability and benefits of the ecosystem concept in construction industry

Papers II and III examined the dynamics of discontinuous innovation at the inter-organisational level. Paper II highlighted the inter-dependency of specialised actors in the pursuit of an ambitious goal by using the concept of change-based momentum to effectively show the impact of different actors on the innovation process. Paper III used the theory of path creation to illustrate the two-way interaction between the network and its environment. However, neither paper really discussed more generalizable, desirable properties of the innovating network, which is the purpose of this paper.

This study examines how special features of the construction industry affect the applicability of ecosystem theory. If the ecosystem concept is applicable in the construction industry context, it has the potential not only to help understand value creation in construction networks but also to narrow the perceived gap between construction and other industries. The ecosystem concept of Thomas and Autio (2014) is used as a starting point. It is a versatile analytical lens, which can be used to examine any network of actors that recognize they
are engaged in a common enterprise of collective value creation. It consists of three characteristics: network of participants, governance system and shared logic. The characteristics break further down into three elements each. Based on a review of literature specific on the construction industry, theoretical propositions are suggested that link the ecosystem elements to value creation in construction networks.

<table>
<thead>
<tr>
<th>Case</th>
<th>Network of participants</th>
<th>Governance system</th>
<th>Shared logic</th>
<th>Value creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Failure to utilize high potential for combining complementary and specialized inputs of capable participants</td>
<td>Discrepancy between centralized goal setting and weak formal task coordination resulted in shallow collaboration</td>
<td>Despite mutual awareness, no informal support for task coordination, due to lack of trust</td>
<td>Failed to meet goals; Poor functioning</td>
</tr>
<tr>
<td>B</td>
<td>Participants contribute highly complementary inputs that have been partially customized for greater synergies</td>
<td>Prominence of expert power and informal task coordination promote efficiency of combining inputs</td>
<td>Dedication to shared goals and high level of mutual trust support co-evolution and task coordination</td>
<td>Exceeded initial goals; Good functioning</td>
</tr>
<tr>
<td>C</td>
<td>High complementarity of technical inputs but also participants’ business models; design-to-cost method required co-evolution</td>
<td>Developer and retailer formed a joint company for shared responsibility and decision making</td>
<td>Design-to-cost method and transparency regarding business logics created mutual awareness, increasing commitment</td>
<td>Achieved goals; Good functioning</td>
</tr>
<tr>
<td>D</td>
<td>High complementarity of specialized inputs through mutually reinforcing incentives</td>
<td>Transparent authority structure and informal task coordination drove joint problem solving</td>
<td>Transparency, trust and high cognitive legitimacy created a shared vision</td>
<td>Achieved goals; Good functioning</td>
</tr>
<tr>
<td>E</td>
<td>Complementarity of inputs coordinated through contracts; conflicts over content of adjustments</td>
<td>Inefficient task coordination due to ambiguous formal and informal authority structure</td>
<td>Mistrust, lack of transparency and fears of opportunism decreased commitment</td>
<td>Achieved goals; Poor functioning</td>
</tr>
<tr>
<td>F</td>
<td>Complementarity coordinated through negotiations; clients’ activity important for mutual awareness and co-evolution</td>
<td>Governance system consisted of partially overlapping sub-groups of participants with varying authority and coordination tasks</td>
<td>Active clients helped to create shared vision and mutual awareness that guide parts of the project towards common goals</td>
<td>Achieved goals; Good functioning</td>
</tr>
</tbody>
</table>

The study employs a multiple-case design following replication logic (Yin, 1994). The cases can be split into two categories based on the purpose of the
network. The three networks in the first category aim at innovation. More specifically, they examine the creation, commercialisation and subsequent development of a novel concept for an apartment or detached houses. The purpose of the three networks in the second category is the completion of a construction project. This distinction between networks with different purposes mirrors the distinction between permanent networks and temporary project networks (Dubois & Gadde, 2002). The cases include the two networks that were introduced in Papers II and III.

The data consists of interviews, documents, participant observation and written case study reports. The analysis was conducted at three levels: propositions, ecosystem elements and ecosystem characteristics. The process was not linear but moved back and forth between different levels of abstraction. Value creation was operationalised as goal attainment and functioning. The former refers to whether the network was able to meet its own, explicitly set goals. Functioning refers to the activities and processes taking place in the network and to the interactions between participants.

The main finding is that operating according to ecosystem principles is positively connected to value creation in construction networks (Table 6). That is, the ecosystem concept is applicable in the construction industry context. The networks that operated according to the ecosystem principles were able to attain their goals and functioned well, whereas the networks that operated against the principles had trouble with goal attainment and functioning. The results also suggest that the three ecosystem characteristics impact value creation in different ways. The governance system and shared logic shape the network of participants, which determines value creation. The link from the network of participants to value creation is direct, but the governance system and shared logic are connected to value creation indirectly through the network of participants. Furthermore, shared logic, more specifically the element of trust, can influence and substitute for parts of the governance system.

The contribution of this paper is significant. The ecosystem concept offers a structured and holistic way for analysing construction networks—the inter-organisational context in which change-based momentum and path creation take place. Based on the results, it seems that networks which operate according to the ecosystem principles are more conducive to value creation, including innovation.
4. Conclusions and discussion

In this dissertation I set out to answer the following research question: how should organisations collaborate to spur discontinuous innovation in the construction industry? My answer is based on a combination of the findings of the four papers that comprise the body of the dissertation.

The answer consists of three main arguments numbered in Figure 3. First, discontinuous innovation depends on gaining momentum for the innovation process, which requires collaboration. Collaboration, however, increases the complexity of innovation management. The process can be facilitated by adopting what I term the innovation-centric approach to innovation management. Second, gaining momentum is also facilitated when innovation is aligned with regulation and the dominant technological trajectory. This is problematic, because potentially most attractive opportunities lay outside current technology and regulation. The network can attempt to influence the environment it is embedded in through active path creation. Third, networks that operate according to the ecosystem principles are more conducive to innovation. This is possibly due to such networks being able to prioritise collective value creation over value appropriation, but it is not certain, as the research does not examine the relationship between value creation and value appropriation in detail. The three arguments and the related challenges are discussed in turn.

Figure 3. Summary of the answer to the research question.
Adopting an innovation-centric approach to innovation management

Discontinuous innovation is virtually impossible for one organization alone because new solutions must be negotiated with other actors (G. Winch, 1998). New products, for example, cannot be implemented in construction projects without ensuring complementarity with the inputs of other project participants. Minor tweaks to equipment, components or internal processes—incremental innovation—can be possible in isolation. Discontinuous innovation cannot. A radically new solution in one part of a construction project creates pressure for change and innovation in other parts, leading to “interacting wakes of innovation” (Boolland et al., 2007). Moreover, the inter-organizational nature of construction innovation and the need for collaboration is well-documented in literature (Ruten et al., 2009). The benefits of engaging a broad base of stakeholders are particularly evident in sustainability innovation and manifest in more holistic, sustainable and ambitious designs (Dewick & Miozzo, 2002; Hartshorn et al., 2005).

If the advantages of pursuing innovation in a network rather than within a firm are known, why isn’t there more and closer collaboration? Lack of collaboration was identified in Paper I as a major hindrance to innovation in the construction industry. The main challenge related to it is the increased complexity of innovation management. A greater number of collaborating organisations and dependencies between them increase the complexity of innovation in any industry (Frenken, 2000; Valkokari et al., 2012). The increased complexity of managing innovation in collaborative relationships also arises from differing goals, lack of trust and having to relinquish control over procedures and outcomes (Powell et al., 1996). Gaining and maintaining change-based momentum, i.e. the energy and enthusiasm associated with pursuing transformative change (Jansen, 2004), becomes difficult if collaborators are pulling different ways.

The challenge discussed here is not isolated to the construction industry, but the impact of the challenge is arguably more noticeable in that industry due to its characteristics. Complexity of the product leads to a high number of participants (Winch, 1998). Moreover, the industry’s project-based nature, fragmentation of its structure and dominance of transactional instead of relational exchanges complicate building long-term relationships (Dubois & Gadde, 2000). The negative effects are further heightened by construction being a low-trust industry (Green et al., 2005; Nicolini et al., 2000). These characteristics lead to an emphasis of exploitative over explorative learning behaviour, or incremental over discontinuous innovation, in collaborations (Bygballe & Ingemansson, 2014). The description of the K3 houses initiative in Paper II offers a detailed look at some of the nuances that make up the complexity of managing discontinuous innovation in the construction industry.

Thus collaboration enables discontinuous innovation in the construction industry and is therefore preferable, but collaboration also makes innovation more difficult by increasing the complexity of its management. An innovation-centric approach to innovation management is proposed as a solution to mitigate the challenge. Such an approach is discussed in Paper II and illustrated through the gravitational slingshot analogy. The essence of the approach is that
requirements of innovation come first. What and who is needed to carry the idea into practice? And what other actors affect the momentum and direction of the process? The approach reduces complexity of innovation management through the negotiation of shared goals. In addition to the benefits listed in Paper II, the approach is particularly suitable for discontinuous innovation because it is per definition a non-continuous activity; surrendering some control over the process and outcome may be more agreeable when it is the exception, not the rule.

**Alignment with regulation and the dominant technological trajectory**

Discontinuous innovation hinges in part on legitimacy (Bergek *et al*., 2008; Geels & Verhees, 2011). Legitimacy is “a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions” (Suchman, 1995, p. 574). In the construction industry, what is appropriate, proper and desirable is defined largely by expert and policy discourse and set in regulations (Lovell, 2008). Gaining legitimacy reinforces a technological trajectory, which in turn guides and facilitates future innovation. Technological trajectories guide search behaviour of firms into the same direction through embeddedness of skills, procedures and knowledge in institutions and infrastructures (Dosi, 1982; Geels, 2002; Kemp *et al*., 1998). That is, because firms in the construction industry share similar knowledge, face the same challenges, talk about them using professional vocabulary and utilize comparable procedures in their operations, they tend to resemble each other in many ways, including what they consider an improvement and hence where they focus their development efforts. When innovation is aligned with the dominant technological trajectory and regulation (when innovation is legitimate), it is more likely to gain momentum simply because it meets more acceptance and less resistance. The comparison of two cases with opposite outcomes in Paper III illustrates this aptly.

But this poses a bit of a paradox as discontinuous innovation is not about choosing the path of least resistance. Innovation as the pursuit of what doesn’t exist or hasn’t even been conceived of yet cannot be constrained to that which falls neatly within the current technological trajectory and regulation. Potentially most attractive opportunities lay outside current technology and regulation (Dewick & Miozzo, 2002; Huber, 2004). This is perhaps most obvious in the context of sustainable development: if many current practices are grossly unsustainable, shouldn’t at least some new solutions be radically different?

Prospects of success of discontinuous innovation increase when innovation is perceived as legitimate. However, many novel, potentially very beneficial ideas in the construction industry are not viewed favourably by the expert community or are not compatible with regulations from the outset. This was the case with MeraReponen and K3 Houses, the cases studied in Paper III. Active new path creation (Simmie, 2012; Simmie *et al*., 2014) is proposed as a solution to gain legitimacy for discontinuous innovation. More specifically, when focusing on new path establishment processes, I refer to the actions that are taken to carry ideas into practice. The theory of new path creation offers a suitable framework
for analysing and possibly assisting in managing discontinuous innovation, for two reasons. First, the theory accounts for the environment in which innovation takes place during all of its phases, from initial conditions to the landscape change outcome. It is holistic. It accounts for regulators, competing organizations and technologies, and public preferences, among other factors, and their influence on innovation. Second, and more importantly for managing innovation, active path creation highlights the possibility of innovators to actively shape their environment to their advantage.

In practical terms, active path creation for discontinuous innovation in the construction industry can consist of, for example, proof-of-concept projects. Such a project played a pivotal role in the success of MeraReponen. Moreover, the lack of one was speculated to be one of the main reasons behind the failure of K3 Houses. It seems that a tangible demonstration of the functioning of a new technology is a good means to influence the perceptions of experts and policy makers in the construction industry and, hence, to influence the direction of the technological trajectory and regulatory development.

**Operating according to the ecosystem principles**

The third argument is essentially the main finding of Paper IV: value creation in a network is facilitated when it operates according to the ecosystem principles. The principles were outlined by examining how the special features of the construction industry affect the applicability of the ecosystem concept of Thomas and Autio (2014) and described in a set of 15 propositions. The propositions were investigated across six construction networks, three of which were explicitly aiming at discontinuous innovation. The results indicate that the networks whose governance system (the coordination of the activities of the participants) and shared logic (the identity of the network) support the network of participants (complementarity of specialised inputs) functioned well and were able to attain their goals.

The ecosystem concept combines into one framework many elements whose importance for value creation and innovation in construction has already been identified. Thus using ecosystem theory to assess construction networks is not that far-fetched. It is important to note that the ecosystem concept is not a distinct organisational form or a contractual arrangement, although some practices are more compatible with the ecosystem principles than others, particularly those that attempt to deepen inter-organizational collaboration in construction, such as the quasi-firm (Eccles, 1981), partnering and alliancing (Bresnen & Marshall, 2000; Anvuur & Kumaraswamy, 2007), long-term business relationship (Nam & Tatum, 1992), integrated solutions (Brady et al., 2005) and partnering projects as engagement platforms (Jacobsson & Roth, 2014). Other examples of ecosystem elements that have been identified in construction literature are plenty. The economic logic of the ecosystem is compatible with what Bygballe et al. (2013) term the “network-oriented models”, which emphasise inter-organizational relationships as assets in the construction industry. These as-
sets include greater commitment, knowledge and resource sharing, trust, goodwill and reputation as informal governance mechanisms, (Dyer & Singh, 1998; Bygballe et al., 2013; Shiu et al., 2014).

Operating according to the ecosystem principles is argued to be conducive to discontinuous innovation in construction networks, but it is, of course, very challenging. Construction is considered a low-trust industry (Green et al., 2005; Nicolini et al., 2000), and the industry is typified by market-based, short-term interactions between independent firms (Gann, 1996; Thompson et al., 1998). Applying the ecosystem principles is not an easy task. Another issue that affects the strength of the third argument is that Paper IV focused on value creation and gave little consideration to value appropriation or how value is divided among participants. It has been argued that they are interrelated and should be analysed together (Ritala et al., 2013). For example, in the case of discontinuous innovation, the motivation of participants to join and stay in a network is certainly influenced by their possibilities to benefit from the outcome of the innovation process.

4.1 Relevance of the research

The construction industry holds great societal, environmental and economic importance. Innovation is central to the industry’s attempts to simultaneously respond to multiple industry-wide and global challenges. Rapid urbanization, climate change mitigation and stalling productivity of construction create pressures for the industry to come up with radically new solutions. The main relevance of this research for researchers, practitioners and policymakers is fourfold. First, the ecosystem concept provides a novel framework for analysing and potentially managing collaboration in the construction industry. Second, using the innovation-centric approach, together with the accompanying gravitational slingshot analogy, can mitigate the complexity of managing discontinuous innovation in the construction industry. Third, the research highlights some of the problems related to policies that are supposed to induce sustainability innovation. Fourth, the research has relevance for public funding of innovation and how public actors view their role regarding innovation.

To my best knowledge, Paper IV reports the first study to use the ecosystem concept to examine collaboration in the context of the construction industry. Importantly, the ecosystem concept was shown to be applicable to analysing both temporary and permanent networks. The results are in line with studies suggesting that the quality of inter-organisational couplings is a determinant of the success of the network (e.g. Dorée & Holmen, 2004; Dubois & Gadde, 2000; Dubois & Gadde, 2002). However, compared to the concept of couplings, which vary from tight to loose, the nine elements of the ecosystem concept offer researchers a much more detailed structure for analysing the quality of inter-organisational relations in networks. This research used the ecosystem concept as an analytical lense. In many other industries, especially in information technology, the ecosystem has become a successful organisational form that is condu-
cive to innovation (Van Alstyne et al., 2016). Hopefully, demonstrating the applicability of the ecosystem concept in the construction industry context can help narrow the gap between general organisational and innovation literature and literature specific to construction industry. Although the ecosystem concept was not tested in practice as a management framework for practitioners, I do not see any obstacles for using it at least as a check list of elements that should be considered and discussed by the members of the network.

The innovation-centric approach is a mindset for practitioners that emphasises the importance of common goals and change-based momentum in reaching them. The gravitational slingshot analogy tries to illustrate and communicate the approach in a clever way. Pursuing innovation jointly in a network and adopting an innovation-centric approach to its management may present a challenge to the firms’ organizational culture, defined as a set of shared mental assumptions that guide appropriate behaviour (Ravasi & Schultz, 2006). However, the innovation-centric approach is not without an antecedent, at least in spirit. The project-first mentality of strategic alliances (Clegg et al., 2002) is similar to the innovation-first mentality of the innovation-centric approach. Participants of successful alliance projects have claimed that alliancing has enabled not only a better outcome but also a smoother process through the creation of a shared collaborative environment (Walker et al., 2015). Alliancing is a proven way to address complexity of individual projects through collaboration. Its success provides at least some support to my claim that collaboration with a focus on what’s best for innovation—the innovation-centric approach—can mitigate the complexity of managing discontinuous innovation in the construction industry. But how to adopt the approach in practice? Typical construction projects are primarily constrained by time and money, and innovation requires some slack in both (Tatum, 1989). Therefore the innovation-centric approach may not work in the context of a normal construction project and instead requires a special innovation project that can more freely access the various resources of the permanent network.

The research warns against a reductionist approach to sustainability. The issue is discussed in greater detail in Papers II and III. Here it suffices to repeat that emphasising one aspect of sustainability, such as energy efficiency, over others in policy-making may limit opportunities for innovation, which decreases technological diversity and increases risk. Second, even supposedly technology-neutral regulation may unintentionally favour a certain technological trajectory (Azar and Sandén, 2011). The instance of discontinuous but low-technology innovation described in Paper II serves as an example of how regulators’ narrow conception of sustainability can hinder experimentation with alternative technologies that have proven benefits concerning other aspects of sustainability.

Finally, the research has direct implications for the public sector in two ways. Both the ecosystem and innovation-centric approach call for a broader than typical understanding of the role of public actors. They are not only regulators and planners. That is, their function is not only to constrain and steer value creation. They should be considered as active participants in value creation and, more
importantly, they should assume that role. It is argued, based on the research, that public actors do not always understand their impact on innovation of firms and even less their potential to positively contribute to it. Second, the current ways of allocating public funding for innovation do not reflect the importance of collaboration. In Paper I it was shown that collaboration is lacking in publicly funded innovation projects. The ecosystem approach is based on the idea that value is always created on the network level and precedes value appropriation that takes place on the firm level (Thomas and Autio, 2014). Directing public funding from firms to value-creating networks encourages more collaboration in innovation.

4.2 Evaluation of the research

Multiple issues can be seen to affect the external validity and reliability of the findings. External validity refers to the domain to which the findings can be generalised and reliability to the confidence that the study can be repeated with the same results (Yin, 1994). The issues concerning individual studies are described in Papers I–IV of the dissertation; here the focus is on issues that affect the entire dissertation. The context of the research is mainly the Finnish construction industry. The impact of the national context cannot be disregarded, as it has been shown that the activity of collaboration varies greatly between different countries (Miozzo & Dewick, 2004). Therefore, there is reason to believe that especially the survey could have led to different results in a different context. On the other hand, I am yet to find any indication in literature of seamless and trouble-free collaboration in any national context.

The generalisability of the survey, even in the Finnish context, can be questioned, because the sample was not random and the population represent a fraction of all organisations in the construction industry. The invitations were sent out to all participants of two innovation programmes. However, targeting this population specifically was not necessarily bad for validity, because the organisations are supposed to be the most innovative and active in R&D in the industry, yet the results still indicated a lack of collaboration. The results would have likely been even more pronounced had the sample been drawn from all organisations in Finland.

Due to the qualitative nature of the case study research, researcher bias cannot be completely excluded. However, multiple strategies for promoting the research validity were used within and across the different studies, most importantly data, investigator and theory triangulation and reflexivity (Johnson, 1997). Data triangulation was used in the multiple case study, as the replication logic used in it allows for cross-case analysis. Investigator triangulation was used in all four papers, as all of them are co-authored. Theory triangulation, i.e. using multiple theories and perspectives to interpret and explain the data, was perhaps the most important strategy for increasing the validity of the research. Within the qualitative component, three different approaches were used to examine collaboration in innovation. One of the cases was analysed using all three approaches, and two cases using two of them, with consistent results. Reflexivity
means self-awareness of potential predispositions that may affect the research process or conclusions. Reflexivity can be considered a trait of any good researcher, but its importance was perhaps greatest in Paper IV—particularly for one of my co-authors who works in the industry and collected some data through participant observation.

All of the papers have been accepted for publication in peer-reviewed journals. Peer-review increases the confidence in the findings of the individual papers, which form the foundation for the conclusions of this dissertation.

4.3 Future research

In addition to the multiple topics suggested in Papers I–IV, three avenues for future research arise that are particularly interesting. First, integrating service-dominant logic and ecosystem theory. Both have the concept of collective value creation or “value co-creation” at their core. In S-D logic, value is co-created with the user or customer; in ecosystem theory, value is co-created among the participants of a network. This difference is particularly interesting in the context of the construction industry, in which the client and user are often different actors. The absence of the user in the ecosystem concept of Thomas and Autio (2014) is striking. Value creation was operationalised in Paper IV as goal attainment and functioning. Would the results change, if the process of value creation, in line with S-D logic, would not end at goal attainment but were extended to value-in-use? In other words, how does the user benefit from the value proposed by the network?

The second avenue for future research is how to develop a better understanding of the role of public actors, particularly municipalities, in value creation. The adaptation of the ecosystem concept in Paper IV recognises the pervasive influence of public actors. They have an active role in constraining and steering value creation and participating in it, but they are often not treated as participants. This can lead to unexpected difficulties for the network, as seen for example in Paper II. Moreover, not treating public actors as active participants can more easily lead to situations where the network’s logic of value creation turns out to be incompatible with the logic of value appropriation of, for example, municipalities.

Thirdly, and related to the above, there are contrasting logics not only between but also within organisations that can affect the functioning of the network. For example, a company can have conflicting business and sustainability logics that are championed by different individuals. The fact that organisations speak with many voices and their position can shift over time has been mentioned only superficially in Papers II and IV. This phenomenon deserves closer attention.
References


The construction industry holds great societal, environmental and economic importance. Innovation is central to the industry’s attempts to simultaneously respond to challenges of increasing urbanization, climate change mitigation and stalling productivity. Because construction work is inter-organisational by nature, collaboration is required to introduce and implement new ideas. The main aim of this research is to develop a better understanding of the inter-organisational dynamics of discontinuous innovation in the construction industry. How should organisations collaborate to spur innovation? Success depends on gaining momentum for the innovation process. Adopting an innovation-centric rather than firm centric approach to innovation management is suggested. Gaining momentum is also facilitated when innovation is aligned with regulation and the dominant technological trajectory. Finally, networks that operate according to the ecosystem principles are more conducive to innovation.