THE DARK SIDE OF ECOSYSTEM ORCHESTRATION:
AN EMPIRICAL INVESTIGATION OF
BUILDING INFORMATION MANAGEMENT
IN THE DIGITAL BUILT ENVIRONMENT SECTOR

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DECLARATION

This work has not been submitted in substance for any other degree or award at this or any other university or place of learning, nor is being submitted concurrently in candidature for any degree or other award. This thesis is being submitted in partial fulfilment of the requirements for the degree of PhD. This thesis is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by explicit references. The views expressed are my own. I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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ABSTRACT

THE DARK SIDE OF ECOSYSTEM ORCHESTRATION:

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Ecosystem strategies have increased in importance as a powerful means by which competing interdependent organisations cooperate to create innovation that no single firm can match. As such, nowadays, scholars, practitioners and policy makers actively search for mechanisms to enable ecosystem emergence and orchestration. Prior research has generally examined strategies of *established long-lived successful* ecosystems in which ecosystem orchestrators take different approaches (*closed-system* and *open-system*) to ecosystem orchestration. Less is known about *failed ecosystems* and the *failure of ecosystem emergence in mature sectors*.

This thesis addresses this gap through three linked empirical studies set in the digital built environment (DBE) sector. The first is an inductive single-case study of failed open-system orchestration set in the national Building Information Management (BIM) programmes in Finland over the period from 1982 to 2002. The second is an inductive single-case study of a failed closed-system orchestration process led by a software vendor in the northern Californian DBE sector. Despite the significant differences in orchestration processes and contexts between the first and the second study, analysis of these cases indicated very similar results, namely the intentional preservation of the status quo by the sector and a failure in business model innovation, which indicates the importance of the nature of context. This led to the third study that inductively examined the contexts of the Finnish and northern

Californian DBE sectors and their importance for ecosystem orchestration. The failure of the DBE sector is further contrasted with successful ecosystems to articulate the critical constructs and components for ecosystem orchestration.

Together, the empirical studies of this thesis offer theory regarding why and how ecosystems fail. Overall, this research contributes to the literature on strategy and organisation theory and sets the stage for ongoing discussions on the dark side of interorganisational relations.

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It is important to note that although, I was officially based at the Digital Architecture Research Group at the School of Architecture and hold background in digital design, this PhD thesis was delivered under Prof. Tom Elfring's supervision. I also received continuous support by Prof. Arto Kiviniemi despite his retirement. This thesis was defended at the School of Management and, therefore, is a product of Management School as well as

Architecture School, and, therefore, interdisciplinarity. Also, I would like to thank my viva committee, Prof. Ard-Pieter de Man and Dr Benito Giordano, for their insightful feedback.

Undertaking a qualitative thesis presents a student with many opportunities to engage with industry leaders. As such, I would like to thank my interviewees in Finland and California who generously agreed to be interviewed, some more than once, for the purpose of this study. It was great to know that industry experts at all levels support young inexperienced scholars like me. I was impressed by their altruistic support, and their time, effort and willingness to share. I hope this thesis will offer some value to those who are interested.

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LIST OF ABBREVIATIONS AND SYMBOLS

DBE	Digital Built Environment
BE	Built Environment
BIM	Building Information Management
CIFE	Center for Integrated Facility Engineering
EEC	European Economic Community
EU	European Union
GC	General Contractor
IA	Industry Architecture
ICT	Information and Communication Technologies
IPD	Integrated Project Delivery
PM	Project Manager
PPP	Public-Private Partnership
SaaS	Software as a Service
TEKES	Finnish Funding Agency for Technology and Innovation
VIF	Vertically Integrated Firm
VDC	Virtual Design and Construction

PREFACE

Under the networked digital economy, the traditional views of linear models of innovation have shifted to view innovation as non-linear, complex, multidisciplinary and a highly collaborative phenomenon driven by global forces (Horn, 2005). As such, ecosystem strategies have increased in importance, and are a powerful means by which competing organisations cooperate to create innovation in ways that no single firm can; moreover, through co-evolution and interdependence, they focus on value creation and capture (Adner, 2006; Iansiti & Levien, 2004a; Moore, 1998). Therefore, ecosystems are often portrayed as a necessity to succeed in the modern economies (Jacobides, Sundararajan, & Van Alstyne, 2019; Russell & Smorodinskaya, 2018). The innovation that emerges from extensive collaboration between complementors in ecosystems is difficult for competitors to replicate, as Toyota and its suppliers exemplified (Dyer & Nobeoka, 2000; Dyer & Singh, 1998).

Nowadays, scholars, practitioners and policy makers actively search for mechanisms to enable ecosystem emergence and orchestration (Lang, von Sczepanski, & Wurzer, 2019; Nambisan & Sawhney, 2011; Rinkinen & Harmaakorpi, 2018). As the research progresses, numerous studies emerge to deepen the insights of how long-lived successful ecosystems have been orchestrated, while discovering the secrets of their success stories. Although these insights are critical for the development of the ecosystem discourse, more ecosystems fail than succeed (Cusumano, Gawer, & Yoffie, 2019b) which suggests further useful insights to the discourse on ecosystem orchestration may be possible.

Ecosystems can fail for different reasons. For example, some ecosystem strategies can fail and others can win in the same contexts with strong opposition from powerful incumbents (Gurses & Ozcan, 2015). Alternatively, an ecosystem strategy can be successful in one context and fail in another (Tee & Gawer, 2009), or they can be affected by power relations and the desire to preserve control in the sector (Jacobides, MacDuffie, & Tae, 2016; Ozcan & Santos, 2015). Finally, ecosystems might not emerge because actors are blindsided by their perceptions of the environment (Helper & Henderson, 2014; Lucas & Goh, 2009; Porac, Thomas, & Baden-Fuller, 1989). However, little research has been conducted to provide a systematic empirical approach to the failure of ecosystem emergence and orchestration.

Without a rigorous analysis of failed ecosystems, the debates around the success of ecosystem orchestration suggest a "*serious form of selection bias: to the extent that researchers study only industries that survived long enough to make their mark […] they overlook the unsuccessful industries*" (Aldrich & Fiol, 1994: p.665). Recognising the need for empirical research on failed ecosystems, the current debates on inter-organisational networks further emphasise the dark side of inter-organisational relations (Oliveira & Lumineau, 2019). The term "dark side" was introduced to refer to the ill-intended behaviours of individuals (Bizzi, 2013) and the negative effects of inter-organisational relations, such as opportunism (Seggie, Griffith, & Jap, 2013), unethical practices (Dawson, Karahanna, & Buchholtz, 2014; de Man, Koene, & Ars, 2019), detrimental outcomes (Villena, Revilla, & Choi, 2011), and conflict and disagreements (Zaheer, McEvily, & Perrone, 1998). Thus, the dark side can manifest in multiple forms.

As most ecosystems are viewed from a firm perspective, scholars tend to recognise the success of individual firms in orchestrating ecosystems but overlook the side effects produced by a successful individual firm that also might negatively affect the interdependent complementors and customers. For example, while Uber was recognised as a success story (Bashir, Yousafm A., & Verma, 2016; Cramer & Krueger, 2016; Libert, Wind, & Fenley, 2014), there is empirical evidence of Uber's business model negatively affecting dependent communities, thereby producing negative side effects (Heikkilä & Heikkilä, 2019) and constituting the dark side of ecosystems. Therefore, the idea that an ecosystem strategy could become a success story seems to be paradoxical.

This emphasises that the research on ecosystems needs further empirical evidence with a focus on interdependence while shifting the focus from singular firms to ecosystems and the side effects they produce. A new approach is called for that simultaneously looks in two directions of '*grey areas'*; it should focus on the *empirical analysis of ecosystem orchestration*, while also exploring *the dark side of ecosystem orchestration* in the context of implementation. This thesis aims to provide comprehensive insights into how and why ecosystems fail and whether the context matters for ecosystem orchestration.

CHAPTER 1

Chapter 1. INTRODUCTION

This chapter starts with a review of existing theoretical and empirical knowledge within strategic management and organisation science literature. This review presents some important theoretical relationships within ecosystem theories in order to provide a theoretical basis for the forthcoming chapters. The basis constitutes the introduction to the ecosystem concept and its difference to other related concepts. I also offer my own definition of the concept. Hence, this thesis aims to contribute to the discourse on ecosystem orchestration, I present current debates and gaps in the ecosystem field that I also aim to address. As orchestration processes comprise ecosystem related constructs and components, I present each to provide a theory and language that I will use throughout this thesis. Then, I articulate key contributions and the aims of this study while also presenting the overall framework that guided the theoretical contributions of this thesis. Considering the empirical nature of the conducted research, I provide a description of the research setting while presenting the critical issues within the digital transformation of the built environment sector in the UK and the world. I also present and explain the importance of the Building Information Management (BIM) concept that is the focus of the selected case studies. The selected case studies are systematically justified. This is followed by the methods of study section that offers a justification of the methodology while also noting its methodological limitations. It presents a framework that illustrates how cases are connected within one coherent storyline and how the process of research occurred.

The introduction chapter concludes with a thesis outline that provides an overview of the empirical chapters and its key contributions. These chapters offer a series of logical steps for the empirical exploratory research, which resulted in the design of three consecutive studies. These studies constitute chapters 2, 3 and 4. A list of the related publications and presentations are also presented to offer an additional validation of the empirical results, which proves the significance of the study and the sector's interest. Overall, the introduction demonstrates how the analysis of these consecutive cases individually and collectively contribute to the specific topic of ecosystem orchestration, while the study's importance and contributions to the theory and practice are articulated in the conclusion chapter.

1.1 CONCEPTUAL BACKGROUND

In the following section, I present the concept of the ecosystem and articulate the pressing debates around the success of ecosystem orchestration while highlighting gaps in the literature. I draw the attention to the multiple levels of ecosystem orchestration and elaborate why the dark side of ecosystems has been chosen as a topic for this research.

The following sections will provide the theoretical basis on ecosystems, which will support the subsequent chapters and the development of the thought process towards a grounded theory.

1.1.1 Ecosystem Concept in Management

Over the last two decades, the 'ecosystem' has proliferated across strategy management and organisation science in academia, policy and practice. The proliferation is so extensive that ecosystems have become a 'buzzword'. However, it is useful to understand why ecosystems have become important for modern organisations. With the global shift towards digitalisation, sectors are becoming knowledge-intensive digital economies (Russell & Smorodinskaya, 2018). Technological advancements offer new ways of disintegration, from vertical organisation to dispersed disintegrated forms of inter-organisational collaboration that are no longer limited by a single sector or geography (Yoo, Henfridsson, & Lyytinen, 2010). Thus, in the last few years, scholars have shifted focus towards the relationship between firms and their environments, which offers profound implications for how firms self-organise and strategise.

As such, the linear models of innovation (products developed in isolated laboratories to commercialisation) have shifted to non-linear models in which value creation is dependent on the collaboration of diverse multi-disciplinary organisations outside of single firm (National Research Council, 2012). The work is no longer bounded by the sector’s organisation but can be organised across organisational and geographical boundaries. Such work calls for capabilities that a single organisation is not able to offer or develop on its own. It led to a new method of inter-organisational collaboration that was not previously possible.

Therefore, traditional industry analysis is no longer capable of explaining this phenomenon as organisations increasingly organise themselves into webs of collaborating and competing firms that offer interconnected products and services (Iansiti & Levien, 2004c; Moore, 1993). Teece (2007) argued that ecosystems cover the limitations of the Five Forces framework of industry analysis (Porter, 1985), such as the competitive environment, the role of complementors, institutional interdependencies, the consideration of a dynamic environment, and that learning and innovation defines market structure while a firm’s survivability depends on the selection process. Consequently, the nature of competition has changed from intra-firm, through firm to firm, to inter-organisational, which is a mixed duopoly where an ecosystem competes with another ecosystem (Piepenbrock, 2009), meanwhile the focus shifted from efficiency and productivity to effectiveness.

Ecosystems reflect a paradigm shift in how firms operate nowadays. The increasing interest is also justified by the importance of inter-organisational relationships and the superior advantage that ecosystem strategies promise to its leaders and participants. The advantage is achieved through interdependence, complementarity, co-evolution, mutual benefit and simultaneous cooperation and competition for new value propositions that a singular actor cannot produce on its own (Dhanaraj & Parkhe, 2006; Iansiti & Levien, 2004b; Moore, 1993; Tsujimoto, Kajikawa, Tomita, & Matsumoto, 2018). Typical examples of successful ecosystems are Facebook, Airbnb, Uber, Amazon, Google, Qualcomm and Intel. Successful ecosystems create unique mechanisms for value creation and capture that link the complementarities and, through mutual symbiosis, achieve a superior organisational advantage that threatens to displace traditional markets and vertically integrated forms of organisation (Jacobides, Cennamo, & Gawer, 2018). Ecosystems exhibit a group level co-specialisation of complementarities, thus complementors depend on one another for value creation (Ozcan & Eisenhardt, 2009) while competing for value capture (Hannah & Eisenhardt, 2019). This raised opportunities for new configurations of inter-organisational relationships that require investments that are not fully fungible (Jacobides et al., 2018).

A review of ecosystem literature has illuminated that the majority of research scholars typically take a single actor - at firm level - from a top-down perspective and specifically focus on singular successful examples, thus forming "*a selection bias*" (Aldrich & Fiol, 1994). Despite this bias, there is a difference between scholars' interests in ecosystems that operate in the US and EU. For example, some US scholars extensively focus on singular firms that lead heroically successful business ecosystems and their platforms (Dhanaraj & Parkhe, 2006; Gawer & Cusumano, 2002; Iansiti & Levien, 2004c; Moore, 2006; Piepenbrock, 2009). Meanwhile, some scholars in EU countries actively search for orchestration mechanisms for innovation and knowledge ecosystems to support the emergence and growth of business ecosystems (Clarysse, Wright, Bruneel, & Mahajan, 2014; Rinkinen & Harmaakorpi, 2018; Sunesen, Henriksen, Kantanen, Dressler, & Buhrmann, 2019; Thomas & Autio, 2020). Jacobides et al. (2019) argued that ecosystems thrive in unregulated and information intensive industries. Therefore, it seems that the focus of scholars is largely influenced by the varieties of capitalism (Hall & Soskice, 2001) and successful examples that operate in their regions. Indeed, most of these successful examples of business ecosystems operate in the US context but are not limited to it.

There is also a difference between scholarly domains in terms of their conceptual focus. For example, strategic management scholars focus their attention on how firms simultaneously compete and cooperate with rivals to capture value in business ecosystems (Iansiti & Levien, 2004c). Technology management scholars tend to focus on the adoption and evolution of networked interconnected technologies in technology ecosystems (Adomavicius, Bockstedt, Gupta, & Kauffman, 2007), digital ecosystems (Henningsson & Hedman, 2014) and platform ecosystems (Gawer, 2014). Economic geography scholars tend to focus on the spatial features of innovation ecosystems (Feldman, Siegel, & Wright, 2019), whilst innovation scholars tend to focus on knowledge creation and diffusion in innovation and knowledge ecosystems (Ritala & Almpanopoulou, 2017; Thomas & Autio, 2020). Finally, entrepreneurship scholars tend to focus on the enablement of entrepreneurial activities within a certain context (Autio, Nambisan, Thomas, & Wright, 2018; Stam & Spigel, 2018).

Regardless of the popularity of ecosystems amongst scholars and their importance, the debate around their usefulness is still ongoing. Oh, Phillips, Park, and Lee (2016) called the ecosystem a "*flawed analogy*" with a lack of rigor, while Adner (2017) argued for its usefulness to understand modern digital economies. Overall, the ecosystem concept "*requires a great deal of conceptual and empirical rigor*" (Ritala & Almpanopoulou, 2017: p.39) and needs clarity to reach theoretical maturity (Thomas & Autio, 2020). In recent years, there have been increasing attempts to explore the constructs of the ecosystem concept in order to provide a theoretical underpinning and make sense of the phenomenon (Aarikka-Stenroos & Ritala, 2017; Adner, 2017; Gomes, Facin, Salerno, & Ikenami, 2018; Jacobides et al., 2018;

McIntyre & Srinivasan, 2017; Oh et al., 2016; Suominen, Seppänen, & Dedehayir, 2019; Tsujimoto et al., 2018).

This thesis aims to contribute to the development of theory by exploring the constructs and components of ecosystem orchestration while contributing to the stream of research on the dark side of ecosystem orchestration (Oliveira & Lumineau, 2019). The empirical insights on the dark side of ecosystem orchestration will invaluably alleviate existing biases and provide novel perspectives on failed ecosystems that are currently insufficiently explored, both theoretically and empirically. The exploration of failed ecosystems will offer an indispensable opportunity to ground ecosystem components in failed empirical cases to understand why, how and what contributes to the failure of ecosystem emergence and orchestration.

1.1.2 Ecosystem Definition

Despite emerging research and proliferating interest in ecosystems amongst scholars and practitioners, there is general confusion on what an ecosystem is and how it differs from other concepts (Thomas & Autio, 2020; Valkokari, 2015). **Table 1** highlights terminological and conceptual inconsistencies across the literature on what ecosystems are. The analysis of existing terminology suggests that the underlying logic of ecosystems rests upon the notion of multilateral networks, value co-creation, interdependence, non-generic complementarity, simultaneous cooperation and competition, and co-evolution. Across the literature, the ecosystem term typically refers to a network structure of interdependent complementary actors that, through mutual symbiosis, survive and co-evolve around focal value propositions (Adner, 2017; Iansiti & Levien, 2004b). Adner and Kapoor (2010: p.309) suggested that the ecosystem concept is “*a way of making interdependencies more explicit*”.

Table 1 Overview of Ecosystem Definitions

N	Author	Type[1]	Definition	Keywords
1	(Granstrand & Holgersson, 2019: p.3)	IE	*"An innovation ecosystem is the **evolving set of actors**, activities, and artefacts, and the institutions and relations, including **complementary** and **substitute relations**, that are important for the **innovative** performance of an actor or a population of actors."*	Co-evolution, set of actors and institutions, complementarity, substitute, innovation
2	(Stam & Spigel, 2018: p.2)	EE	*"A set of **interdependen**t actors and factors **coordinated** in such a way that they enable productive entrepreneurship within a particular te**rritory."***	Interdependence, coordination, territory, enablement
3	(Jacobides et al., 2018: p.2264)	E	*"An ecosystem is a set of actors with varying degrees of **multilateral, non-generic complementarities** that are **not fully hierarchically controlled. […]** ecosystems are **distinct forms of organizing** economic activities that are linked by specific types of **complementarities**."*	Multilateral, non-generic specific types of complementarities, not fully hierarchically controlled, distinct forms of organising
4	(Tsujimoto et al., 2018: p.7)	E	*"To provide a product/service system, an historically **self-organized** or managerially **designed multilayer social network** consists of actors that have different attributes, decision principles, and beliefs."*	Self-organised, designed, multilayer, network
5	(Russell & Smorodinskaya, 2018: p.115)	IE	***"Open non-linear systems** that are characterized by changing multi-faceted motivations of **networked actors**, high receptivity to **feedback**, and persistent structural transformations, induced both **endogenously and exogenously."***	Open, non-linear system, network, feedback, endogenous and exogenous induction
6	(Autio et al., 2018: p.74)	EE	*"A distinct type of **cluster** that specializes in harnessing **technological affordances** (Gibson, 1977) created by **digital technologies and infrastructures**…and combines them with spatial (i.e. proximity-related) **affordances** to support a distinctive cluster dynamic that is expressed through the creation and **scale-up of new ventures."***	Cluster, technological affordances, digital technologies and infrastructure, proximity affordances, scale-up ventures
7	(Gomes et al., 2018: p.16)	IE	*"A set for the **co-creation**, or the jointly creation of value. It is composed of **interconnected and interdependent networked actors**, which includes the focal firm, customers, suppliers, **complementary** innovators and other agents as regulators. This definition implies that members face **cooperation and competition** in the innovation ecosystem, and an innovation ecosystem has a **lifecycle**, which follows **a co-evolution** process."*	Value co-creation, interdependence, focal firm, complementary actors, cooperation and competition, co-evolution, lifecycle
8	(Adner, 2017: p. 40)	IE	*"The **alignment structure** of a **multilateral set of partners** that need to interact in order for a focal **value proposition** to materialize."*	Alignment structure, multilateral set of partners, value propositions

[1] **Types:** Ecosystem -E; Business Ecosystem -BE; Innovation Ecosystem – IE; Knowledge Ecosystem – KE; Entrepreneurial Ecosystem – EE.

9	(Autio & Thomas, 2014: p.3)	IE	***"A network** of **interconnected** organizations, connected to a **focal firm or a platform**, that incorporates both the production and **use of side participants** and creates and appropriates **new value through innovation."***	Network, interdependence, focal firm, platform, complementarities, value propositions
10	(Thomas & Autio, 2014a: p.1)	E	*"The fifth facet of the organizational field, consisting of both **network** and **institutional elements** with **value co-creation** as its recognized area of institutional life."*	Value co-creation, network, institutional elements
11	(Williamson & De Meyer, 2012: p.24)	BE	*"A **network** of organizations and individuals **that co-evolve their capabilities** and roles and **align** their investments so as to **create additional value** and/or **improve efficiency**."*	Network, co-evolution, alignment, value creation, efficiency improvement
12	(Piepenbrock, 2009: p.68)	BE	*"An **aggregate collection** of externally **interacting heterogeneous** organizations or **competing** enterprises. These external interactions tend toward the competitive selling of substitute products and services."*	Aggregate level, heterogeneous, cooperation and competition, product, service
13	(Teece, 2007: p.1325)	BE	***"The community** of organizations, institutions, and individuals that impact **the enterprise** and the enterprise's customers and supplies."*	The community, the enterprise
14	(Iansiti & Levien, 2004c: p.6)	BE	*"Characterized by a large number of **loosely interconnected participants** who **depend on** each other for their **mutual effectiveness and survival."***	Loos interdependence, mutual benefit, survival, mutual effectiveness
15	(Moore, 1993: p.76)	BE	*"A business ecosystem […] crosses a **variety of industries** […], companies **coevolve capabilities** around **a new innovation**: they work **cooperatively and competitively** to support new products, satisfy customer needs, and eventually incorporate the next round of innovations."*	Co-evolution of capabilities, cooperation and competition, complementarity

The conceptual inconsistency of ecosystem terminology relates to the unit of analysis and the type of ecosystem (Thomas & Autio, 2020). Descriptions of ecosystem types are provided in Section 1.1.4.

Moore (1993) was the first to introduce the concept of an ecosystem with a biological approach, which he described as a set of organisations and consumers that align themselves with a focal firm. He suggested viewing a firm not as a member of a single sector but as part of a "*business ecosystem*" that includes suppliers, complementors, competitors and other stakeholders. Teece (2007) has further emphasised that ecosystems cross a variety of industries and stakeholders such as customers, competitors, complementors, suppliers, regulatory authorities, standard-setting bodies, the judiciary, and educational and research institutions, see **Figure 1**.

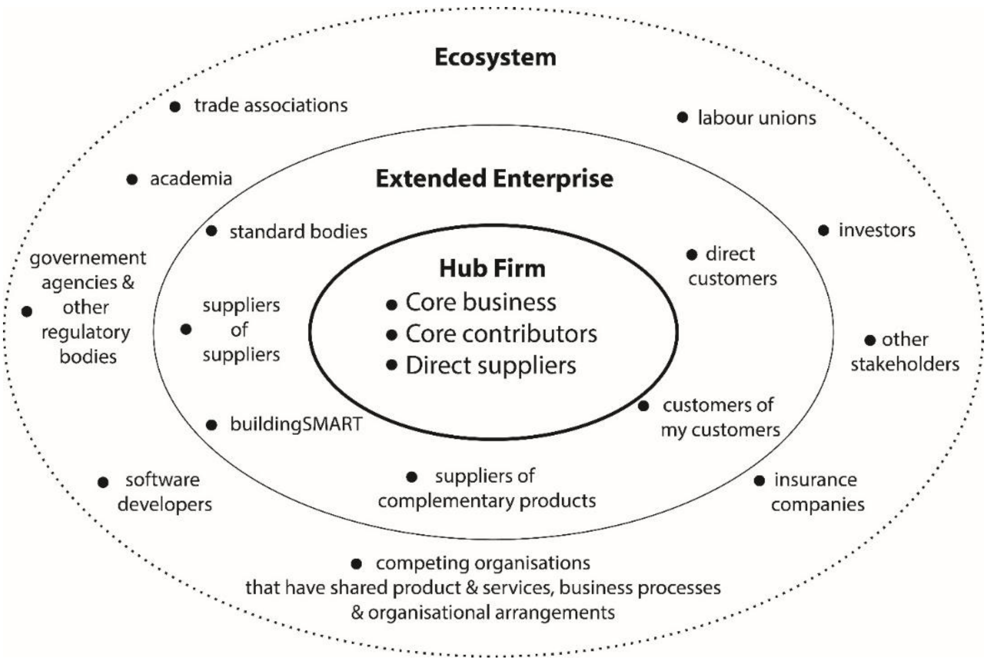

Figure 1 Ecosystem Stakeholders (Adapted from Moore (1997))

The fundamental idea is that ecosystems produce value that singular firms cannot and therefore, by recognising the advantages and opportunities, competitors are willing to cooperate for their collective survival. Piepenbrock (2009) distinguished "*the extended enterprise*" (Dyer, 2000) as an organisational set that defines the focal firm and its key exchange actors and ecosystems. These represent an "*organisational community*" (Aldrich, 1999) and "*an aggregated collection of externally interacting heterogeneous or competing enterprises*" (Piepenbrock, 2009: p.68), see **Figure 2.**

Adner (2017) recognised two streams of the ecosystem concept that are compatible despite their distinctive approaches, namely *ecosystem-as-structure* and *ecosystem-as-affiliation*. The *ecosystem-as-structure* views ecosystems as a network configuration of activities around a focal value proposition; in comparison, the *ecosystem-as-affiliation* views ecosystems as networked communities that are interconnected around a platform or defined by their networks. The *ecosystem-as-affiliation* is aligned with the biological characteristics of

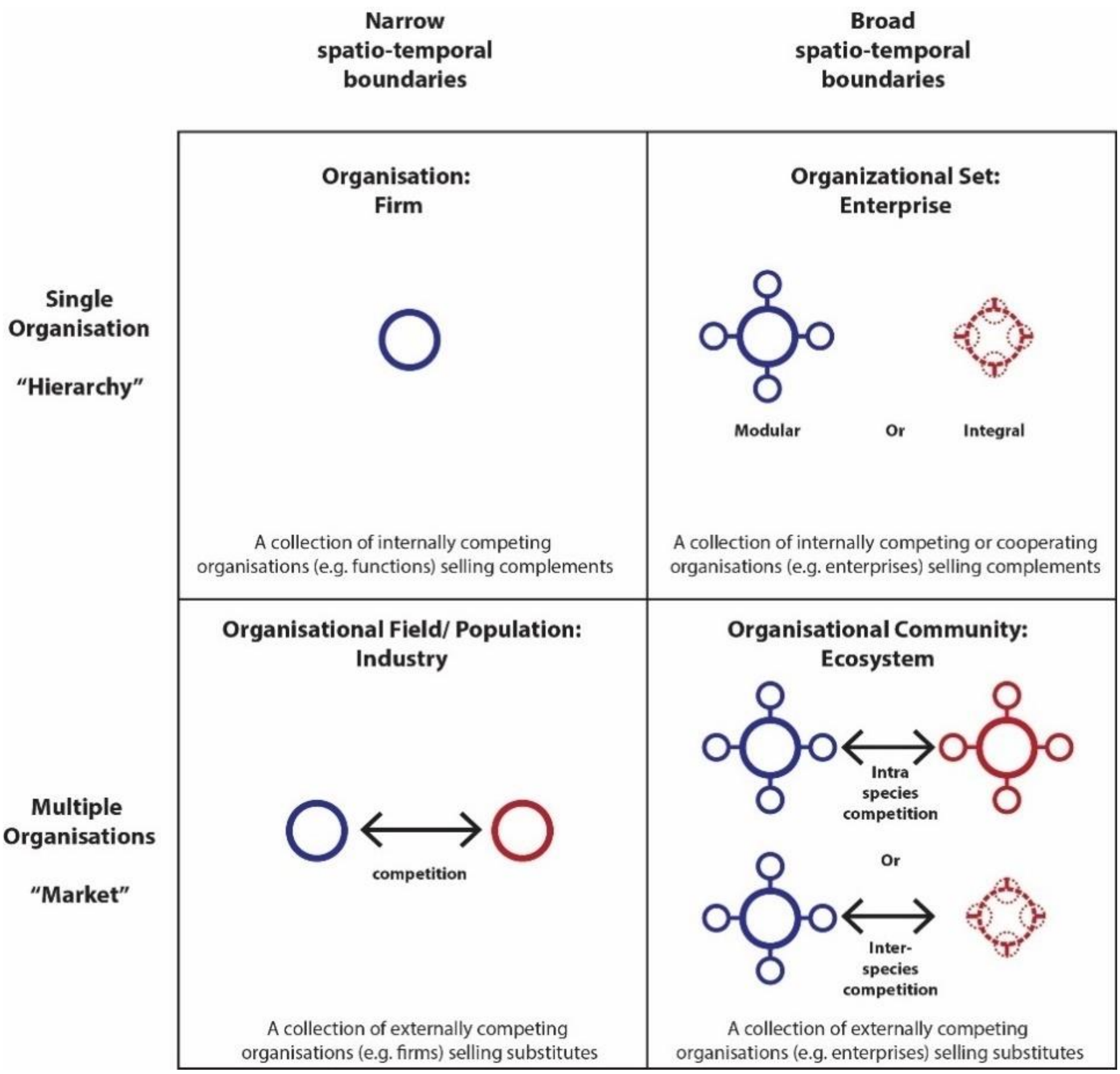

Figure 2 Distinctions of Firm, Enterprise, Sector and Ecosystem

(Reproduced from Piepenbrock (2009))

ecosystems emphasising interdependence and symbiotic relationships. To explain aggregate forms of interactions for value co-creation, Adner (2017) noted the following examples of ecosystem-as-affiliation: Silicon Valley, healthcare ecosystems and the Microsoft ecosystem. The *ecosystem-as-structure* is aligned with the current view of what constitutes an ecosystem. In particular, an important contribution made by Adner (2017: p.47) is to emphasise an *alignment structure* which is *"the extent to which there is mutual agreement among the members regarding positions and flows, […] to secure its role in a competitive ecosystem".*

Thus, a question arises as to what makes up the alignment structures within ecosystem strategies?

Recently, Jacobides et al. (2018) took a further step by considering conditions and *modularity*, which are necessary for ecosystem emergence, and the interactions and co-existence of different types of *complementarities* that make ecosystems non-linear and non-hierarchically controlled. Although the ecosystem is an evolving concept and as it is continuously refined, the ecosystem definition provided in this thesis is aligned with the work of Jacobides et al. (2018). Thus, in this thesis I build on, refine further and conceptualise my own definition of ecosystem concept as:

> *"A multilateral non-generic community of complementary interdependent unilaterally non-hierarchically managed organisations that cross a variety of industries. These organisations serve different functions, have conflicting goals and therefore is a political coalition. Through simultaneous value creation (cooperation) and value capture (competition), they co-evolve capabilities individually and collectively around multiple value propositions, and produce distinct system structure consisting of sub-systems, the business models, that generate ecosystem dynamics, define ecosystem type, and, thus, affect the business environment through its performance and activities."*

1.1.3 Ecosystem and Related Concepts

As a stream of management literature, the ecosystem concept rests on network theories as the characteristics of ecosystems have been present within "*strategic networks*" (Gulati, Nohria, & Zaheer, 2000), "*business networks*" (Möller & Halinen, 2017), "*value networks*" (Christensen & Rosenbloom, 1995), and "*value nets*" (Brandenburger & Nalebuff, 2011). Networks are treated as a distinct mode of organisation that is different from both the vertically organised hierarchy and the market (Thorelli, 1986). Networks can be conceptualised as a system with interconnected nodes where nodes can be any entities, such as actors, technologies and organisations (Powell, 1990), and "*represent webs of standardised formal and informal alliances between participants"* (Jacobides et al., 2018: p. 2261) . The characteristic that sets ecosystems apart from networks is that the opportunity in an ecosystem for customers to choose among components of a product or a service that are supplied by each complementor while affiliating themselves with a specific platform or an ecosystem. In comparison, in networks, customers choose a standardised offer from a predefined menu based on market-based arrangements (Jacobides et al., 2018). The research on networks also largely focuses on a single sector (Uzzi, 1997) while ecosystems span multiple sectors and have *"the existence of a set of distinct and asymmetrical links tied at the group level by specific complementarity"* (Jacobides et al., 2018: p. 2275).

The theoretical underpinnings of the ecosystem concept set it apart from other related concepts. The ecosystem concept differs from "*supply chains*" (Mentzer et al., 2001) and "*value chains*" (Porter, 1985) by their non-linear and non-hierarchical focus on value creation and capture through co-evolution and interdependence (Iansiti & Levien, 2004c). Industry and sector structure are irrelevant in ecosystems (Moore, 1998). "*Value nets*" (Brandenburger & Nalebuff, 2011) do not take into consideration the emergence and co-evolution of actors nor the structural dynamics that affect the arrangements of value creation and capture. Ecosystems draw on the research traditions of both "*clusters*" that are *"geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions … in particular fields that compete but also co-operate"* (Porter, 1998: p.197) and "*innovation systems*" (Edquist, 1997). In comparison, innovation systems incorporate clusters (McDonald, Huang, Tsagdis, & Josef Tüselmann, 2007) and differ in terms of the unit of analysis. The clusters and innovation systems focus on firms and industries while ecosystems incorporate various levels starting with the individual and its relationship within the larger socio-economic system or context (Spigel & Harrison, 2018). Rinkinen and Harmaakorpi (2018) emphasised difference in terms of the functions relevant for new digital global economies, such as clusters that focus on local economies and learning. Meanwhile, ecosystems are on the scale of global economies, and the competitive advantage of clusters is to enable firms to achieve economies of scale based on local spill overs that appear and evolve at both local and global levels (Boari, Elfring, & Molina-Morales, 2016). Clusters are representative of an industry where firms compete fiercely and exploit the cluster's resources (Porter, 2000; Tallman, Jenkins, Henry, & Pinch, 2004). However, Porter (2000) emphasised that firms also cooperate in clusters. Competition and cooperation happen on different levels and in different dimensions, specifically between buyers and suppliers. In ecosystems, firms simultaneously compete and cooperate (Hannah & Eisenhardt, 2019) while the complementary assets of firms add value to the end product and service through interdependence. The notion of interdependence and co-creation are also present in the literature on clusters (Saxenian, 1994). Spigel and Harrison (2018) adopted three principles from clusters: collective networking and exchange between firms, the ability of firms to get knowledge from the environment, and the acknowledgment that knowledge creation is a core component of the modern economy. However, clusters also share similarities in their focus on the external business environment which contributes to a firm's competitiveness (Boari et al., 2016; Stam & Spigel, 2018). Both ecosystems, particularly entrepreneurial ecosystems and clusters, build on the arguments of Marshall (1920) that the geographic features of economic activity influence a firm's competitiveness. As with ecosystems, clusters can also cross city, regional and national borders (Porter, 1998) and a variety of industries (Rinkinen & Harmaakorpi, 2018). Overall, clusters are characterised by geographic concentrations, proximity, location, pro-competition and productivity growth (Porter, 2000). These characteristics differentiate clusters from ecosystems.

The co-evolution of populations have been present in the literature on the ecology of *populations* (Hannan & Freeman, 1977). The population ecological perspective focuses on the relationship between the environment and firm-level output including its survival and growth, while ecosystems focuses on the ecosystem level and value co-creation by heterogeneous interdependent actors (Thomas & Autio, 2020). In comparison, "*open innovation*" (Chesbrough, 2003) concerns the governance of innovation, and aligns with the ecosystem in the willingness of the leading firm to exercise flexibility and support interdependent communities, however, it differs from ecosystems in relation to multilateral coordination.

Dhanaraj and Parkhe (2006) suggested that innovation networks, referring to ecosystems, can be viewed as *loosely coupled networks* of actors. *Loosely coupled networks* are viewed as separate entities but have a certain interdependence (Weick, 1976). Orton and Weick (1990) described such systems as formed voluntarily, with no hierarchical control and have some degree of indeterminacy and interdependency. "*Loosely coupled systems correspond to the notion of modular architectures*" (Piepenbrock, 2009: p.379).

Overall, ecosystems are explicitly set apart from other theories by the following features: the consideration of complementarity (Teece, 1986); a system-level goal of value creation (Gulati, Puranam, & Tushman, 2012); simultaneous competition and cooperation (Hannah & Eisenhardt, 2019); the health of the ecosystem (Iansiti & Richards, 2006); the consideration of a wider network of value creating participants (Teece, 2007); interdependence (Adner & Kapoor, 2010); the complexity of relationships, structures and governance mechanisms (Dhanaraj & Parkhe, 2006), and the co-specialisation of complementors that requires non fully fungible investments that 'lock in' the complementors in the ecosystem (Jacobides, Knudsen, & Augier, 2006). To conclude, ecosystems are distinct forms of organising due to their structures and coordination mechanisms (Jacobides et al., 2018).

1.1.4 Ecosystem Types

Over the last decade, the ecosystem concept has become granular. The nature and extent of dependencies, common goals, and shared capabilities vary and gave rise to different types or contrasting forms of ecosystem (Nambisan, Lyytinen, Majchrzak, & Song, 2017). As such, a wide range of descriptive phenomenon and related concepts have emerged, such as the "*business ecosystem*" (Moore, 1998), "*knowledge ecosystem*" (Clarysse et al., 2014), "*innovation ecosystem*" (Adner, 2006), "*service ecosystem*" (Wieland, Polese, Vargo, & Lusch, 2012), "*digital ecosystem*" (Weill & Woerner, 2015), "*entrepreneurial ecosystem*" (Autio et al., 2018), *etc.* While new types of ecosystem continue to emerge, business, knowledge and innovation ecosystems typically dominate the literature alongside the platform concept. **Table 2** provides the characteristics of business, knowledge and innovation ecosystems. Valkokari (2015) provides a useful comparison of these three ecosystems.

Table 2 Characteristics of Knowledge, Innovation, and Business Ecosystems.

Characteristics	Business ecosystem (Iansiti & Levien, 2004; Moore, 1993)	Knowledge ecosystem (Clarysse et al., 2014)	Innovation ecosystem (Adner & Kapoor, 2010)
Logic	Business value co-creation, sharing and capturing for customers amongst competing and cooperating actors with a complementary niche	Knowledge exploration, co-creation and sharing around knowledge hubs	Innovation co-creation, sharing and capturing throughout all actors fostering the creation of growth, interaction, and innovative start-ups around so-called knowledge hubs
Connectivity, interdependence	Global value network, closed and open decentralised decision-making, loosely interconnected actors	Geographically clustered knowledge hubs to co-create and share knowledge between non-competing actors, closed and open, high density of actors	Geographically or internationally clustered actors that create an open network to diffuse innovation, closed and open, high speed innovation diffusion
Complementors	Suppliers, customers, and companies as a core, other actors more loosely involved as complementary actors	Public and private research institutes, academia, technology entrepreneurs serve as knowledge nodes	Innovation policymakers, local intermediators, innovation brokers, international alliances, absence of customer actors
Orchestrator	Global large company or an alliance	University, PRO	Alliance or an intermediary organisation

The *business ecosystem* highlights a business relationship between actors focusing on the value capture and end-users which are orchestrated by a hub firm (Iansiti & Levien, 2004c). The *knowledge ecosystem* focuses on knowledge generation and value creation reflecting the open processes of R&D and innovation at the regional level (Clarysse et al., 2014; Järvi, Almpanopoulou, & Ritala, 2018). The *innovation ecosystem* is concerned with the mechanisms for fostering value creation around knowledge hubs and often share technological standards to enable ecosystem-level value co-creation (Adner, 2017). Thomas and Autio (2020) suggested that distinctive theoretical logics have not matured, as it is difficult to distinguish knowledge from innovation ecosystems. *Entrepreneurial ecosystems* are initiated by new ventures to facilitate business model innovation that reflects the entrepreneurship of individuals instead of knowledge, a product, service or technology innovation (Autio, Cao, Chumjit, Kaensup, & Temsiripoj, 2019; Stam & Spigel, 2018). Often, ecosystems and platforms are used interchangeably (Teece, 2018b) despite their theoretical complementarity. Cusumano and Gawer (2002: 54) referred to the "*platform and its innovation ecosystem*" suggesting that these two entities are interrelated. Platforms are primarily concerned with the management of interfaces and offer the basis for value co-creation while ecosystems are concerned with structure and interdependence (Jacobides et al., 2018). Platform ecosystems are associated with a platform hub within a technology-based business system (Thomas, Autio, & Gann, 2015). Considering the extensive proliferation of the ecosystem concept and the existing lack of theoretical clarity, researchers are increasingly trying to make sense of the trends of ecosystem research. As such, scholars present conflicting but partly overlapping results on how the ecosystem field is evolving. For example, Jacobides et al. (2018) suggested three emerging streams of research on ecosystems: platform ecosystem, business ecosystem, and innovation ecosystem. Partly overlapping with Jacobides et al. (2018), Tsujimoto et al. (2018) defined four streams of research: industrial ecology, business ecosystem, platform management, and multi-actor network perspective. A multi actor network stream does not have a clear theoretical background, which resonates with the observations of Jacobides et al. (2018). Scaringella and Radziwon (2018) further recognised four main types of ecosystem: business, innovation, entrepreneurial, and knowledge. Gomes et al. (2018) conducted a systematic literature review, from 1993 to 2016, highlighting that the original interest in business ecosystems (Moore, 1993) has recently shifted towards the concept of innovation ecosystems, thus also shifting the focus from value capture towards value creation. Furthermore, Thomas and Autio (2020) articulated that business, platform, innovation and technology ecosystems are types of innovation ecosystem while knowledge and entrepreneurial ecosystems are considered separate streams.

Considering the emerging state of the ecosystem field, Thomas and Autio (2020) suggested that the proliferation manifests along two dimensions - the unit of analysis and the type of output. They further distinguished four characteristics that are common to all ecosystems: heterogeneity, system-level output, the nature of interdependence and ecosystem orchestration. The notion of ecosystem boundaries have also provided some focus in defining ecosystem types; for example, Adner (2017) articulated boundaries at the level of firms (Apple's platform ecosystem), sectors (payment ecosystem or a healthcare ecosystem) and regions (Silicon Valley). He further argued that the focus on boundaries creates inconsistent views and an illusion of focus while the focus on value propositions gives rise to the emergence and governance of ecosystems. Valkokari (2015) further suggested that boundaries can be set in several ways: by geographical scope (local vs. regional or national vs. global); on a temporal scale (from history to future or static snapshots vs. dynamic interactions); by permeability (open vs. closed), as well as by the types of flow (knowledge, value, material) chosen. Organisational boundaries can also be set in relation to power

(Santos & Eisenhardt, 2005). For example, in the recent years, successful leading ecosystems cooperate to develop superior capabilities and power by forming super ecosystems (Jacobides et al., 2019).

1.1.5 Ecosystem Emergence and Orchestration

With the increasing interest in ecosystems, ecosystem orchestration has become an important research theme. In strategic management literature, the term orchestration refers to the capability of a firm to purposefully manage the interdependent set of co-specialized and interdependent customers and complementors without a hierarchical authority (Nambisan & Sawhney, 2011). However, there are several issues that remain unclear in relation to ecosystem orchestration (Dattée, Alexy, & Autio, 2018; Nambisan & Sawhney, 2011; Ozcan & Santos, 2015). Empirical research on the processes for ecosystem and innovation orchestration remains poorly understood and is considered of great importance for practice and theory (Batterink, Wubben, Klerkx, & Omta, 2010; Dhanaraj & Parkhe, 2006; Gawer, 2014; Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013; Pittaway, Robertson, Munir, Denyer, & Neely, 2004; Powell, Koput, & Smith-Doerr, 1996; Spencer, 2003; Teece, 2018b).

Research on orchestration processes is divided into two main streams: studies that look at the process of emerging ecosystems (Hannah, 2016; Navis & Glynn, 2010; Roundy, Bradshaw, & Brockman, 2018; Santos & Eisenhardt, 2009; Thomas, 2013), and orchestration processes in established long-lived ecosystems (Dhanaraj & Parkhe, 2006; Gawer, 2000; Nambisan & Sawhney, 2011). Particular focus is given to ecosystem and network leadership from a firm's perspective and how a successful firm intentionally coordinates, directs and manages network members (Lorenzoni & Baden-Fuller, 1995; Nambisan & Sawhney, 2011). From the perspective of leading firms, the value created in the network should be extracted (Kogut, 2000). Indeed, some firms are found to be successful at directing networks' innovation efforts, e.g Toyota (Dyer & Nobeoka, 2000) or Intel (Gawer & Cusumano, 2002). As the processed deployed by leading firms differ in outcome, scholars often attribute the success of such firms to its capabilities in orchestrating the ecosystems (Helfat & Raubitschek, 2018; Teece, 2007) and mechanisms deployed for network orchestration (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011).

Research into ecosystem orchestration is often built on the frameworks provided by Dhanaraj and Parkhe (2006) which were updated by Nambisan and Sawhney (2011) and theorised how leading firms orchestrate innovation network activities. They provide useful insights on established, long-lived firm-centric ecosystem orchestration mechanisms which reflects the interplay between network design and innovation design. In their frameworks, they clearly distinguish between network design, orchestration processes and the outcome. The focus of their work is on the processes that leading firms must perform and the interactions between them.

Dhanaraj and Parkhe (2006) offer a framework of network orchestration by elaborating three processes that a leading firm must perform: *managing innovation mobility, innovation appropriability,* and *network stability* (see **Figure 3** A Framework for Orchestration in Innovation Networks Network (Reproduced from Dhanaraj and Parkhe (2006)) **).** Dhanaraj and Parkhe (2006: p.660) defined *knowledge mobility* as *"the ease with which knowledge is shared, acquired, and deployed within the network"; innovation appropriability* as "*environmental property that governs an innovator's ability to capture the profits generated by an innovation" (Teece, 1986: 610)*"; and *network stability* as "*dynamic (not static) stability, which aims for a nonnegative growth rate while allowing for entry and exit of network members.".*

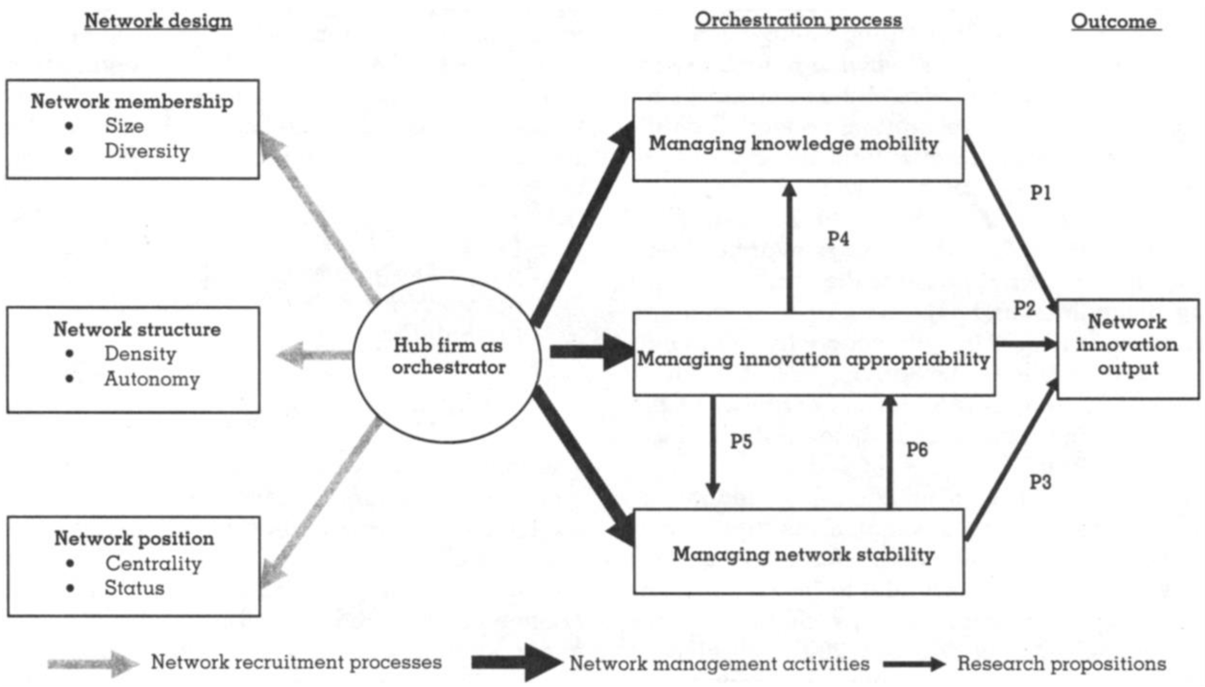

Figure 3 A Framework for Orchestration in Innovation Networks Network

(Reproduced from Dhanaraj and Parkhe (2006))

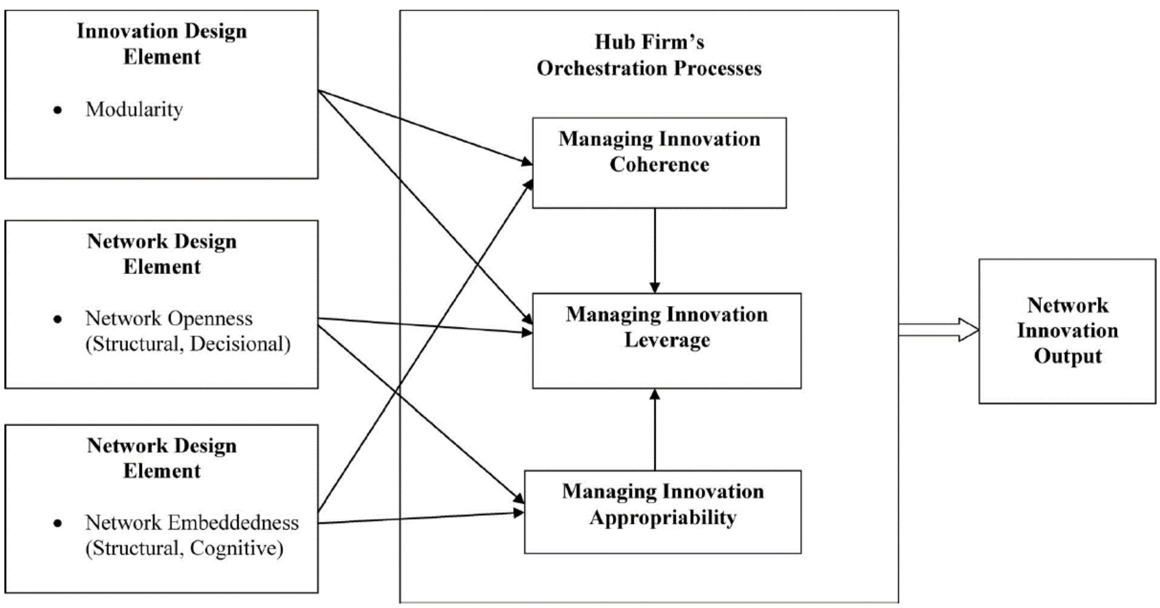

Figure 4 Orchestration Processes, Innovation Design, and Network Design

(Reproduced from Nambisan and Sawhney (2011))

Nambisan and Sawhney (2011) focus on the hub-based processes of *managing innovation leverage, innovation coherence* and *innovation appropriability* (see **Figure 4**). *Innovation leverage* allows ecosystem actors to reuse and deploy the available resources, capabilities and knowledge to facilitate innovation co-creation. *Innovation coherence* allows for the internal and external coherence of activities. Internal coherence relates to the coordination and alignment of processes within the ecosystem while *external coherence* relates to the alignment of the goals and outputs of ecosystem actors with the external market and technology environment. Innovation appropriability provides the mechanisms for value capture by ecosystem actors. A hub firm has a central role in setting the standards, rules and roles while coordinating innovation activities for value creation and value capture (appropriation) (Nambisan & Sawhney, 2011).

Nambisan and Sawhney (2011) focused on a few constructs at one level that require the further refinement of theory because the complexity of network-centric innovations can vary with the industry or sector's structure, agency and the power relations of interrelated innovators (Jacobides & Winter, 2012; Nambisan & Sawhney, 2011). Thus, understanding orchestration at multiple levels in different contexts can provide new constructs that are relevant to orchestration processes. Thus, the contextual nature of orchestration processes and what constructs and components contribute to success and failure are a promising line of inquiry in this research.

Ecosystem orchestration builds on two intertwined processes value creation and value capture. It is important to distinguish value creation from value capture (appropriation) for theoretical clarity. In strategic management literature, scholars clearly distinguish between value creation and value capture by recognising that, in some cases, organisations can lose or share value while engaging with other organisations (Bowman & Ambrosini, 2000). Thus, it is important to understand that value creation and value capture in ecosystems are two distinct processes that require further research to examine the relationships between these two concepts (Lepak, Smith, & Taylor, 2007). Lepak et al. (2007) argued that a tension between cooperation for value creation and competition for value capture is a multi-level phenomenon that operates across all levels of analysis. Oskam, Bossink, and de Man (2020) explored the tensions between collective and individual value creation, and the gain and loss of value during sustainable ecosystem development. The process of value creation and value capture reflects the process of exploring new ideas and exploiting ideas (March, 1991), and that which Bowman and Ambrosini (2000) distinguished between use value and exchange value. Jacobides et al. (2006) further emphasised that value creation concerns *who can do what* while value capture concerns the division of revenue and *who gets what*. Gomes et al. (2018) further highlight a shift in focus from value capture towards value creation and the re-distribution of value. This shift can be observed in ecosystem literature as scholars shifted their focus from business ecosystems that are associated with value capture towards innovation ecosystems that are associated with value creation. Organisations adopt different approaches to the process of orchestrating value creation and value capture.

Orchestration processes are determined by the *closeness* and *openness* of the system approach (Giudici, Reinmoeller, & Ravasi, 2018); business ecosystem orchestration falls into a category of *closed-system orchestration* that reflects the self-interest orientation of the hub firm in deliberately extracting value from the ecosystem (Nambisan & Sawhney, 2011). This suggests that the value in ecosystems is not necessarily equally distributed amongst participants. Some orchestrators can become dominators destroying the ecosystem's health, as conceptualised by Iansiti and Levien (2004c). Thus, ecosystems can become "*ego-systems*" (Jacobides et al., 2019). *Open-system orchestration*, as opposed to *closed-system orchestration*, reflects the orchestrator's orientation in supporting network members in value creation and capture (Giudici et al., 2018). For example, when Intel created an open modular platform, it undercut its ability to compete effectively by not owning an intellectual property of industry standards and distributing it to its partners to co-create value (Gawer & Henderson, 2007). Firms in ecosystems balance tensions between value creation (cooperation) and value capture (competition). Closed-system orchestrators tend to capture value for themselves while occupying bottlenecks and restricting competition in their own component and, at the same time, fostering competition in complementary components (Bremner, Eisenhardt, & Hannah, 2017). There are underlying foundations of orchestration that seem to be common across all types of ecosystem:

- Mechanisms for value creation and capture (Jacobides et al., 2018);
- Business model innovation (Teece & Linden, 2017);
- System-level business goals, outputs or value propositions (Jacobides et al., 2018).

There is an increasing understanding that ecosystem strategies require distinct structures and processes to generate certain outcomes. For example, Clarysse et al. (2014) argued that different types of ecosystems differ in system dynamics and orchestration mechanisms for value creation and capture. They further argued that it is not clear whether the success factors of business ecosystems are similar to knowledge ecosystems. This has serious implications for orchestration and policy research. The same debate applies to the orchestration mechanisms adopted in Business-to-Consumer (B2C) contexts. As successful ecosystems tend to operate in B2C contexts, it is still unclear how ecosystems operate in Business-to-Business (B2B) contexts (Aarikka-Stenroos, Jaakkola, Harrison, & Mäkitalo-Keinonen, 2017). It is evident that more B2B ecosystems and platforms fail than succeed. For example, a study of 209 failed platforms by Cusumano et al. (2019) highlighted that twice as many platforms fail in B2B contexts than in any other category. They also have the shortest lifespan (as shown in Appendix Table 4-1 in the book *'The Business of Platforms: Strategy in the Age of Digital Competition, Innovation, and Power*' written by Cusumano et al. (2019).

Although there is an emerging stream of research on orchestration mechanisms, less is known about early-stage ecosystems (Hannah, 2016; Thomas, 2013) and even less is known about why and how ecosystems emerge or fail, and the critical components and constructs necessary for ecosystem orchestration andemergence or how they contribute to failure and success. Determining these factors is therefore critical. Early-stage ecosystems pose certain challenges to scholars as they did not live long enough to leave a *"blueprint"* of who does what, when and how (Ozcan & Eisenhardt, 2009: p.256). As previously mentioned, most literature focuses on the limited empirical analysis of successful examples, which suggests a "*serious form of selection bias: to the extent that researchers study only industries that survived long enough to make their mark [...] they overlook the unsuccessful industries*." (Aldrich & Fiol, 1994: p.665).

There are two long-standing debates in relation to ecosystem orchestration. First, whether sources of successful long-lived ecosystems rest on the firm's capabilities or the firm's environment (e.g. industry architecture). While some scholars argue that the emergence of ecosystems is largely dependent on industry architecture (Jacobides et al., 2006; Jacobides & Winter, 2012), Piepenbrock (2009: p.5) argued that:

> "S**ources of superior firm performance lie** neither exclusively within the firm, nor in its industrial environment, but **in how the firm interacts with its environment** - i.e. in the network architecture of the firm's extended enterprise. It appears that these enterprise architectures, which both enable and constrain managerial agency and adaptation through spatially and temporally bounded rationality, give rise to architectural inertia and the power of environmental selection".

Second, whether ecosystems can be intelligently orchestrated to determine the outcome or are part of an evolutionary organisational design that is directed by the selection process in the context (Piepenbrock, 2009). Indeed, some studies imply that ecosystems are intentionally designed (Gawer & Cusumano, 2002; Iansiti & Levien, 2004c; Nambisan & Sawhney, 2011; Ritala & Almpanopoulou, 2017) while others suggest a self-organised nature (Clarysse et al., 2014; Jacobides & Winter, 2012). However, this research is agnostic on this debate, and instead explores the process of emergence and failure in a specific context of digital innovation.

Research on ecosystems seems to miss a critical understanding of the success factors of ecosystem orchestration. What can be perceived as a success from a single firm perspective, can also be a failure from end-users' and complementors' points of view. This understanding of what contributes to failure and what is a failure has been limited in the research on failed ecosystems (Heikkilä & Heikkilä, 2019; Ozcan & Santos, 2015). The dark side of ecosystem orchestration (Oliveira & Lumineau, 2019) is another promising line of inquiry taken in this thesis. Indeed, new organisational forms have advantages as well as downsides and effects on the societies at large (de Man et al., 2019). Although a new stream of research on the dark side of ecosystems has emerged, it calls for further rigorous empirical research (Guerrero & Urbano, 2017; Heidenreich, Wittkowski, Handrich, & Falk, 2015; Mantovani & Ruiz-Aliseda, 2016; Mele et al., 2018). Therefore, this thesis aims to address this call.

The following sub-section offers a definition of ecosystem orchestration process.

1.1.6 Ecosystem Orchestration Definition

There is clear inconsistency and a lack of theoretical clarity on what ecosystem orchestration is (Aarikka-Stenroos & Ritala, 2017; Jones, Hesterly, & Borgatti, 1997). As ecosystem orchestration is a new phenomenon, a clear definition of *what it is* does not currently exist. However, ecosystem orchestration literature largely builds on inter-firm network governance literature referring to the terms of "*interfirm networks*" (Grandori & Soda, 1995; Uzzi, 1997), a "*network form of organisation*" (Powell, 1990), "*quasi-firms*" (Eccles, 1981), "*loosely coupled systems*" (Weick, 1976), "*network organisation*" (Miles & Snow, 1986), *"complex entities of group-related actors"* (Brusoni & Prencipe, 2013) and "*network-centric innovation*" (Nambisan & Sawhney, 2011). This literature refers to interfirm coordination that is mostly characterised by dyadic relations that are formed as informal social systems as opposed to hierarchically and contractually managed systems (Jones et al., 1997). Purposeful action by a leading firm or network hub is often considered of great importance in orchestrating ecosystems and networks. According to Jacobides et al. (2018: p.2260), "*an important but neglected characteristic of ecosystems is that they help coordinate interrelated organisations that have significant autonomy*". Indeed, successful ecosystems are not hierarchically managed but often enabled by modular architecture (Baldwin & Clark, 2000). Therefore, orchestration processes are the result of a partly designed process (Jacobides et al., 2018). Overall, powerful firms design rules and try to shape processes wittingly and sometimes unwittingly. As such, the ecosystem orchestration literature often builds on the definitions provided by Dhanaraj and Parkhe (2006) and Nambisan and Sawhney (2011). Key definitions used in the ecosystem orchestration literature are presented in **Table 3.**

In this thesis, I refer to ecosystem management and governance as ecosystem orchestration and conceptualise it thus:

> *Ecosystem orchestration is characterised by the processes and mechanisms that are used by a leading firm or a leading hub to intentionally direct, coordinate, influence and manage diverse sets of conflicting complementors and customers. These processes are not fully hierarchically controlled and enable individual and collective value co-creation and capture at multiple levels. Depending on the context and the approach taken by the leading hub or firm, these processes can be re-configured and contextualised.*

Table 3 Overview of Network Orchestration Definitions

N	Source	Term	Definition
1	Perks, Kowalkowski, Witell, and Gustafsson (2017: p.106)	Network orchestration	*"An orchestration **practice** is an observable, re-peated and routinized single or **set of activities** of the **lead firm** related to the **development of the value platform."***
2	Planko, Cramer, Chappin, and Hekkert (2016: p.2329)	Collective system building, a sub-set of strategic networks	*"**Processes** and activities that **firms** can conduct in networks to **collectively create** a favourable environment for their innovative sustainability **technology**."*
3	Paquin and Howard-Grenville (2013: p.1623)	Interorganisational network orchestration	*"The process of **assembling and developing** an interorganizational network."*
4	Nambisan and Sawhney (2011: p.40)	Network-centric innovation orchestration	*"Orchestration processes that **a hub firm** must perform to **coordinate, influence**, and/or **direct** other firms in the innovation network."*
5	Dhanaraj and Parkhe (2006: p.659)	Innovation network orchestration	"***The set of deliberate, purposeful actions*** *undertaken by the **hub firm** as it seeks to **create value** (expand the pie) and **extract value** (gain a larger slice of the pie) from the network*."
6	Jones et al. (1997: p.914)	Network governance	*"Network governance involves a **select, persistent, and structured set of autonomous firms** (as well as non-profit agencies) engaged in creating products or services based on implicit and **open-ended contracts to adapt** to environmental contingencies and to **coordinate** and **safeguard** exchanges. These contracts are socially—not legally—binding."*
7	Powell (1990: p.295)	Network forms of organisation	*"Reciprocal **patterns** of **communication** and **exchange** - represent a viable pattern of economic organization. Networks are contrasted with market and hierarchical governance structures."*

1.1.7 Theoretical Components and Constructs Underpinning the Ecosystem Concept

Despite the plurality of definitions and lack of clarity, there have been attempts to describe and explore the theoretical underpinnings of the ecosystem concept[2] (Adner, 2017; Grandori & Soda, 1995; Jacobides et al., 2018; Thomas & Autio, 2014b; Thomas et al., 2015). While extensive research has been produced to characterise ecosystems and to frame their system level output and unit of analysis, there is limited understanding as to what

[2] I refer to the ecosystem as a concept to underline its theoretical under-development as a concept, which is used to describe something that is not yet well understood theoretically. I will refer to components as building blocks or ingredients of the ecosystem concept. A construct is a statement of a concept that is useful for theorizing and incorporates various components that form a certain configuration to make up a construct.

constructs and components make up ecosystems. In particular, the constructs offer a theory of how different conceptual elements or components come together while the components are elements that are used to construct theory. Ecosystems reflect system dynamics, which occur at aggregated levels and are accompanied by a cohort of other related theoretical constructs, such as leadership, capabilities, complementarity, business models, industry architecture[3] and components, such as platforms, modularity, bottlenecks. These constructs and components were selected because they are present across the literature; this suggests their critical importance for ecosystem orchestration and therefore for value creation and capture. There are possibly more elements that comprise ecosystems that were not included in this thesis. The selected constructs also include several components that are not described in detail but can be included in the future. To my knowledge, this is the first attempt to understand what constructs and components are critical to ecosystem orchestration, which sets the foundation for future research. The selected constructs and components are summarised in the following sub-sections.

Leadership

Studies in the strategic management research stream focus on the role of a central firm or orchestrator as a central actor in the orchestration process. Some say that the facilitation and coordination of innovation is necessary (Thomas, 2013) and requires "*architectural leadership*" (Piepenbrock, 2009) while others argue that, without an orchestrator, networks are unable to meet the global challenges of modern economies (Lorenzoni & Baden-Fuller, 1995). The presence of an "*architect*" who sets the system-level goal and directs the rules,

[3] The components and theoretical constructs were selected based on the available literature and my own reading. Although other constructs and components exist in ecosystem literature, I will focus on these as the most important and common across all ecosystems.

roles and mechanisms for value co-creation and capture are essential in ecosystem orchestration (Gulati et al., 2012).

Research on the leadership of orchestrators has proliferated across a broad range of management literature in which it has been referred to as "*hub firms*", "*system integrator*", "*platform leader*" (Dhanaraj & Parkhe, 2006), "*keystones and dominators*" (Iansiti & Levien, 2004c), "*network administrative organisations*" (Human & Provan, 2000), "*kingpins*" (Jacobides & Tae, 2015), "*strategic centre*" (Lorenzoni & Baden-Fuller, 1995), "*anchor firm*" (Wang, Madhok, & Xiao Li, 2014), "*platform leader*" (Gawer & Cusumano, 2014), "*lead firm*" (Williamson & De Meyer, 2012), "*organisational leader*" (Nadler & Tushman, 1990), and "*innovation broker*" (Batterink et al., 2010). These types of orchestrators typically represent closed-system orchestration processes. Open-system orchestrators (Giudici et al., 2018) are referred to as "*bridging organisations*" (Berkes, 2009) or "*open system intermediaries*" (Dutt et al., 2016; Giudici et al., 2018) or "*innovation brokers*" (Winch & Courtney, 2007).

Piepenbrock (2009) argued that, as the nature of strategic leadership has changed, the role of orchestrators should focus on the power (Pfeffer & Salancik, 1981) and politics of inter-organisational relationships (Freeman, 2010). The success of innovating firms depends on the efforts of other actors in the ecosystem (Adner & Kapoor, 2010). Not every firm is capable of becoming an orchestrator as orchestrators master specific capabilities and are able to perform multiple roles simultaneously (Hurmelinna-Laukkanen & Nätti, 2018).

Capabilities

Interdependencies within ecosystems tend to be standardised within each role, which creates the need for a new set of skills when designing ecosystems (Helfat & Raubitschek, 2018). Ecosystem formation requires new capabilities at least at three levels, namely the orchestrator, firm and ecosystem as a collective notion. Capabilities are required to design new business models, while change must be possible in response to competition, and abilities should be present to deal with inter-organisational politics and to understand customer and technology needs (Teece, 2018a). A firm's capabilities have been widely explored in the literature on dynamic capabilities (Teece, Pisano, & Shuen, 1997). The established view of dynamic capabilities theorised the firm-level capacity to drive innovation, such as sensing opportunity, seizing the opportunity, and continuing to transform or renew the firm (Teece et al., 1997).

The role of orchestrators requires new capabilities to direct activities upward (components, suppliers) and outward (complementors) (Dyer, Singh, & Hesterly, 2018) as opposed to traditional management activities that are directed mostly inward (organisation) and downward (supply chain) (Piepenbrock, 2009). Teece (2018a) argued that firms require dynamic capabilities in order to design new business models and to be able to create and capture value. Dynamic capabilities theorists (Teece et al., 1997: p.516) define these capabilities as "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*". Helfat and Raubitschek (2018) further argued that three distinct types of dynamic capability are necessary for ecosystem orchestrators. They are innovation capabilities, environmental scanning and sensing capabilities, and integrative capabilities for ecosystem orchestration. Integrative capabilities play a key role in the orchestrator's ability to capture value; these are used interchangeably across the literature as architectural capabilities (Teece et al., 1997). The orchestrator's architectural capabilities are a subset of dynamic capabilities that allow managers to comprehend the complexity of systems in an abstract way and understand how the system functions in order to intentionally change the system's structure by rearranging its components (Teece et al., 1997). Architectural capabilities allow one to construct bottlenecks and modularity to create and capture value. For example, over the course of its ecosystem orchestration, Intel developed architectural capabilities through trial and error (Gawer, 2000), which shows that capability development is context dependent and can be exercised. However, most orchestrators do not have all the necessary capabilities or resources to design systems, so they need to collaborate with complementors (Cusumano & Gawer, 2002).

Most of the strategy literature, such as research by Helfat and Raubitschek (2018) and Teece (2018a), is largely concerned with the capabilities of singular firms. However, the industry architecture shapes and is shaped by the capabilities of actors in the ecosystem (Huygens, Van Den Bosch, Volberda, & Baden-Fuller, 2001; Jacobides & Winter, 2012). While there is heterogeneity in the capabilities of firms embedded in the same structure (Gibbons & Henderson, 2012), capabilities emerge from differences in perception and belief (Nelson, 1991). Literature on dynamic capabilities considers these as a given and necessary component for ecosystem orchestration; however, less is known about an ecosystem's capabilities, how these develop collectively and whether they are given or must be orchestrated. Jacobides and Winter (2012) emphasised the role of industry architecture in driving capabilities through feedback loops. A firm's capabilities co-evolve with the ecosystem and the business environment in which firms are embedded (Huygens et al., 2001). This will be explained in the section on industry architecture later in this chapter. However, further research is needed to explain the ecosystem's capabilities at the aggregate level, which could provide an interesting avenue for future research.

Platform

Platforms are typically seen as multi-sided markets that enable transactions by end-users and offer an open or semi-open interface upon which complementors can co-create value (McIntyre & Srinivasan, 2017). Platforms are leveraged through transactions, production and innovation across different customer groups (Thomas et al., 2015). Platforms have been referred to as "*two-sided markets*", or "*multi-sided markets*" or "*multi-sided platforms*" (Cusumano & Gawer, 2002; Gawer & Cusumano, 2002; Parker, Van Alstyne, & Jiang, 2016a). Two-sided markets can be defined as "*markets involving two groups of agents interacting via 'platforms' where one group's benefit from joining a platform depends on the size of the other group that joins the platform*" (Armstrong, 2006: p.668). Rysman (2009: p.127) states that "*in a technical sense, the literature on two-side markets could be seen as a subset of the literature on network effects*.".

Platforms are characterised by the *"network effects"* (Katz & Shapiro, 1985) between the "*two sides*" of market participants and are facilitated by intermediaries (Eisenmann, Parker, & Van Alstyne, 2011). Network effects can magnify advantages to the platform orchestrator because the value to customers on one side of the platform increases with the number of participating complementors and customers on the other side when using compatible technology (McIntyre & Srinivasan, 2017). For example, sellers on Amazon gain more value when there are more buyers and vice versa. Network effects can have a chicken-and-egg barrier as one side will not join unless the other side joins. Platform owners can face a challenging task overcoming this barrier (Eisenmann et al., 2011). The literature further distinguishes between two types of network effects: *direct network effects and indirect network effects* (McIntyre & Srinivasan, 2017). *Direct network effects* are when a benefit to the user depends on the number of othersusing the platform (Gawer, 2014). The value of *direct network effects* can be augmented by *indirect network effects* whereby all sides of the network benefit from the size and diversity of network members (McIntyre & Srinivasan, 2017). For example, users of Netflix, a video streaming service, benefit from a large number of movies and videos, while movie studios and other context providers benefit from their large base of users (McIntyre & Srinivasan, 2017). Gawer (2014: p.1241) further emphasised that *"direct network effects constitute demand-side economies of scale, indirect network effects in fact constitute demand-side economies of scope".* According to Hagiu and Wright (2015: p.163):

> "a cross-group network effect arises if the benefit to users in at least one group (side A) depends on the number of users in the other group (side B) that joins. An indirect network effect arises if there are cross-group network effects in both directions (from A to B and from B to A). In this case, the benefit to a user on side A depends on the number of participants on side B, which in turn depends on the number of participants on side A. Thus, the benefit to a user on side A depends (indirectly) on the number of users on side A".

While multi-sided platforms build on network effects, the platforms are not necessarily technological systems. Indeed, most of the successful platforms are digital (Amazon, Google, Facebook), but they can be non-digital. For example, Gawer (2014) suggests that, in biology, a human genome database is a platform, whereas in banks, credit cards like visa are platforms for micropayments and other services, whilst pharmaceutical firms develop compounds that are the basis for many drugs (Gawer, 2014). Platforms can be a standard or a contract upon which complementors can co-create value. Ecosystems are extensively building on the standards required for coordination. Thus, digital and non-digital platforms can be present within ecosystems to offer a foundation for orchestration (Nambisan & Sawhney, 2011). A new kind of platform that is orchestrated without a focal leader or any intermediary is emerging. Parker, Van Alstyne, and Choudary (2016b) argued that blockchain, a distributed public ledger, offers decentralised and completely trustworthy interactions without the need for intermediaries or platform leadership. They further argued that blockchains put pressure on existing platforms by threatening to displace some elements, for example, financial services that rely on costly gatekeepers for transactions.

Gawer and Cusumano (2014: p.418) recognised two predominant forms of platform "*internal or company-specific platforms, and external or industry-wide platforms*." Internal platforms (Gawer & Cusumano, 2014: p.418) are:

> A set of assets organized in a common structure from which a company can efficiently develop and produce a stream of derivative products. […] external (industry) platforms as products, services, or technologies that act as a foundation upon which external innovators, organized as an innovative business ecosystem, can develop their own complementary products, technologies, or services

Internal platforms are a set of assets that allow a firm to develop and produce a stream of derivative products (Meyer & Lehnerd, 1997). They offer a reusable foundation for product development and "*product platforms*" allow customers to modify the platform's features or increase product variety (Wheelwright & Clark, 1992). This type of platform typically exists in manufacturing production processes, such as the automotive, aircraft and consumer electronics sector. Firms such as Sony, Rolls Royce and Boeing build their products on internal platforms. Supply chain platforms also fall into this category as *"a set of firms follow specific guidelines to supply intermediate products or components to the platform owner or the final product assembler"* (Gawer & Cusumano, 2014: p.419).

External platforms, like internal platforms, offer a foundation for reusable modular components and technologies. Gawer and Cusumano (2014) draw a distinction between internal and external platforms in terms of their openness to outside firms. The purpose of external platforms is to bring multiple users and complementors together to increase the degree of innovation on complementary products and services. As the adoption rate grows, the rise of the industry platform can lead to a number of issues, such as barriers to entry, and trade-offs between the social benefits and negative effects created. The case studies comprise Intel for microprocessors, Qualcomm for telecommunication and semiconductor systems, Microsoft Windows and Linux for operating systems, Google's internet search engine, video-game consoles, Android's operating systems for smart phones, and giants such as Facebook, LinkedIn and Twitter (Gawer & Cusumano, 2014). Gawer and Cusumano (2014: p.421) further argue that the platform must "*(1) perform a function that is essential to a broader technological system, and (2) solve a business problem for many firms and users in the* *industry".* Intel is a good example of a platform leader that sustained its position as an orchestrator and offered relevant incentives to complementors to continue participation while giving away their intellectual properties (Gawer & Henderson, 2007).

There are four streams of research on platforms: organisational, product family, market intermediary and platform ecosystem (Thomas et al., 2015). Scholars have tried to provide an "*integrated framework*" (Gawer, 2014) or a "*unified view*" (Baldwin & Woodard, 2009) to platforms. Gawer (2014) states that all platforms share a fundamental unity in platform architecture, modularity (Baldwin & Woodard, 2009), technological interface and coordination mechanisms. All platforms build on the modularity of complex systems where components are stable while complements are encouraged to vary and innovate (Ethiraj & Levinthal, 2004). Modularity is described in the following section.

Modularity

Modularity enables ecosystem emergence by providing technical structures to grow upon (Jacobides et al., 2018). Jacobides et al. (2018) argued that modularity has been a neglected topic in ecosystem research as, in almost all empirical cases, successful ecosystems were enabled by modular architecture (Baldwin & Clark, 2000). Baldwin and Von Hippel (2011) suggested that the transition to modular architecture coupled with the low cost of internet-based communication technologies creates a "*paradigm shift"* where innovation is based on the distributed nature of collaboration, thereby displacing the restriction of traditional innovation by producers. Modularity helps to manage complexity by breaking up complex system into modules that are connected through interfaces with a standardised architecture that facilitates autonomous innovation within modules, and the mix and match of modules combined within the system (Garud & Kumaraswamy, 1995). "*The value of the system as a* *whole is greater than the value of the components disassembled*" (Baldwin, 2015: p.3). Modularity opens up opportunities for open innovation (Chesbrough, 2003).

Modularity incorporates defined standards and rules that ensure compatibility amongst modules and flexibility in product design (Rietveld, Schilling, & Bellavitis, 2019). Baldwin and Clark (2000) defined modular architecture as a structure that consists of interdependent modules that follow "*design rules*".

Figure 5 presents the concept of modularity. Design rules specify the degree to which the modules of a system interact through standardised interfaces, rules, and specifications (Baldwin & Clark, 2000).

According to Baldwin and Clark (2000), design rules are predefined, agreed and coordinated by a hub firm or design architect. Modularity allows the coordination of independently structured yet loosely connected modules. They are highly structured while the modules are loosely structured. Modularity reduces interdependence between modules but does not eliminate it (Adner & Kapoor, 2010). Each module consists of interdependent elements that allow for innovation in one module without the need to change the whole system. Each module can be produced by different producers with limited coordination. The modules fit through standardised interfaces and are coordinated by operators. The set of interfaces that connect modules determine how organisations evolve. Interfaces are fundamental to how modularity enables innovation. For Baldwin and Clark (2000: p.64), "*when the complexity of one of the elements crosses a certain threshold, that complexity can be isolated by defining a separate abstraction that has a simple interface. The abstraction hides the complexity of the element; the interface indicates how the element interacts with the larger system".* The interface holds the dual role of connector and separator between the modules and therefore enables the emergence of co-specialisation (Baldwin, 2015) and innovation by allowing a

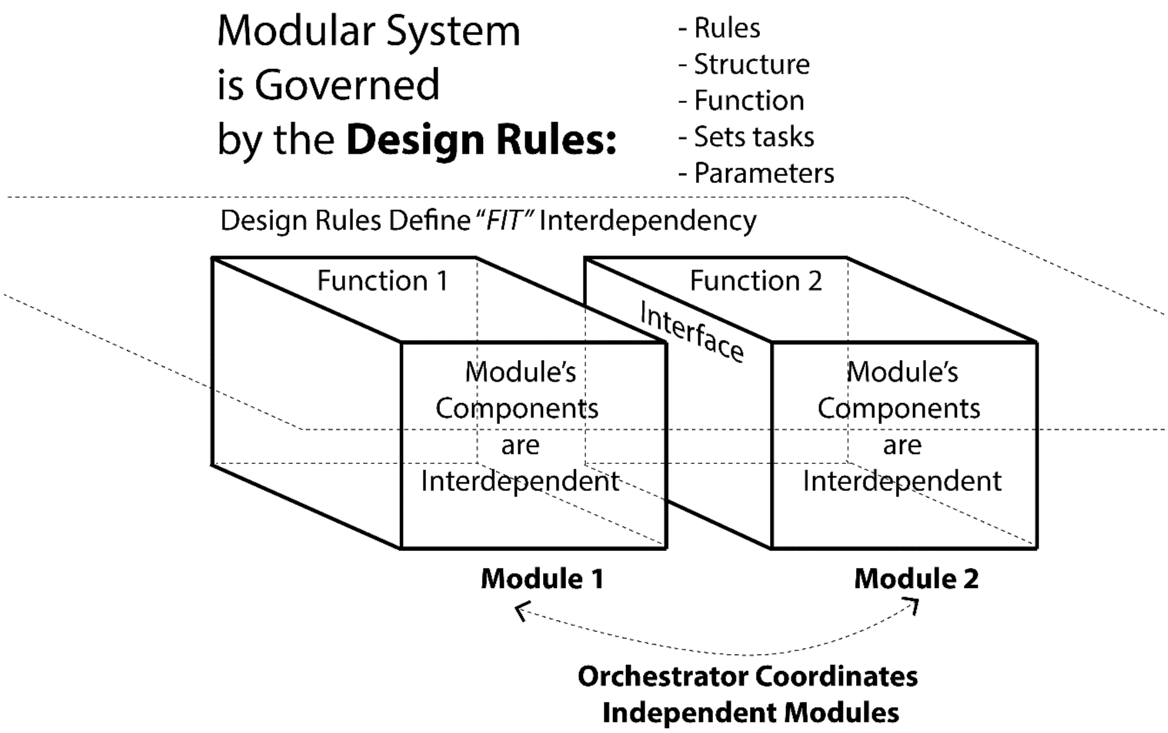

Figure 5 Concept of modular system

division of labour (Baldwin & Clark, 2000). While modularity is relevant for internal and external platforms, the degree of interface openness influences the facilitation of innovation and determines whether a platform is internal or open for facilitation at the sector level (Langlois & Robertson, 1992).

Afirm that establishes a modular system does not always have control over the modules, and thus generates its own negative consequences for the orchestrator. For example, the end product or service is not necessarily fully predetermined by the orchestrator if the modular platform is designed for sector use (Gawer & Cusumano, 2014).

Bottleneck

The bottleneck is a concept used in ecosystem research (Hannah & Eisenhardt, 2019; Jacobides & Tae, 2015). It is a component in a complex system whose performance significantly limits the performance of the whole system through poor quality, poor performance, or short supply (Baldwin, 2015; Goldratt, 1990; Hannah & Eisenhardt, 2019).

A system is made up of conceptually separable but complementary components which, in their own way, contribute to the overall performance of the system. Bottlenecks arise as important issues that constrain the system's growth, performance (Baldwin, 2015). Scholars argued that bottlenecks can be key in capturing and creating value (Hannah & Eisenhardt, 2019) while others searched for ways to resolve bottlenecks to create value (Ethiraj, 2007; Langlois & Robertson, 1992). For example, to support complementors Intel used its own resources to improve the bottlenecks of PC ecosystems (Gawer & Henderson, 2007). Firms that want to capture value are advised to control bottlenecks, thus becoming a bottleneck, and to beware of bottlenecks that other firms want to control (Jacobides & Tae, 2015).

Baldwin (2015) defined two types of bottlenecks, technical and strategic. A technical bottleneck limits the system's performance with the physical properties of the system (Ethiraj, 2007). A strategic bottleneck is the ability to control the technical performance. Strategic bottlenecks offer points of disproportional value capture for the firm through control over the access or availability of a unique solution to the technical bottleneck. For example, a strategic bottleneck can be a property right (Kim & Mahoney, 2005) or a valuable inimitable and non-substitutable asset (Barney, 1991). The literature distinguishes among technological, adoptive, and strategic (Bremner et al., 2017). Adoptive bottlenecks rely on the availability of component providers (Adner, 2012); technological bottlenecks represent technical or supply limitations (Ethiraj, 2007); strategic bottlenecks are a firm or a network of firms that control a critical component and are able to capture disproportional value (Hannah & Eisenhardt, 2019).

Interdependence in ecosystems naturally leads to the emergence of bottlenecks (Ozcan & Eisenhardt, 2009) while innovation is challenged by the location of bottlenecks (Adner & Kapoor, 2010). The presence of bottlenecks in ecosystems further suggests that the potential for value creation and capture in ecosystems is distributed unevenly (Adner & Kapoor, 2010).

Hannah and Eisenhardt (2019) articulated a bottleneck strategy for nascent ecosystems requiring a dynamic balancing of the ecosystem's tension between cooperation and competition. They further emphasised the critical role of bottlenecks for ecosystem orchestrators by creating opportunities for its own advantage.

Complementarity

"*Ecosystems are distinct forms of organizing economic activities that are linked by specific types of complementarities*" (Jacobides et al., 2018: p.2256). Complementarity is a core construct of ecosystems. However, *"the literature on complements is both confused and complex*" (Teece, 2018b: p.1373) and requires further modern fresh theorising (Jacobides et al., 2018).

Ecosystems incorporate the co-existence of different types of complementarities that offer focal and complementary innovations. Ecosystem actors are viewed as co-specialised complementors (Jacobides et al., 2006). Ecosystems include upstream suppliers and downstream complementors (Adner & Kapoor, 2010). Ecosystems are set apart from market-based arrangements by a set of products or services offered by producers or complementors who are interdependent with the end users (Jacobides et al., 2018).

Jacobides et al. (2018) characterised two types of complementarity: unique and supermodular. Unique complementarity is when one component cannot function without a second component although both are specific items (Hart & Moore, 1990), or "*A doesn't 'function' without B. […] the value of A is maximized with B.*" (Jacobides et al., 2018: p.2261). Unique complementarity is underpinned by the idea of co-specialisation (Teece, 1986). Supermodular complementarity means "*a group of activities are (Edgeworth) complements if doing more of any subset of them increases the returns to doing more of any subset of the remaining activities*" (Milgrom & Roberts, 1990: p.6) or "*more of A makes B* *more valuable, where A and B are two different products, assets, or activities."* (Jacobides et al., 2018: p.2262). For example, Jacobides et al. (2018) distinguished between unique and supermodular complementarities in OS platform/app ecosystems.[4]

Ecosystems cannot create value, or the value is limited unless complementors are present. For example, the case of nascent wireless game publishers led the emergence of the new industry by organising complementors around handset making (Ozcan & Eisenhardt, 2009). Toyota's close relationship with its suppliers have provided a superior advantage over its competitors suggesting that complementary relationships are important for ecosystem formation (Dyer, 2000). Toyota's case draws on the nature of formal interdependence and relational mechanisms for effective coordination (Dyer & Singh, 1998) while ecosystems rely on the "*alignment structure"* for joint value co-creation which is not necessarily a formal mechanism (Adner, 2017). The alignment structure further defines the business models, interoperability and distribution of value to complementors. The advantage of engagement with complementors is that ecosystems allow for the coordination of innovation activities without the need for vertical integration. Most ecosystem actors are complementors with limited power. The analysis of complementarities by Jacobides et al. (2018) offers useful guidance on ecosystem orchestration.

Business Model

Ecosystems are characterised by new types of focal value propositions, alongside the rules, roles, complementor's interdependence, the mechanisms for monetization, and value creation and capture which are essential parts of the business model design (Jacobides et al.,

[4] "In the example of an OS platform/app ecosystem, the app and the platform have a unique complementarity in the sense that the app does not function without the OS (unique complementarity, unidirectional, as the OS operates without most apps); and supermodular complementarity, as the presence of apps increases the value of the OS, and (possibly) the breadth of the OS installation increases the value of the app." (Jacobides et al., 2018: p.2263)

2018). The business model construct "*articulates the logic … that demonstrates how a business creates and delivers value to customers [and] outlines the architecture of revenues, costs, and profits associated with … delivering that value*" (Teece, 2010a: p.173). Zott, Amit, and Massa (2011) found four emerging common themes in business model literature: *"(1) the business model is emerging as a new unit of analysis; (2) business models emphasize a system-level, holistic approach to explaining how firms "do business"; (3) firm activities play an important role in the various conceptualizations of business models that have been proposed; and (4) business models seek to explain how value is created, not just how it is captured."* A business model design defines how all these components work together; therefore, an ecosystem is a new type of business model design.

All successful ecosystems have embraced business model innovation. Their success depends on business model design and implementation as well as the orchestrator's capabilities (Teece, 2018b). Poor technology with a great business model is more valuable than great technology with a poor business model (Chesbrough, 2010). The imitation of a novel system is a difficult process compared to the imitation of a product or a service; thus, business model innovation is contributing to the next generation of competition (Bashir & Verma, 2017). An ecosystem orchestrator designs a business model or a combination of business models that define its ecosystem. By designing the business models, it defines the rules of the ecosystem while also imposing these rules on the complementors and customers. Value capture depends on the design of the ecosystem's business model, which is often designed by a leading firm, and the business models are adopted by the individual firms. For example, Teece (2018b: p.1376) explains that *"owning or controlling a successful platform upon which other firms erect their business model can provide a commanding position from which to enhance an ecosystem and capture value from it."*

Thus, my interpretation is that ecosystems can combine multiple business models at different levels in the same way that ecosystems can combine multiple sub-ecosystems, which can be interconnected at different levels. For example, Google's original business model was based on ad-supported technology development. Then, Google structured Android's ecosystem to capture royalties from mobile ads while the makers of Android devices competed against each other (Teece, 2018b). Google first designed a business model for its search engine product, and then for Android but connected the two in a larger ecosystem and allowed competing complementors to design their own business models. However, Google is one of the few examples able to sustain business model innovation. A well-designed business model is rare and its suitability must be assessed against a particular context (Teece, 2010a). The existing literature provides little insight into how new business models can be operationalised while each business model has its unique operationalisation requirement that should be contextualised (de Man & Luvison, 2019).

The business model design of ecosystems has implications for the ecosystem's evolution. For example, Jacobides and Winter (2012) argued that the co-evolution of a sector's context and the business models of individual firms provide structures that generate firm-specific choices and the development of agency and capabilities. They articulated industry architecture as a context that defines the division of labour as well as the profit share within the sector. Therefore, the context influences the choice of business models, whilst successful business models can shape the industry architecture. They further called for research that seriously considers the context of business model implementation, thus contributing to the origin of capabilities. This thesis partly addresses their call for research on the relationship between context and ecosystem in Chapter 4. Industry architecture is presented in the following section.

Industry Architecture

The nature of aggregate levels, what they constitute and how a division of labour in the industry or sector is organised was largely taken for granted (Jacobides et al., 2006; Jacobides & Winter, 2012). Scholars have started to extensively look at the "*Industry architecture*" (IA) construct (Jacobides et al., 2006) while also linking it with ecosystem research (Jacobides et al., 2016; Jacobides & Tae, 2015; Tee & Gawer, 2009). "*IA is a sector-wide construct that defines the terms of division of labour*" (Jacobides et al., 2006: p.1202) . Jacobides et al. (2018) argues that there are connections between ecosystems and the industry architecture as "*ecosystems appear to be one of many ways that a sector or set of sectors can be structured; that is, they seem to represent a specific type of industry architecture.*" (Jacobides et al., 2018: p.2274). They further argue that industry architecture, as a unifying concept, allows for the existence of ecosystems and platforms but does not assume its existence. It rather focuses on the structural properties of the industry or sector. Therefore, the concepts, IA and ecosystems, are complementary as ecosystems can benefit from a construct that explores the industry context (Jacobides et al., 2018).

IA is a construct that explores the structural features of the division of labour in the sector while treating complementarity and mobility as components of co-specialisation (Jacobides et al., 2006). Jacobides et al. (2006) argue that the division of labour, rules and roles can be intentionally shaped and redefined by firms to create an architectural advantage as they shape the division of profit. They further argue that the industry architecture shapes and is shaped by the capabilities of actors. For example, Cacciatori and Jacobides (2005) studied the British building industry and found that the division of labour shaped the capability and development of a knowledge base. It also shapes the feedback loop that drives the system dynamics (Jacobides & Winter, 2012). The perception of the actor's role within the sector drives the agency to pursue architectural advantage or to preserve the status quo (Jacobides & Tae, 2015). Industry architecture provides the foundations that allow an understanding of how labour is divided, and how rules and roles are shaped by understanding that, ecosystems represent a special business model case that can also intentionally and unintentionally shape sectors.

Firms can take a lead in changing IA, and become the orchestrators of their industry, thus also becoming bottlenecks to retain value (Jacobides & Tae, 2015). Jacobides and Tae (2015), for example, followed the leading firms, "*Kingpins*", that intentionally aim to shape the computer sector to their advantage by tracking profitability in the sector within different segments. As such, the competition between different segments can happen vertically in the traditional sense and between ecosystems that span across many segments and sectors. For example, firms or a group of firms can cooperate to shape the sector through standard wars (Rosenkopf & Tushman, 1994). Standard wars can impose serious implications on the structure of the sector and can impact both power and profit share in the sector (Shapiro & Varian, 1999). Tee and Gawer (2009) explored the reasons why a successful i-mode Mobile Internet Service that operated successfully in Japan failed in Europe. They suggested that similar platform strategies led to different outcomes because of IA, which the incumbent failed to recognise or address in its business strategy.

IA can have serious implications for the evolution of ecosystems. However, there is still limited knowledge on how the changing rules concerning the division of labour and profit shape competitive dynamics and lead to the emergence of ecosystems (Ferraro & Gurses, 2009).

1.2 RESEARCH AIM AND FRAMEWORK

1.2.1 Contributions and Research Aim

The previous section provided theoretical insights into current debates around ecosystem orchestration. In considering these relevant debates this thesis intends to contribute in several ways to ecosystem orchestration literature, as discussed below:

1. Ecosystem orchestration has been underexplored empirically (Dattée et al., 2018; Nambisan & Sawhney, 2011; Ozcan & Santos, 2015). I conducted research that extensively utilised empirical evidence to contribute to the current discourse on ecosystem orchestration while offering novel insights to a specific context of study.

2. While prior studies extensively looked at ecosystem orchestration from a firm's perspective, the nature of orchestration ecosystems, and openness and closeness have been underexplored. This thesis further contributes to the emerging discourse on open and closed-system orchestration (Giudici et al., 2018) by presenting empirical evidence of orchestration processes by *open-system* (public) and *closed-system* (private) orchestrators in two contexts.

3. Ecosystem literature tends to focus on the success stories of ecosystem orchestration, while empirical research on failed ecosystems remains a "*grey area*" thus forming a selection bias (Aldrich & Fiol, 1994). This thesis addresses this gap by empirically analysing failed cases in two contrasting contexts and offering a theory of what and how contributes to these failures.

4. The emergence of new markets and sectors nowadays is attributed to the emergence of ecosystems that co-evolve value propositions (Jacobides et al., 2018). However, an ecosystem is a network of interdependent actors that depend on each other for mutual effectiveness. While the success of these interdependencies is told from a successful firm perspective, the stories told from other perspectives can manifest the dark side of inter-

organisational networks (Oliveira & Lumineau, 2019). This thesis contributes to the theory of the dark side of ecosystem orchestration by providing novel insights into how the dark side manifests in ecosystems and how ecosystem orchestration can damage the innovative capability of complementors and customers.

5. While ecosystems are a multi-level phenomenon, the majority of ecosystem studies take a firm level perspective (Jacobides & Winter, 2012). This thesis aims to develop a multi-level perspective on ecosystem orchestration by identifying critical constructs and the components of ecosystem orchestration, and by juxtaposing the empirical evidence of failure derived in this research to the documented examples of success.

6. The importance of industry context has been recognised in the work of Jacobides et al. (2006). However, the importance of the industry or sector context for ecosystem orchestration has been neglected (Nambisan & Sawhney, 2011). This thesis explores the nature and importance of context for the emergence and orchestration of ecosystems while reconciling the mixed findings in the literature.

7. The context of study, namely the Digital Built Environment (DBE) sector, was overlooked by management scholars (Katila, Levitt, & Sheffer, 2018; Pries & Janszen, 1995). This sector has distinct characteristics that provide an interesting context of study. By focusing on the digital transformation of the DBE sector with Building Information Management (BIM), this thesis contributes to the current discourse on sector-wide innovation mechanisms with policy implications. It further contributes novel insights to the deployment of BIM by explaining why the sector is preserving the status quo and inadequately transitioning to digital practices. Thus, it provides novel insights to address a practice and policy search for effective mechanisms for BIM implementation in the DBE sector, which is a hot topic in the sector.

Given the aforementioned contributions, the aim of this thesis is:

> *To explore empirically the critical constructs and components of failed ecosystems, and importance of sector's context while discovering and illuminating the dark side of ecosystem orchestration.*

1.2.2 Overall Multi-Level Framework

An overall framework is developed to accomplish the research aim of this PhD. The overall multi-level framework is depicted in **Figure 6** and presents the combination of a firm's ecosystem and the sector's wide-ranging network levels; the antecedents of ecosystem orchestration and the specific contributions to theories of ecosystem orchestration are included. The circles represent the chapters, whilst the straight line illustrates the chapter's contribution to the theory of ecosystem orchestration. Meanwhile, the dashed lines present the results that were derived in Chapters 2 and 3, which contributed to the development of Chapter 4 and therefore represent the interaction effects. As represented in **Figure 6**, Chapter 2 presents the study of open-system orchestration while Chapter 3 presents the study of closed-system orchestration. Both studies analysed ecosystem orchestration from customers' and complementors' perspectives, thereby contributing to the theories of the dark side of ecosystem orchestration. Chapter 4 builds on the results derived from Chapters 2 and 3. Specifically, it extends the findings from the previous chapters by focusing on the sector context's importance for ecosystem orchestration. It conducts a comparative study of the failures in the built environment sector and the successes in the automotive, taxi and semiconductor industry contexts. The study contributes to an understanding of the critical components of ecosystem orchestration. The three studies are discussed in more detail in Section 1.4.

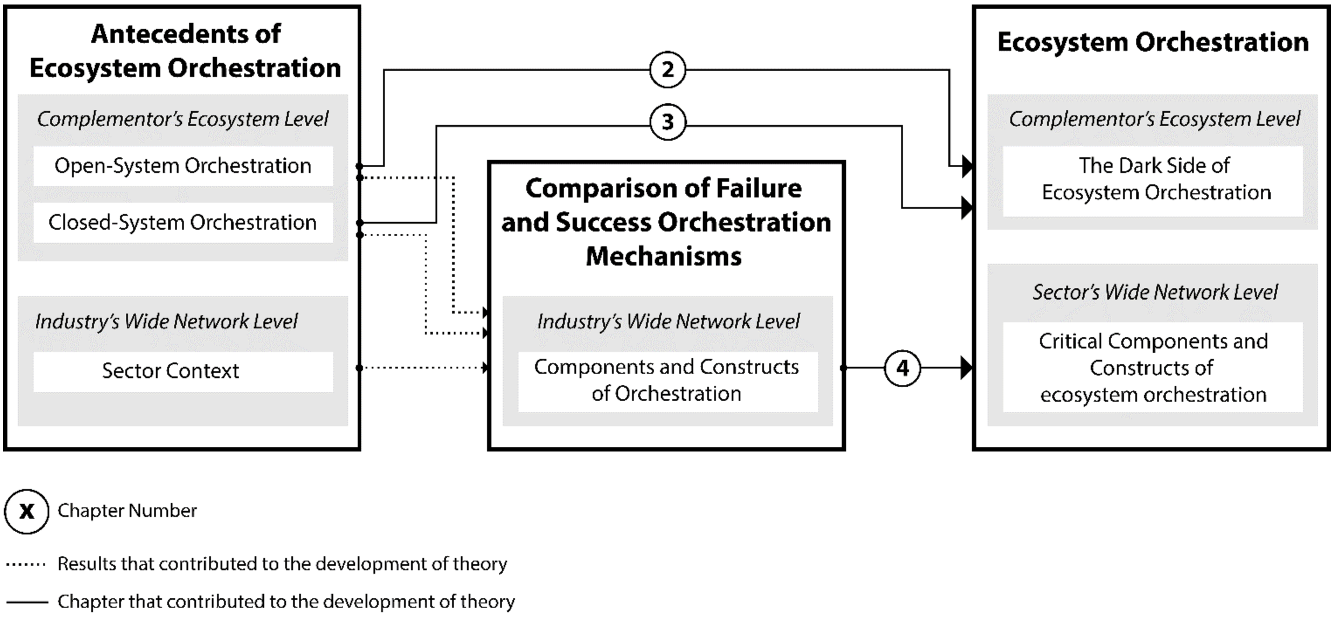

Figure 6 Overall Framework of Ecosystem Orchestration

1.3 METHODS OF STUDY AND RESEARCH SETTING

1.3.1 Research Setting

In order to address the research aim formulated in section 1.2, I adopted a single-sector, multi-case qualitative inductive research design. The settings of the two empirical studies are embedded in the Digital Built Environment (DBE) sector. I will refer to the Built Environment (BE) sector as a generic term that incorporates the supply chain including the owners, their building operators and everyone related to this sector. The Digital Built Environment distinguishes the traditional from the digital sector and will refer to firms in the sector that adopted emerging technologies for building information management. This sector was selected for several reasons.

First, I was trained as a specialist in architectural design and worked for six months as an intern in the BIM department at the largest general contractor in Montreal. I modelled, updated and visualised Building Information Models at the construction site in a project Centre d'Entretien AMT Point Saint Charles (a Public Private Partnership contract, 180 million CAD project budget) in a consortium, Pomerleau & Kiewit. As an architect, I worked with general contractors on the construction site while observing strong resistance from some practitioners across different levels towards the digitalisation of the sector. I was intrigued by the situation; I wanted to know why the sector was resisting the qualitative transition to emerging technologies.

Thus, through my personal observation and academic career, I have developed a great interest in understanding the systemic drivers of technology transformation within the DBE sector. While studying, practicing and observing the nature of the sector, I realised that the sector recognised a need to undergo systemic changes in its practice with innovative solutions and technologies (e.g. Building Information Management, Mixed Reality, Lean, etc.) (Eastman, Teicholz, Sacks, & Liston, 2011)) for a very long time. The early critiques of the modern problems of the sector were documented in the report by Oliver Roskill (1938) for the Royal Institute of British Architects (RIBA). The notion of the need for technological innovation was also accepted by some actors as early as the 1980s but the actual use of BIM and other digital tools across the sector only started to emerge after 2007.

Despite numerous efforts by different governments and actors across the world to transform the sector with technologies, the sector systematically fails to make the qualitative transition to inter-organisational cooperation and value capture from the adoption of technology (Morrell, 2015; Winch, 1998). Therefore, little progress has been made to date (Cabinet Office, 2011; Langford & Murray, 2003; Roskill, 1938). The initial observation was that the current established methods of studying the transition to digital technology in this sector are ill-suited to explain this phenomenon. A new holistic approach is needed. The ecosystem concept has proved to be useful in exploring and comprehending this phenomenon.

Second, the available literature on BIM reveals an overemphasis on the technological possibilities while overlooking the inter-organisational, socio-cognitive and political aspects of adopting technology (Borup, Brown, Konrad, & van Lente, 2006; Deutsch, 2011; Emmitt & Gorse, 2009; Kerosuo, Miettinen, & Mäki, 2012; Miettinen & Paavola, 2014). The literature on BIM tends to focus on singular successful projects and firms marketing the benefits of BIM, and thus fails to capture the multiple and complex dimensions associated with adopting innovation and technology which transcend the boundaries of any singular firm, project or industry/sector.

Third, very few management scholars have examined this sector (Katila, Levitt, & Sheffer, 2018; Pries & Janszen, 1995), although it provides a fruitful ground to study a system-level phenomenon such as ecosystem orchestration. First, it is important to note that the definition of "*ecosystem [as] a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled*" provided by Jacobides et al. (2018: p.2264) fits perfectly with the notion of the project-based nature of co-specialised disciplines in the BE sector. The ecosystem concept and the notion of the project-based nature of the BE sector are both characterised as loosely coupled systems (Dhanaraj & Parkhe, 2006; Dubois & Gadde, 2002). Second, the BE sector is largely dependent on the adjacent sectors as various actors in the sector are complementary and mutually co-specialised. The sector incorporates a large network of actors that go beyond the boundaries of a single industry in the BE sector. The notion of the BE sector integrates various sub-sectors that make up the realisation of a building product. Considering the complexity of the BE sector, Ribeirinho et al. (2020: p.15) further suggest that the construction industry is currently undergoing dramatic changes:

> Construction is already in the perfect storm. Industrialization, globalization, and digitalization have been key drivers of change in all industries. While this change happened in sequential waves—for example, in auto industrialization in the 1970s and 1980s, globalization in the 1990s and 2000s, and digitalization in the 2010s and ongoing—all of these drivers are hitting construction simultaneously. It is a daunting task and will require bold and agile moves to manoeuvre, but the size of the prize is enormous.

Therefore, the study of BE, and particularly the DBE sector, can potentially aid the development of ecosystem orchestration.

Before I present the selection of the case studies, I explain why this sector is an important and interesting context for any study.

1.3.2 Research Setting: Digital Built Environment Sector

It is important to note that the sector is significant to the global economy. The BE sector consists of many sub-sectors constituting industries such as design, construction and operation, etc., and represents the largest sector in the world. It is a $10-trillion-a-year sector and contributes 13 percent of the global GDP (Bartlett, Blanco, Rockhill, & Strub, 2019). Moreover, the importance of the built environment sector has been recognised by governments. The BE sector is one of the four priority sectors (next to life science, AI and automotive) highlighted in the recent UK Government Industrial Strategy Plan for future investment to support further growth of its infrastructure and business environment (HM Government, 2017).

Despite its significance, the built environment sector was criticized for its high costs, low productivity and performance, slow delivery, unsafe working conditions and systematic failure to innovate (Dainty, Leiringer, Fernie, & Harty, 2017; Egan, 1998; Latham, 1994; Morrell, 2015). The sector is infamous for its low performance compared with other industries (Fuchs, Nowicke, & Strube, 2017) (see **Figure 7**). According to the U.S. Bureau of Labour Statistics (Teicholz, 2004), the BE sector's productivity not only lags behind other industries but has also been in decline since 1968 (Allen, 1985). In the US, the decline of

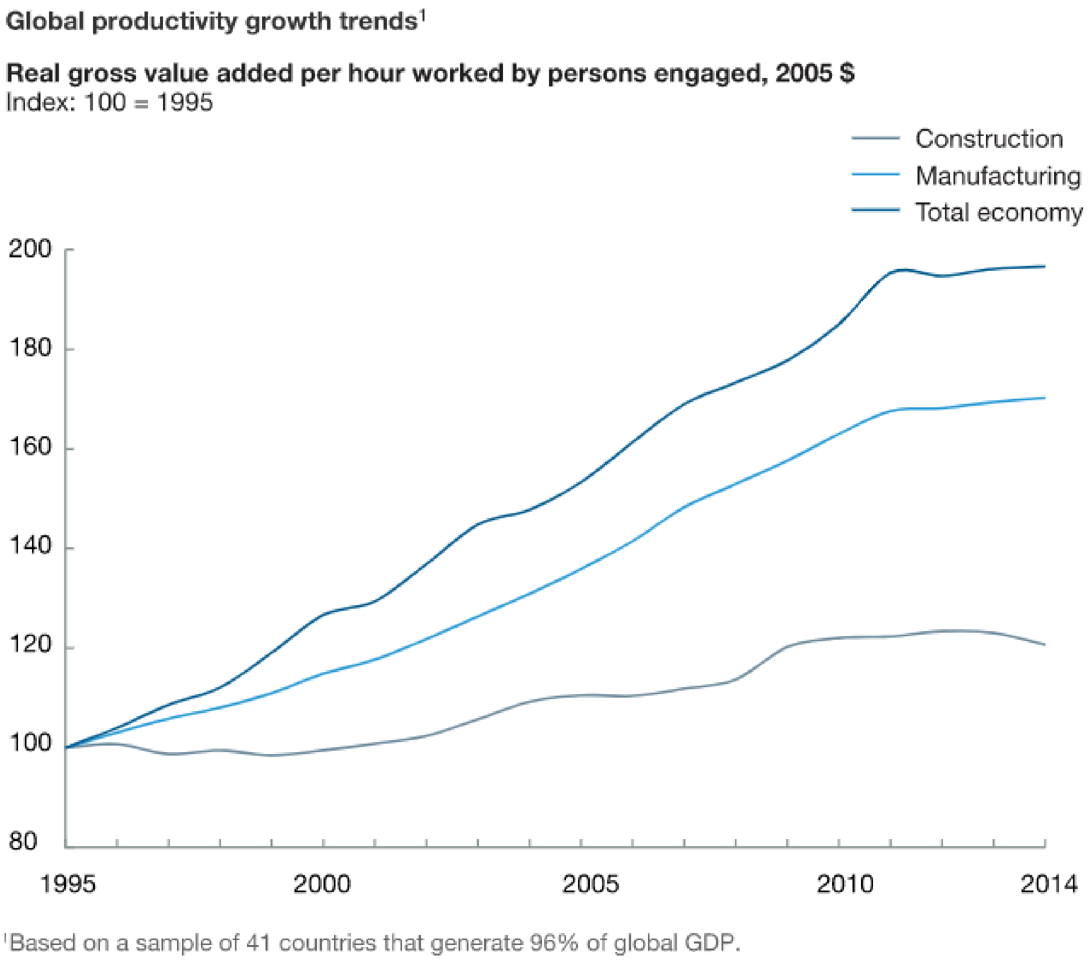

Figure 7. Low Productivity of Construction Practices Compared to Other Sectors[5]

(Fuchs et al., 2017)

productivity has been one of the most serious concerns, as only the mining sector has performed worse (Nam & Tatum, 2010). The failures were largely attributed to the fragmented disorganised complex structure of the sector and its conservative male-dominated culture (Latham, 1994). Winch (1998: p.268) stated:

> As with most of his prognoses for the future of capitalism, Schumpeter, writing in the late 1930s (1976 p. 68), was wrong about construction - his 'gale of creative destruction' (1976, p. 84) has passed construction by. Ever since the emergence of volume production methods in the late 19^{th} Century, there have been repeated attempts to apply them to the construction industry […] Such attempts have repeatedly failed, with the result that the

[5] GGCD-10; national statistica agencies of Malaysia, Sinapore, and Turkey; Organisation for Economic Co-peration and Developmen (OECD); Rosstat; US Bureau of Economic Analysis (BEA); US Bureau of Labour Statistics (BLS); World Bank; World Input-Output Database (WIOD); Mckinsey Global Institute analysis Accessed in March 2020 at https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/navigating-the-digital-future-the-disruption-of-capital-projects

> relative cost of housing compared to other goods and services has been rising inexorably. This is a problem common to all advanced nations […] Therefore, it is worth reflecting upon why the construction of housing and other built products has been so resistant to the virtuous cycle of simultaneous cost reduction and quality improvement that has benefited most other industries over the last century.

The sector is a service-based supply chain with the absence of inter-firm adaptations (Dubois & Gadde, 2002; Weick, 1976), which means it is an inherently social process (Abowitz & Toole, 2010). As mentioned earlier, it is regarded as a "*loosely coupled system"* *(Weick, 1976)* "*with particular complexity factors owing to industry-specific uncertainties and interdependences and inefficiency of operations*" (Dubois & Gadde, 2002: p.611).The sector operates as a network of simultaneously cooperating and competing firms in the same and different projects. These networks are characterised by co-specialised firms; thus, a single project, namely the delivery of a building product, is always the result of collective activity. According to the World Economic Forum (2016: p.11):

> Construction is a "horizontal" industry (like the Financial Services industry), serving all industry verticals; in other words, construction has considerable interaction with numerous other sectors, since value creation almost always occurs within or by means of buildings or other constructed assets The construction industry is affected by megatrends in four domains: markets and customers, sustainability and resilience, society and workforce, and politics and regulation

Projects are characterised as "*distributed (designed and constructed by multiple, autonomous actors), heterogeneous (composed of communities with distinct skills, expertise, and interests), and sociotechnical (requiring trust, values, and norms, as well as IT capabilities and complex fabrication processes)"* (Bolland, Lyytinen, & Yoo, 2007: p.633). Buildings are characterised as "*expensive customized goods with a comparatively long-life span, and typically are purchased before the client can fully assess their features"* (Cacciatori & Jacobides, 2005: p.1856). The value of the building is largely defined by the cost of land, which depends on the location. Moreover, buildings are immobile products. Jacobsson, Linderoth, and Rowlinson (2017) suggested that the BE sector and manufacturing sector have reverse relationships between the building product and "the factory"; thus, in the BE sector "*the "factory" is mobile whereas the product is immobile*" (Jacobsson et al., 2017: p.9). Overall, the BE is one of the oldest and mature sectors.

Any innovation effort in the BE sector is mostly dedicated to sub-optimization and technical development (Gann, 1996). Some argued that the BE sector is "*a complex systems industry*" (Winch, 1998) that follows a model of complex systems in the context of the flight simulation industry developed by Miller, Hobday, Leroux-Demers, and Olleros (1995). Winch (1998: p.270) argued that the BE sector exhibits unique particularities that set it apart from "*the model of the complex systems industry developed by Miller and his colleagues*". These particularities are: the systems integrator role, which is shared between an architect or engineer and the principal general contractor; the fragmentation and competition between professional bodies that hold protectionist attitudes towards their professions; trade contractors or specialised suppliers who have limited power in propagating technology innovation and whose role is different from the specialist components described by Miller and his colleagues. However, others argue that the characteristics of this sector are better suited to incremental than systemic innovation because of the inherent characteristics (Katila et al., 2018). There is a general belief in this sector that it is unique or different.

Therefore, various governments are developing strategies and mandates in an attempt to integrate their sector with the use of BIM (Björk, 1986; GSA, 2007; Office, 2011). The UK government views BIM as an enabler of the sector transformation agenda, as indicated in its industrial strategy (HM Government, 2013: p.9): "*... only through the implementation of BIM will we be able to deliver more sustainable buildings, more quickly and more efficiently*". BIM Level 2 was mandated in all public contracts procured by the central UK government in 2016 (The Infrastructure and Projects Authority, 2016). Around the world, there is a disproportionate emphasis on the technological side of BIM implementation in the sector. Dainty et al. (2017) point to a potential danger that performance improvement could easily be elevated beyond a mandated technological improvement and seen as the only possible mechanism for realizing "*radical, transformational change*", as is the case with the positioning of BIM in the UK government's industrial strategy. For example, NBS (2017) reported that the Government is failing to enforce the BIM mandate as "a *lot of government agencies and bodies have used loopholes in contract form to get out of mandated BIM requirements*" because "*everyone has their own version of what it means to meet the mandate*" (NBS, 2017: p.12). The adoption of BIM disrupts prevailing practices and challenges institutional momentum, and consequently, it suffers from a slow rate of BIM practice adoption.

There has been a steady yet slow emergence of work practices in which BIM has effectively been utilised to support collaborative knowledge sharing across organisational and disciplinary boundaries. However, the adoption and efficacy of BIM faces limitations when there are complex problems involving multiple organisations and collaborators with diverse and often conflicting viewpoints (Dossick, ASCE, & Neff, 2010). For example, a report by Mosey et al. (2016) presents critical issues suggesting that structural changes in contracts and procurement must take place to support BIM adoption and the complementors, such as software vendors who must take responsibility for the quality of data produced in the BIM software. There is evidence that the transition to BIM highlighted systemic inherent contradictions in the sector that hinder its innovative potential.

Despite this, BIM is considered an invaluable process to enable an integrated process of information management across the BE sector (Sacks, Eastman, Lee, & Teicholz, 2018); however, the promises of BIM, which advocates the revolution of sector practices, are yet to be realised (NBS, 2017). The deployment of BIM has proved to be an incremental innovation with modest improvements although the potential benefits for ecosystem formation are evident (Aksenova, Kiviniemi, Kocaturk, & Lejeune, 2018; Dainty et al., 2017; Miettinen &

Paavola, 2014). The report by HM Government (2013) emphasizes the emerging need for a more critical perspective to address the diverse implications of the BIM policy and management approach. A broader view is needed to identify the impact of various endogenous and exogenous factors that influence the sector's qualitative transition towards BIM and make up the ecosystem. In comparison, others suggested that the structural features of the sector seriously hinder innovation rate (Winch, 1998). It seems that sector's structure has been taken for granted or ignored in the research on BE practices (Egan, 1998; Morrell, 2015).

Thus, the characteristics of BIM as a networked technology and process (Linderoth, 2010), the sector's project-based networked nature, the importance of BIM for governmental strategies and the systemic struggles of innovators in the sectors' ecosystem to gain the promised benefits from BIM have narrowed the focus of this research and defined the selection of cases.

Building Information Management, Modelling and Model (BIM)

The focus of this research is on the context of BIM implementation in the DBE sector; thus, I provide a short description of BIM. There is general confusion in the industry and academia regarding what BIM is, whilst the understanding of BIM also varies across countries and individuals.

Building Information Modelling, as a term, is used interchangeably with Building Information Management. While both concepts are interrelated, the first concept proposes fundamentally new methods of handling, creating and sharing information and new ways of working with other stakeholders in project networks by re-aligning the disciplinary roles and responsibilities, and creating opportunities for additional roles in the sector (Eastman, Teicholz, Sacks, & Liston, 2011). The second concept, Building Information Management is concerned with "*business processes across the built environment sector in support of the management and production of information during [the] life cycle of built assets*" (BSI Standards Limited, 2019) with the use of Building Information Modelling processes to deliver Building Information Models. Building Information Modelling is the "*use of a shared digital representation of a built asset (3.2.8) to facilitate design, construction and operation processes to form a reliable basis for decisions*" (BSI Standards Limited, 2019). A Building Information Model refers to the digital model that is delivered with BIM processes and underpinned with the use of BIM technologies. Echoing the definition of a Building Information Model by Prof. Arto Kiviniemi, Rothenberg (1989: p.1) states that "*a model represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality".* Kiviniemi (2020) further emphasises "*This means that we must always define the purpose before we can define and build the model, and that there will always be several models for different purposes*". Therefore, in this thesis I refer to BIM as Building Information Management as it provides an integrated concept that is aligned with the research aims.

The BIM concept has a long history of development. According to Prof. Arto Kiviniemi, the first notion of the BIM concept emerged in 1962 when Engelbart (1962) presented a vision of the future architect in his seminal work "*Augmenting Human Intellect*" in which a virtual model is imagined to *"augment an architect*" and aimed to extend "*human intellectual effectiveness*" (Engelbart, 1962:p.4). However, Eastman (1975) presented a more articulated definition of the use of computers instead of drawings in building design.

Before 2002, BIM was referred to and researched as "*Building Product Modelling*". For example, as early as the 1980s, the Finnish national strategy for the transformation of the design and construction industry was dedicated to the research, development and deployment of *Building Product Modelling* (Björk, 2009). Nevertheless, the BIM concept was implemented in mainframe computers much earlier than 1980s; the first BIM software developed for personal computers was, according to Jerry Laiserin, "*Lisa*" which was published in 1984 and in 1987 renamed as ArchiCAD. ArchiCAD was the first BIM software developed for architects which is still widely used nowadays. The term "*Building Information Model*" was first used by van Nederveen and Tolman (1992) and became commonly used after Autodesk Building Industry Solutions (2002) published a white paper on Building Information Modelling in 2002. Despite the long history of BIM development, its concept is considered by many actors in the sector as a "novel technology", which suggests a limited understanding and is largely marketed by software vendors. The following definition of Building Information Management is used in this thesis, which overlaps with the definition provided by BSI Standards Limited (2019):

> *Building Information Management is characterised by the business processes across the built environment sector underpinned with the emerging digital technologies that enable management and production of information and communication during life cycle of built assets.*

1.3.3 Research Setting: Case Selection

Two empirical case studies were selected to address the research aims, and the Finnish and northern Californian DBE sectors. Finland was selected because it is known as one of the leaders on a national scale in the implementation of Building Information Modelling (BIM) (Ciribini, Mastrolembo Ventura, & Bolpagni, 2015; Fischer & Calvin, 2002; Froese, 2002). Its long history of trust and open standards, its small and agile BE sector is viewed as the perfect environment for BIM implementation (Taylor and Levitt, 2007). TEKES, the National Technology Agency of Finland wholed one of the most advanced and longest research and technology programmes in the history of BIM, developed a programme that has been recognised as an international success story (Froese, 2002). Despite the far-reaching technological capabilities within the sector, BIM has primarily been adopted as a "*productivity tool*" within individual firms which did not lead to systemic change nor business transformation within the sector (Aksenova et al., 2018).

The northern Californian DBE sector was selected because of its proximity to growing and co-evolving Silicon Valley business ecosystems, the availability of capital, and its strong synergistic relationship with the network of top universities (Lee, 2000; Lenoir, 2014). The regional advantage of the Silicon Valley is seen as its "*cumulatively self-reinforcing agglomerations of technical skill, venture capital, specialized input suppliers and services, infrastructure, and spill overs of knowledge associated with proximity to universities and informal information flows*" (Saxenian, 2001: p.42). The northern Californian DBE sector is an early adopter of BIM and, over the years, academic research in the area has been driven by leading firms that have extensively focused on project process improvements as well as technology development (Fischer, Khanzode, Ashcraft, & Reed, 2017). In comparison, previously Finland was largely focused on technology development to support inter-organisational practices with BIM and the life-cycle management of building information (Aksenova et al., 2018; Uusikylä, Valovirta, Karinen, Abel, & Froese, 2003); however, it has now shifted its focus towards the development of digital business ecosystems at both sector and country levels (Lehtinen, 2016; Sunesen et al., 2019).

There are distinct differences between Finland and northern California, such as the varieties of capitalism (Hall & Soskice, 2001) and differences in building systems (Winch, 2000). Several studies indicated that building systems, business systems and the division of labour at the sector level varies across many different countries (Cacciatori & Jacobides, 2005; Winch, 2000). For example, the Finnish BIM deployment was led by the public agency while California is a self-organised ecosystem (Taylor & Levitt, 2007). While Finland is a country and northern California is a region, the cases were selected because their territories are *'socially constructed'* and represent a set of local practices (Giordano & Dubois, 2019) as Finland and northern California clearly identify themselves as specific geographic units that hold similarities and differences within institutional, social and economic dimensions. The differences and similarities are presented in **Table 4.** They were collected from the literature and completed during the analysis of the cases. During the analysis of these cases and while reading about the nature of the DBE sector and BIM adoption across the world, several trends were also observed that were common to all contexts. These trends and observed similarities across the selected cases are presented in **Figure 8.**

Table 4 Similarities and Differences in the Contexts of the Finnish and Northern Californian DBE Sectors[6]

CALIFORNIA		FINLAND
	DIFFERENCES	
Liberal market economy	**Varieties of capitalism (Hall & Soskice, 2001)**	Coordinated market economy
Short term and long-term relations	**Temporal (Hofstede, 1983)**	Short term and long-term relations
Highly valued individualism (i)	**Social (Hofstede, 1983)**	Collectivism (we)
Inequality (you do not keep up, you are out)	**Power (Hofstede, 1983)**	Equality (support is highly valued)
Derives from allocation of work in the USA	**Alignment (Taylor & Levitt, 2007)**	Derives from allocation of work in Finland
Weak (tendency to contract from 5-6 firms per specialist type)	**Relational stability (Taylor & Levitt, 2007)**	Strong (tendency to contract from 1-3 firms per specialist type)
Firm	**Interests (Taylor & Levitt, 2007)**	Network
Impermeable	**Boundary permeability (Taylor & Levitt, 2007)**	Permeable
Avoidance (we fire)	**Uncertainty orientation (Hofstede, 1983)**	Tolerance (we allow deviation)
Market driven	**Power relations**	Institution driven
Extremely large	**Market size**	Extremely small
Co-Located with the Silicon Valley	**Geography**	Isolation
Regulation but otherwise government intervenes as little as possible	**Corrective mechanisms**	Government and BuildingSMART
Strong	**University alignment with the sector**	Low (but high in relation to research institutes, e.g. VTT)
Low	**Consistency in practice**	High
Non-existent	**Open standards support**	Strong
Non-existent	**BuildingSMART influence**	Strong
Low	**Practice Standardisation**	High
Varies	**Quality of final products**	High
Short-term (does it help me now?)	**Planning mentality**	Long-term (does it help me in the future?)
Self-organised, software vendor	**Leadership in the sector**	Public organisation, coordinated
Large	**Availability of capital**	Low
High demand	**Demand**	Low demand

[6] Where the reference is not provided, the differences between Finnish and northern Californian contexts are derived from the empirical data presented in this thesis

Hire and fire' principle, low-trust relationships	**Employment relations**	Long-term, higher trust relationships between co-workers
Non-existent	**Issue of blurred boundaries of ownership and responsibilities**	Largely recognised
None (network is self-organised)	**Agent of change (Taylor & Levitt, 2007)**	National Technology Funding Agencies
Software vendor	**Ecosystem orchestrated by**	Public funder, currently public agency
	SIMILARITIES	
Local business	**Market view**	Local business
Diminished	**Labour market**	Diminished
Market defines power relation between sub-contractors and contractors	**Market power**	Market defines power relation between sub-contractors and contractors
Lack of talents and capabilities	**Capabilities of champions**	Lack of talents and capabilities
High	**Variability in skills**	High
High	**Proximity to high-tech communities, universities and complementors**	High
High	**Mobility between organisations**	High
Low	**Diversity**	Low
High	**Diversity in the area**	High
Diverse portfolio of technology related solutions	**R&D focus**	Diverse portfolio of technology related solutions
High	**Focus on technology**	High
People are at different levels	**BIM practice**	People are at different levels
Collaborative and competitive	**Relationship between firms**	Collaborative and competitive
High	**Collaboration capability**	High
High	**Market fragmentation**	High
Closed, siloed	**Ecosystem type**	Closed, siloed
Established	**Culture**	Established
Low	**Culture of risk taking**	Low
High	**Trust**	High

1.3.4 Methods of Study

Given the limited theory and empirical research on ecosystem orchestration, I conducted a *multi-level, multi-case study* (Eisenhardt, 1989; Yin, 2017). Considering the complexity of ecosystem orchestration, I chose a *qualitative inductive inquiry* using *grounded theory* (Gioia, Corley, & Hamilton, 2013; Strauss & Corbin, 1990) to investigate the subjective experiences of key actors in each context (Langley & Abdallah, 2015). Inductive studies are useful when existing theories are underdeveloped or provide limited insights to articulate key questions (Bansal, Smith, & Vaara, 2018; Langley, 1999). Although theory-building from cases is seen as subjective, rigorously executed theory from the cases is objective due to close interaction with the data (Eisenhardt & Graebner, 2007).

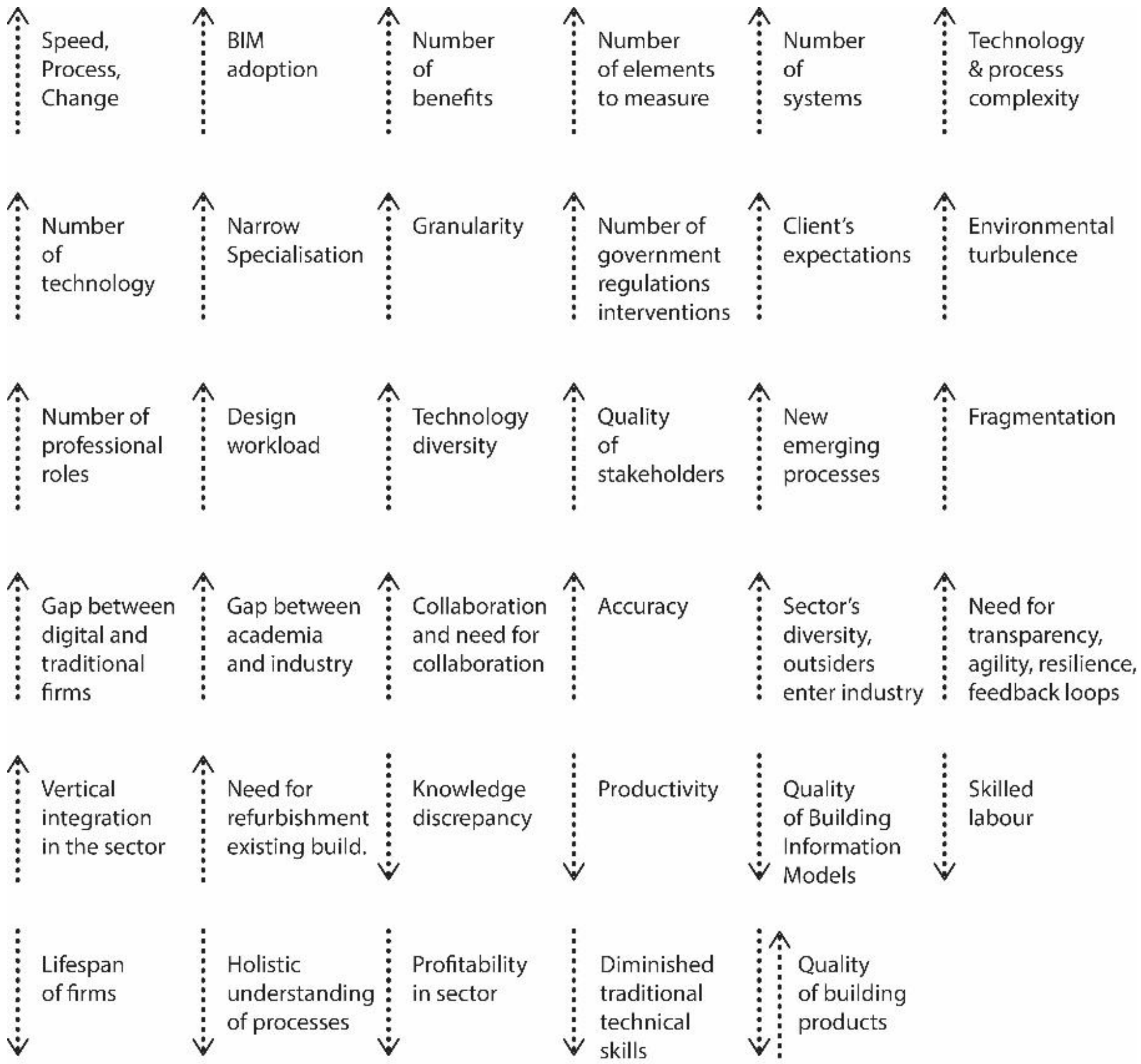

Figure 8 Similar Trends Observed in the Finnish and Californian DBE Sectors[7]

A multi-method was used to collect data from a variety of sources. The research design evolved progressively and iteratively allowing for the progressive refinement of the focus of this thesis throughout my inquiry (Sinkovics & Alfoldi, 2012). First, I conducted the Finnish study, then the Californian study, and then conducted a comparative-cross case analysis of two contexts (Eisenhardt, 1989; Yin, 2017). Therefore, I examined two cases separately and consecutively.

[7] The arrows indicate increase or decrease of trends. For example, while the productivity overall has decreased with the implementation of BIM, the accuracy of information has increased in projects.

The Finnish study (Chapter 2) was initiated in Canada where I served as a research associate at the Management and Technology, ESG – UQAM, The Université du Québec à Montréal (UQAM) for a project "*A Study of the Quebec-Finland Gap In Building Information Modelling (BIM) deployment: A Critical Perspective Approach*". The research was financed by an SSHRC grant 2014-2016 (#430-2014-01070) and led by Prof. Albert Lejeune at UQAM. The project was dedicated to the study of the Quebec-Finland gap in BIM deployment as the Finnish design and construction industry is considered the earliest adopter of BIM. The aim of the project was to identify the critical success factors of BIM deployment in Finland, present the gaps between two industries, and thus design guidelines for BIM deployment in Quebec's industry. Ethical approval was received at the UQAM and the project adhered to its guidelines. The data use in this thesis was approved by Prof. Albert Lejeune. The contacts for interviews in Finland were identified with the help of Prof. Arto Kiviniemi. The invitation letter to BIM experts is presented in **Appendix A.1.** The participant's information sheet and consent form used in Finland are presented in **Appendix A.3.** The Finnish data was collected in 2015, on a face-to-face basis and in English. The results of the Finnish case clearly indicated the need for acontrasting case, namely the Californian study.

The Californian study (Chapter 3) was conducted in the UK when I was a PhD student at the School of Architecture, the University of Liverpool and undertaken for the project "*Business ecosystem for BIM – comparative study between Californian and Finnish BIM adoption*" which was led by Prof. Arto Kiviniemi. The aim of the project was to identify the critical success factors in the business ecosystem around BIM. The study was sponsored by The School of the Arts Research Development Initiative Fund (RDIF) and supported by Prof. Martin Fisher at the Center for Integrated Facility Engineering (CIFE), Stanford University, California, USA. Prof. Fisher provided an official invitation and extensive support during the researcher's visit, such as an invitation to the key events at Stanford and an introduction to the key interviewees. The invitation letter to the Californian BIM experts is presented in **Appendix A.2.** The participant's information sheet is presented in **Appendix A.4** and the consent form used in California is presented in **Appendix A.5.** The Californian data was collected in 2018, on a face-to-face basis and in English.

The data collection in California and Finland follows similar approaches and procedures. The data collection and analysis process started with the preliminary research assessment, selecting the case, planning the data collection, entering the field, processing the data, analysing the data, validating the data and results, and, finally, reaching the closure of the case. The overall data collection, processing, analysis and validation for each case took approximately two years as the process was ongoing and iterative. The overall detailed procedure of steps undertaken in each phase of the research process is depicted in **Table 5.** The Aim of this Table is to Illuminate the Rigor of the Research Methods Conducted in this Thesis.

Table 5 Process of Data Collection and Analysis

N	Phases of Research Process	Activities performed by the researcher during the cause of PhD research
1	**Preliminary research assessment**	• Identifying gaps and assumptions in the topic • Selecting the case • Developing objectives • Problem statement formulation • Identifying and planning key steps • Forecasting expected results
2	**Selecting case**	• Selecting a relevant case • Reviewing literature about the case (reports, articles and online media) • Developing a preliminary understanding of the case
3	**Planning data collection**	• Crafting protocol for semi-structured interviews • Preparing and obtaining ethical approval • Obtaining a travel grant and preparing a trip to the location • Identifying key contacts for interviews • Inviting key contacts for interviews • Arranging interviews at least 2 weeks ahead of the planned visit • Building a preliminary understanding about the case • Studying the background of each key contact for interview

		• Training the researcher to conduct interviews
4	**Entering the field**	• Conducting interviews (signing ethical consent, introducing project, asking questions) • Building new networks by visiting industry-related events • Applying snowball sampling toidentify new contacts for interview • Arranging new interviews • Updating the list of key interviewees • Recording memos and notes after the interviews while depicting observations and key findings • Identifying key contacts that are interested in the project and arranging a second meeting for the presentation of preliminary findings for validation purposes • Organising the data for data storage purposes by uploading it on the departmental drive • Anonymising data for confidentiality purposes (assigning numbers to the audio recordings)
5	**Processing data**	• Preparing the final list of conducted interviews with specific notes observations attached to each folder assigned to the interviewee • Writing 'thank you letters' to the interviewees and key support members • Reporting to key leaders of the project • Preparing Microsoft Word (MW) for interviews • Transcribing interviews in a prepared MW document • Anonymising transcripts by removing information that can identify interviewees and organisation • Sending transcripts to the interviewees for approval indicating the deadline beyond which the transcript will be used in the research unless overwise indicated • Organising approved transcripts for coding • Updating the list of the collected interviews
6	**Analysing data**	• Conducting the open coding of data in Nvivo software • Visualising relationships between emerging topics • Writing memos • Writing a preliminary report with the results of the open coding to the interviewees for feedback • Incorporating feedback into the report • Clarifying specific issues with the key interviewees • Discussing the emerging results with the supervisor team (ongoing) • Re-formulating the research questions and gaps • Preliminary synthesising of the research results • Searching for relevant concept to explain the observed phenomenon • Continuing the literature review for triangulation purposes • Conducting the axial coding of the data while taking advantage of the re-framed research focus • Re-reading key interviews to sharpen the construct definitions and to look beyond the initial impressions and Nvivo coding • Sharpening the construct definitions • Iteratively tabulating data in Nvivo coding for each construct • Searching for "WHY" behind the relationships • Comparing with conflicting literature (ongoing) • Synthesizing the results
7	**Validating data and results**	• Presenting results at the workshops, conferences and industry events for feedback • Sharpening the focus of the study • Writing up the first draft of the study • Sending the draft of the study to key interviewees for feedback • Incorporating the feedback

		• Comparing with conflicting literature (ongoing)
8	**Reaching closure**	• Comparing with similar literature • Finalising the theoretical contributions and constructs • Arriving at theoretical saturation • Ending the process by finalising the study with marginal improvements • Sending the study to key experts in the relevant field • Incorporating the feedback • Refining the writing of the study • Presenting the study in this thesis

Theory-building typically combines multiple data collection methods (Strauss & Corbin, 1990). First, the data collection comprised published material to gain a perspective on the research setting. The literature included secondary data, such as reports, articles published by developers, and publications written about the events by external authors. The collected material served as inputs for the selection of case studies, the development of an interview protocol (see **Appendix A**) and the selection of interviewees for the studies. In order to build a generalisable theory, the researcher purposefully selected industry representatives and diverse organisations that are key ecosystem actors, and included: academics, public and private owners, public organisation representatives, the sector's actors at business & management, and operation levels, and other relevant complementors. Once the data collection started, I applied snowball sampling to follow the recommendations of the interviewees.

The interview sample was not random but reflected the selection of specific cases to extend the understanding of BIM deployment and ecosystem orchestration. Interviews ranged between 50 to 120 minutes. Most of the interviews were 60 minutes, and while 85% of the interviews were conducted face-to-face the rest were held over Skype or on a mobile phone. The interviews were always agreed via email before the meeting or call, and the consent form was signed at the beginning of each interview or in advance of it. The approach for the interviews was based on a long interview by McCracken (1988). Each interview was recorded unless overwise indicated by the interviewee. The data was collected and transcribed verbatim by the researcher. Transcripts were anonymised and sent for approval to the interviewees. The interviewees were free to withdraw from the study at any time. The deadline for response and any changes in the transcript was clearly indicated in the emails sent for approval and if a reply was not provided by the deadline, the researcher was free to use the transcript in the research. The analysis of data in Nvivo software only started after the approval was received or the deadline for changes had passed. During the course of this research, I also kept in touch with the key interviewees in order to frequently clarify specific issues and any misunderstanding of the data while synthesising the results. The sensemaking data process kept those discussions alive and offered an advantage for validation purposes (Gioia & Chittipeddi, 1991). During the data collection, I kept producing field notes. Field notes are an ongoing stream-of-consciousness that involves both observation and analysis (Orton, 1997). Field notes were particularly useful during the analysis and re-framing of the focus of the study.

A limitation in the use of grounded theory in this thesis is theoretical sampling. Typically, the process of grounded theory involves a collection of small data samples, and the analysis and identification of the next potential steps for the data collection, which followed the story of the data (Glaser & Strauss, 1967). This process was not possible because of the limitations of funding that affected the time of the visit to Finland and California. Therefore, a large set of data was collected within a limited time. Despite this limitation, I collected rich data that was substantial for theory development.

The data analysis in both cases closely followed the procedure explicated by Gioia et al. (2013). This procedure allows for the systematic, versatile and rigorous analysis of qualitative unstructured data (Corley & Gioia, 2011). With the use of this research strategy, the research constructs the codes where coding is the result of the researcher's sensemaking and interpretation (Gioia & Thomas, 1996). This research strategy recognises the researcher's biases and preconceptions while encouraging an open mind (Locke, 2000).

The data process analysis in each case started with open coding. This is followed by axial coding and the focused coding in order to make sense analytically. As the data analysis progressed, the focus of this thesis was continuously refined and reformulated. Synthesising the emerging constructs in the axial coding laid the foundation for the chapters. Although, the projects initiated in Finland and California were not specifically dedicated to TEKES and the software vendor, these two orchestrators were identified through the diligent data analysis and interpretation. Following the analysis, the focus of the PhD research shifted to ecosystem orchestration. While observing the failures in both contexts, the research further focused on failures and the dark side of ecosystem orchestration. The grounded theory procedure allowed for the building of generalisable and robust theory around the dark side of ecosystem orchestration. To present the results, I build theory separately from the collected empirical data for each case in order to illuminate the specifics of each case and the chorological order. Following the approach of Yin (2017), this PhD consists of two single cases, Chapters 2 and 3, which are presented as separate chapters, and concludes with Chapter 4, which covers the cross-case analysis. The empirical chapters are dedicated to the cases and present a more detailed explanation of the data analysis that is not covered in this section.

The analysis of each case presents its story that led to the development of this thesis (Eisenhardt & Graebner, 2007). While collecting data in Finland which is considered a success story, the results were mixed and presented a different story that illuminated failures. The surprising observation was that, although, I initially went to Finland with a perception that the Finnish design and construction industry was a leader in BIM deployment, I collected interviews that indicated a more complex issue. The interviewees were not satisfied with the results of the national BIM deployment in TEKES's national technology programmes. The interviewees indicated a complexity in the national and international relationships involved in the national BIM technology programmes and the importance of ecosystem context. As the analysis of the Finnish study progressed, I searched for a relevant theory to complete the analytical process of grounded theory. The ecosystem concept was used to ground the data and build theory. It was the only concept available that provided a useful framework to understand the co-evolving national and global network of complementors, the presence of a hub, a platform for knowledge co-creation, the presence of technology, demand, and institutional environments. The surprising results were objectified and validated that they contributed to the theory-building process around the dark side of open-system orchestration. These results were extensively presented at research events, conferences and private industry events. The results of the Finnish study clearly indicated the need for a contrasting study and key experts recommended a comparison between the Finnish BIM deployment and the Californian BIM deployment. The results of the Finnish study clearly indicated a number of weaknesses in the environment of its BE sector. These weaknesses were strengths in the environment of the Californian BE sector. For example, the availability of capital, sophisticated clients, proximity to Silicon Valley and the network of top universities.

While collecting data in California and considering it a success story, the results were again mixed and presented the failures of the BE sector in BIM adoption. I did not find a government presence leading the sector but rather the strong presence of the specific software vendor who offered an integrated platform to the sector and defined the use value of its platform on behalf of the sector. Thus, I have built a theory around the dark side of closed-system business orchestration, as led by the software vendor. The results of the Californian study clearly indicated that failures are connected to the context of the BE sector. The differences in orchestration processes in two cases seem to be irrelevant drivers of failure.

However, failures of the BE sector in relation to BIM in both cases were surprisingly similar. The failures were observed around business model innovation, change management, education and competency management and multi-stakeholder governance. However, while I was building conceptual, plausible and persuasive arguments around the similarities in failures between the two cases, the data indicated the importance of the sector context. In Chapter 4, I performed a cross-case analysis (Eisenhardt, 1989) to build a close connection between the empirical evidence and emergent theory (Eisenhardt & Graebner, 2007). Thus, the arguments derived from two separately executed studies led to the articulation of the question "*Does the sector's context matter for ecosystem orchestration?".* I answered this question by juxtaposing empirical evidence derived from the two cases with the success stories published in the literature. The success stories comprised Toyota, Uber and Intel. These cases were selected because of the interviewees' recommendations and the contrasts they offered to the observed failures in Finland and California. The cross-case analysis process led to the development of theory around critical constructs and the components of ecosystem orchestration. A detailed visual overall framework of how this thesis was developed is depicted in **Figure 9.**

1.4 THESIS OUTLINE

The research aims and unresolved issues presented in this introduction served as a basis for the development of consecutive chapters as a thought development. The thought process resulted in the studies presented in Chapters 2, 3 and 4. The chapters are presented in a chronological order as the research unfolded following the data analysis over the course of the PhD process. Since this thesis co-evolved with my understanding of the phenomenon, the design of the thesis and each study was evolutionary in nature. Each chapter was built as a standalone study designed to present an individual contribution to ecosystem literature but following one storyline across the whole thesis. Changing the order of the chapters would

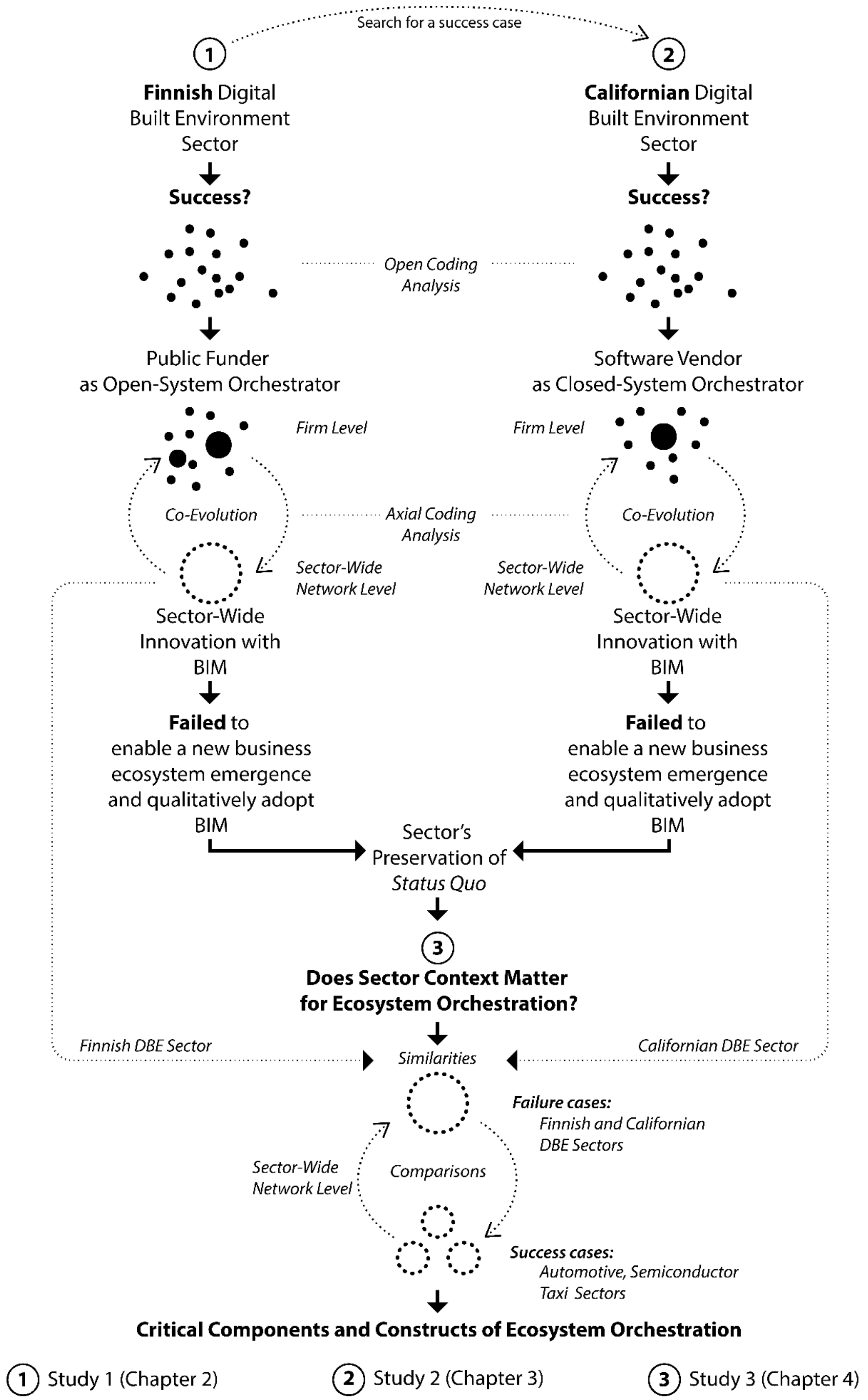

Figure 9 Overall Framework of How This Thesis was Developed

distort the storyline and the overall research process. As the research started with the Finnish study (Chapter 2) from which the analysis indicted the need for a comparative study, I followed the Californian study independently (Chapter 3). As the data of these two cases indicated specific orchestration mechanisms but extensive similarities in failure, I have conducted a comparative study, namely a cross-case analysis, that offered the final contribution of this thesis (Chapter 4). This structure follows the case study research approach defined by Yin (2017: p.184):

> Your full multiple-case report will consist of the single cases, usually presented as separate chapters or sections. In addition to these individual cases, your full report will contain an additional chapter or section covering the cross-case analysis.

This process allows for a comparison of the experiences I had and the development of rich theoretical insights. The approach outlined addresses the call by Dyer and Wilkins (1991: p.613) "*for more qualitative, contextual, and interesting research"* echoing the views of Eisenhardt (1989). Eisenhardt (1989) suggested the use of contrasting multiple cases to illuminate theoretical constructs. Therefore, this thesis presents each study separately (Chapters 2-3) and then builds a theory based on the comparative cross-case analysis (Chapter 4). Following this approach, I was able to offer deeper and more accurate insights, which accounted for the intricacies of a particular context while presenting the rich backgrounds of each study (Van Maanen, 1979).

Overall, the chapters are self-contained providing a relevant synthesis of the literature and methods. The methods section presented in each chapter is largely repetitive but also covers nuances of each study analysis. There is some repetition across the literature as certain concepts and theoretical linkages are used to build arguments for each contribution. However, each study covers a unique angle of the ecosystem orchestration while contributing to the overarching aim of this thesis. These studies are summarised and presented below. This thesis concludes with Chapter 5 in which the two studies of failure in the DBE sector contrasted with the three cases of success in other sectors. Their contributions are juxtaposed in a discussion and evaluation of these contributions. It also identifies and presents theoretical and managerial implications, whilst the limitations and suggestions for further research are also discussed. A short summary of each empirical chapter is presented below.

Study 1 (Chapter 2)

The first study (Chapter 2), entitled "*The Dark Side of Open-System Orchestration: A Case of National Deployment of Building Information Management in Finland*", examines the role of an open-system orchestrator in enabling sector-wide digital innovation. I address this through an inductive case study analysis of the Finnish national deployment of BIM led by TEKES between 1982 and 2002, and the digital evolution in relation to BIM deployment in the Finnish design and construction sector from 1965 to 2018. In particular, I examine the overlooked nature of public agencies' roles as open-system orchestrators and the related actors of knowledge ecosystems, which include the challenges to overcome. In contrast to prior research, this study indicates that open-system orchestration can fail to bridge value creation (R&D) with value capture (sector-wide implementation and innovation). This study offers insights to the dark side of inter-organisational cooperation in ecosystems, even if the orchestrator's aim is to contribute to the public good. A key insight is that, despite the ideal conditions for ecosystems emergence, there are distinct factors related to the complexity of ecosystem orchestration that also explain why business ecosystems might not emerge in certain conditions or simply function in a different way. In particular, I identify the strategies of the open-system orchestrator while clarifying how and when it failed. Building on these insights, I develop a theory of the dark side of open-system orchestration that yields managerial and policy implications.

Study 2 (Chapter 3)

The second study (Chapter 3), entitled *"Closed-System Orchestration: The Dark Side of Orchestrating Business Ecosystems for Industry Platforms",* examines the failure of a closed-system orchestrator to propagate a sector-wide innovation in a B2B context. I address this through the inductive case study analysis of an ecosystem strategy deployed by a software vendor in the northern Californian DBE sector, and examine how it orchestrates the sector for the BIM platform that it owns. A key tension is that a software vendor selfishly succeeds in value capture but negatively affects value creation for BIM innovation in the sector constituting a failed case. I find that the theories on business ecosystems have largely developed in B2C contexts, which are ill-suited to explain the business ecosystem dynamics in B2B contexts. A key question is whether the software vendor, who is a complementor to the sector, is legitimate in orchestrating the sector's ecosystem for BIM innovation. I find that complementors and interdependent actors have to be legitimate participants within ecosystems. I also provide comprehensive empirical evidence that the co-location of a mature sector with successful business ecosystems in an area with a regional advantage is not critical for the emergence of ecosystems. A central contribution of this study is to extend prior work on business ecosystem orchestration in B2C contexts to B2B contexts. This study also contributes to literature on the dark side of ecosystem orchestration.

Study 3 (Chapter 4)

A final study (Chapter 4), entitled *"Does the Sector Context Matter for Business Ecosystem Orchestration?",* examines the critical constructs and components of ecosystem orchestration. Building on the results of two previous orchestration mechanisms in two different contexts that produced similar results in terms of sector-wide innovation, I pose a logical question: *how come both contrasting contexts with two different ecosystem* *orchestration mechanisms have produced similar results?* I address this through a multi-case, multi-level, inductive theory building approach to identify, generalise and analyse the failure similarities between the two sector contexts. I examine the documented success examples of ecosystem orchestration processes and systematically compare them to the empirical evidence of failures presented in the second and third chapters of this thesis. Prior work addressed the role of industry architecture (Jacobides & Winter, 2012) and the conditions for ecosystem emergence in B2C contexts (Hannah, 2016; Jacobides et al., 2018; Thomas, 2013) by studying the mechanisms of successful firms from a single firm perspective. I extend this prior research by examining the strategy in the context of failed business ecosystems and systematically juxtaposing the failures in one sector to successful examples in other sectors through a multi-level perspective that considers *individual, organisational* and *system* levels. A central contribution of this study is the multi-level framework that presents the critical constructs and components that *enable, build* and *fail* ecosystem orchestration. This study also contributes to theory by exploring and presenting empirical evidence on whether the sector context, particularly the nature of the sector, matters for business ecosystem emergence and orchestration.

Related Publications and Presentations

Journal Papers

Aksenova, G., Kiviniemi, A., Kocaturk, T., & Lejeune, A. (2018). From Finnish AECO Knowledge Ecosystem to Business Ecosystem: Lessons Learned from National Deployment of BIM. ***Construction Management and Economics***, DOI: 10.1080/01446193.2018.1481985

Conference Papers

Aksenova, G., Elfring, T. & Kiviniemi, A., 2020. 'The Dark side of ecosystem orchestration'. Paper presented at ***Strategic Management Society Special Conference*** "Designing the Future: Strategy, Technology, and Society in the 4th Industrial Revolution". Berkeley, USA.

Aksenova, G., Kiviniemi, A. & Kocaturk, T., 2018. 'An Empirical Study Investigating Business Ecosystem Strategies for Value Co-Creation with Building Information Modelling in the Architecture, Engineering, Construction, Operation and Owners Industry'. Paper presented at the conference ***Organisational Learning, Knowledge and Capabilities*** (OLKC) "Learning to make a difference". Liverpool, UK.

Conference Presentations

Aksenova, G., Elfring, T. & Kiviniemi, A., 2019. 'Orchestrating ecosystem for the industry platform. Empirical investigation of Finnish and Californian construction industries.' Paper presented at the **World Summit on Digital Built Environment** (WDBE) "Transforming urban user experience". Helsinki, Finland.

Aksenova, G., Kiviniemi & Kocaturk, T. (2018). 'An Empirical Study Investigating a Business Ecosystem Strategy for Value Co-Creation with BIM in AECO industry'. Paper presented at the **6th International Workshop When Social Science Meets Lean and BIM**. Huddersfield, UK.

Aksenova, **G.**, Kiviniemi, A., Lejeune, A., & Kocaturk, T. (2017). 'Lessons for organisational leaders from BIM development in AECO business ecosystem'. Paper presented at the **5th International Workshop When Social Science Meets Lean and BIM**. Aalborg, Denmark.

Book Chapters

Aksenova, G., Kiviniemi, A., Kocaturk, T., & Lejeune, A. (2017). Finnish BIM Development (Oppia suomalaisesta BIM-kehitystyöstä). In R. O. B. I. Ltd (Ed.), '***Jubilee Builders' calendar 2018*'** (Rakentajain kalenteri 2018). Finland Rakennusmestarit ja -insinöörit AMK RKL ry, Rakennustietosäätiö RTS SR [in Finnish language].

Aksenova, G., Kiviniemi, A., Kocaturk, T., & Lejeune, A. (2017). Finnish BIM Innovation Journey (Suomen BIM-innovaatiomatka), '***Jubilee Builders' calendar 2018*'** **(**Rakentajain kalenteri 2018). Finland Rakennusmestarit ja -insinöörit AMK RKL ry, Rakennustietosäätiö RTS SR [in Finnish language].

Industrial and Academic Reports

Simpson, M., Underwood, J., Shelbourn, M., Carlton, D., **Aksenova, G**, Mollasalehi, S. (2018). 'Evolve or Die: Transforming the productivity of Built Environment Professionals and Organisations of Digital Built Britain through a New Digitally Enabled Ecosystem Underpinned by The Mediation Between Competence Supply and Demand'. **The Centre for Digital Built Britain: Pedagogy and Upskilling Network.**

Kocaturk, T., **Aksenova, G**., & Momoh, J. (2016). Intelligent Data-Driven Design Futures. **The University of Liverpool**. Retrieved from: https://tangerinefocusdotcom.files.wordpress.com/2016/07/intelligent-data-driven-design-futures_corrected.pdf

Invited Speaker at the Industry Events

"BIMTECNIA. El BIM en Negativo" ("BIMTECHNIA. The Dark Side of BIM"), public event organised by **AEICE and Junta de Castilla y León**, Valladolid, Spain (2018).

Presentation: "*Lessons Learnt from The National Deployment of BIM in Finland*"

"BIM and the Construction Industry's Competitiveness" (« L'approcheBIM au Service de la Compétitivité de l'Industrie de la Construction»), strategic workshop organised by **GRIDD at École de Technologie Supérieure ÉTS,** Montréal, Canada (2018).

Presentation: "*Lessons Learned from National Deployment of BIM in Finland*"

"BIM Education", symposium organised by **The University of Liverpool**, London, UK (2017).

Presentation: "*From Finnish AECO Knowledge Ecosystem to Business Ecosystem: Lessons Learned from National Deployment of BIM*"

1.5 GLOSSARY

A glossary is provided to inform the reader about the key concepts used in this thesis, which will serve as a basis of working definitions to support the reader. The glossary provides key definitions in their most concise form as they are explained comprehensively in other sections of this chapter. I present the terms in alphabetical order (see **Table 6**).

Table 6 Glossary

Concept	Definition
Bottleneck	Is a component in complex system whose performance significantly limits the performance of the whole system due to poor quality, poor performance, or short supply (Baldwin, 2015; Goldratt, 1990; Hannah & Eisenhardt, 2019).
Business Model	*"Articulates the logic … that demonstrates how a business creates and delivers value to customers [and] outlines the architecture of revenues, costs, and profits associated with … delivering that value"* (Teece, 2010: p.173).
Built Environment	Incorporates the supply chain, clients and all the related parties for the design, construction, operation and integration of physical, social and economic infrastructure and all the service providers that comprise the physical and digital infrastructure of buildings and cities.
Digital Built Environment	Actors in the built environment sector that has adopted, or is trying to adopt, emerging information and communication technologies, such as BIM.

Building Information Model	*"Represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality"* (Rothenberg, 1989: p.1).
Building Information Modelling	*"Use of a shared digital representation of a built asset (3.2.8) to facilitate design, construction and operation processes to form a reliable basis for decisions"* (BSI Standards Limited, 2019).
Building Information Management	Business processes across the built environment sector underpinned with the emerging digital technologies that support management and production of information and communication during life cycle of built assets.
Capabilities	*"The firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments"* (Teece et al., 1997).
Complementarity	Complementary innovations, products, or services are interdependent and co-specialised in a way that the combination of the two complementors provide superior value to both complementors and customers.
Ecosystem	A multilateral, non-generic community of complementary interdependent organisations that cross a variety of industries. These organisations serve different functions, have conflicting goals and therefore form a political coalition. Through simultaneous value creation (cooperation) and value capture (competition), they co-evolve capabilities individually and collectively around a focal value propositions and produce a distinct system structure, a business model that generates ecosystem dynamics, defines the ecosystem type and thus affects all other interdependent actors.
Modularity	*"The idea of interdependence within and independence across modules. A module is a unit whose structural elements are powerfully connected amongst themselves and relatively weakly connected to elements in other units. Clearly there are degrees of connection, thus there are gradations of modularity"* (Baldwin & Clark, 2000: p.63).
Leadership	Presence of an '*architect'* who sets the system-level goal and directs the rules, roles and mechanisms for value co-creation and capture are essential in ecosystem orchestration (Gulati et al., 2012).
Network effects	Magnify advantages to the platform orchestrator because the value to customers on one side of the platform increases with the number of participating complementors and customers on the other side. Network effects can be direct and indirect (McIntyre & Srinivasan, 2017).
Industry Architecture	Is a unifying concept that explores the structural properties of the sector, such as the division of labour, rules, roles and power relations that are derived from the structural organisation (Jacobides & Winter, 2012)
Ecosystem Orchestration	Ecosystem orchestration is characterised by the processes or mechanisms that are used by a leading firm or a network hub to intentionally direct, coordinate, influence and manage a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled for value co-creation and capture at multiple levels and, depending on the context and the approach taken, these processes can be re-configured and contextualised.
Platform	Are multi-sided markets that enable transactions by the end-users and offer an open or semi-open interface upon which complementors can co-create value (McIntyre & Srinivasan, 2017).

Value Creation	*Who can do what,* or the collaborative process of value creation for the users (Jacobides et al., 2006).
Value Capture (appropriation)	*Who gets what* or an ability to create profit from activities (e.g. transactions) (Jacobides et al., 2006).
Value Proposition	A focal-value proposition of a product or a service for the end-customers upon which the value is created and captured. There can be multiple value propositions within one ecosystem

CHAPTER 2

Chapter 2. OPEN-SYSTEM ORCHESTRATION: A CASE OF NATIONAL DEPLOYMENT OF BUILDING INFORMATION MODELLING IN FINLAND

ABSTRACT

The literature on ecosystems highlighted the important role of open-system orchestrators in facilitating innovation ecosystems. They help participating organisations to create their own business opportunities. However, the literature has overlooked the nature of the challenges that open-system orchestrators have to overcome while orchestrating their ecosystems. This study presents a detailed account of the evolution of national technology deployment of Building Information Modelling (BIM) in Finland and the role of the national public funder in supporting this deployment through technology programmes as an open-system orchestrator. The analysis indicates that the public funder successfully facilitated a knowledge ecosystem, but actors in the design and construction industry failed to bridge the created value with value capture in the industry to make a qualitative digital transformation with BIM. This study indicates that the industry context should be taken into consideration in open-system orchestration. By doing so, a discussion is provided on a promising direction for future research into the dark side of open-system ecosystem orchestration.

KEYWORDS

Open-system orchestration, national innovation system, public funder, knowledge ecosystem, industry evolution, digital design and construction industry, BIM, the dark side.

2.1 INTRODUCTION

Modern firms are increasingly moving to the collective creation of innovation (Powell et al., 1996). Previous research on ecosystems has highlighted the important role of hub firms in orchestrating collective efforts to cooperate for value creation and compete for value capture (Hannah & Eisenhardt, 2019; Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013; Spencer, 2003; Teece, 2010b). These hub firms typically orchestrate a "*closed-system*" ecosystem (Giudici et al., 2018: 1370) pursuing self-interest around a collective innovation goal to harness "*the dispersed resources and capabilities*" of the ecosystem members (Nambisan & Sawhney, 2011: 659).

While such hub firms have received a large amount of attention from scholars (Dhanaraj & Parkhe, 2006; Iansiti & Levien, 2004c; Lorenzoni & Baden-Fuller, 1995; Nambisan & Sawhney, 2011), other types of ecosystem orchestrator support members' efforts in the search for their own business opportunities (Giudici et al., 2018). Scholars refer to such organisations as "*bridging organisations*" (Berkes, 2009), "*open system intermediaries*" (Dutt et al., 2016), "*innovation brokers*" (Winch & Courtney, 2007) or "*open-system orchestrators*" (Giudici et al., 2018). In this study, such organisations are referred to as "*open-system orchestrators*" (Giudici et al., 2018: p.1370). For example, business incubators (Phan, Siegel, & Wright, 2005), national systems of innovation (Lundvall, Johnson, Andersen, & Dalum, 2002), national agencies (Sapsed, Grantham, & DeFillippi, 2007), public agencies (Howells, 2006) and Small and Medium-sized Enterprise (SME) associations (Arıkan & Schilling, 2011) are viewed as such orchestrators. Although there is an expansive understanding of the functions of these actors in enabling innovation, "*the fundamental orchestrating role that such organizations play [...] remains undertheorized*" (Giudici et al., 2018: p.1370).

The literature on ecosystem orchestration suggests that open-system orchestrators have the potential to facilitate the emergence of new markets and network-centric businesses (Giudici et al., 2018; Howells, 2006). Thus, policy makers increasingly invest in national innovation systems to foster the creation of start-ups in a platform-based economy around so-called knowledge hubs (Clarysse et al., 2014; Levén, Holmström, & Mathiassen, 2014). These national innovation systems are typically orchestrated by a government representative, e.g. a public agency. However, this literature has overlooked the nature of the challenges that open-system orchestrators and related ecosystem actors have to overcome to become a success story (Adner & Kapoor, 2010). The important role of the public agency as an open-system orchestrator that supports the emergence of innovation and nascent business networks has also been overlooked (Nambisan & Sawhney, 2011).

In order to build a theory around the role of public agency as an open-system orchestrator, this study presents a unique case of national deployment of Information and Communication Technologies (ICT) with a particular focus on Building Information Modelling (BIM) technologies (Eastman et al., 2011; Sacks et al., 2018) in the Finnish design and construction industry[8] . This case offers an ideal context to study the role of the national public funding agency, TEKES, the Finnish Funding Agency for Technology and Innovation. In 1982, the Finnish government established TEKES to boost "*the development of [the] Finnish industry and the service sector by technological means and through innovation*" (Van Der Veen et al., 2012: p.39). TEKES was the main public funding organisation for Research and Development (R&D) promoting innovative, risk-intensive projects across all sectors in Finland, and was evolving in its role and the mechanisms deployed. In 2018, TEKES joined the Finnish trade promotion organisation (Finpro) forming an organisation called Business

[8] In this chapter, I specifically focus on design and construction industry because the national BIM deployment was in consideration of the design and construction industry. The notion of the built environment sector has only become widely used in the recent years.

Finland. Its function was to catalyse new growth and create opportunities for Finnish businesses (Soini, 2018).

The focus of this study is the co-evolution of the digital design and construction industry in the national technology programmes run by TEKES. These were dedicated to BIM deployment and general ICT over the period 1982-2007 with a particular focus on the VERA programme, which ran between 1997 and 2002. Indeed, TEKES invested a large amount of resources and substantial effort in facilitating extensive R&D for ICT (e.g. BIM) in order to support technology initiatives by design and construction technological communities around national technology programmes. For example, in 2001 TEKES invested 20% from a total budget of €373 million on technology development in the energy, environmental and construction industries (Kiviniemi, 2001). This study further analysed national ICT deployment from 2007 until 2018, by presenting important initiatives run at the national level but not with the support of TEKES. These late initiatives by the industry were based on the lessons learnt from national BIM R&D and the failure to capture value.

The role of TEKES in leading the first national technology programmes for BIM deployment in the Finnish design and construction industry is a unique case of the simultaneous success and failure of ecosystem orchestration. It successfully supported value creation in ICT R&D and the initiatives of BIM champions in perusing their technology ideas, but the industry failed to capture value from the knowledge developed in national technology programmes. The initial expectations were that a push toward technology in the industry could create a knowledge hub that would eventually lead to self-renewal and innovation in the design and construction industry with emerging technologies. The expectation was that participating SMEs would be gradually merged and become powerful international firms. However, despite its international success (Fischer & Calvin, 2002; Froese, 2002), TEKES produced an effective knowledge ecosystem that did not lead to value capture by the design and construction industry, and thus failed to bridge the R&D outcomes with industry-wide innovation. Extensive support for technology invention did not lead to technology innovation in the industry. BIM technologies were adopted within the old practices. In other words, the industry failed to evolve beyond the traditional business models as it continued to largely operate in traditional ways.

National ICT deployment in the industry was a learning curve for TEKES, in that a technology push does not lead to a market pull. The analysis of this study revealed the dark side (Oliveira & Lumineau, 2019) of open-system orchestration, as demonstrated by TEKES's failure to support the emergence of global business firms in the design and construction industry. First, the ecosystem participants were cooperating to exploit the system for individual value capture under existing business models. Public funding incentivised firms to rely on public resources rather than seek new business opportunities on a global scale. It contributed to the failure in bridging research and industry-wide innovation. Second, despite the effort that TEKES invested into disseminating the research results of the innovation, these results were often kept privately and intra-organisationally, and knowledge was often redeveloped and recreated afterwards. Knowledge loss from R&D and in the industry was an issue because the created knowledge stayed within the project participants in siloes. Third, although some industry actors followed the R&D results of national programmes, they were not actively involved in implementing technology. The established culture of the industry is "*let's see what happens*" with BIM implementation in other firms before the industry actor invests in a digital transformation. Fourth, this small group of champions developed strong digital capabilities, knowledge, interdependencies and technological visions in siloes despite the presence of international and national inter-organisational cooperation. The network's participants developed capabilities in silos much faster than the rest of the traditional industry. This created conflicting competency levels amongst project participants in design and construction projects. Qualitative BIM implementation requires most project participants to use BIM technologies effectively to deliver BIM processes. Thus, BIM champions were failing to capture value from BIM implementation in the projects that were not part of national programmes. Fifth, TEKES did not have specific mechanisms to incentivise the necessary actors to participate in national development as it relied on the good will of actors. The small group of champions were technology enthusiasts and participation in national R&D for technology was on a voluntary basis. The ecosystem actors also failed to incentivise crucial global and local complementors, leading international software vendors, clients, insurance firms and cities, to participate in the deployment of R&D results. Finally, TEKES, in collaboration with the BIM champions, invested resources and efforts in BIM R&D in a not-for-profit manner; this left them at a disadvantage on a global scale.

The orchestration mechanisms set by TEKES fall into the category of open-system orchestrators according to the description provided by Giudici et al. (2018). However, evidence shows that TEKES intended to be an open-system orchestrator, which aligns with the literature; however, the actual setup resulted in a siloed development by a closed community of champions. Despite the good intentions of the ecosystem actors and effective knowledge creation mechanisms, TEKES failed to support the growth of international businesses in this particular industry. This case study suggests that open-system orchestrators need to consider the context of orchestration and to integrate mechanisms necessary to support the development of mindsets and to break siloes. While general literature suggests the altruistic nature of open-system orchestrators in supporting the firm’s business initiatives, the value capture by ecosystem members is rarely discussed. This study indicates that some open-system orchestrators need to find mechanisms to connect value creation in knowledge ecosystems with value capture in business ecosystems supporting the evidence discussed by

Clarysse et al. (2014). It also suggests that public agencies can struggle to simultaneously support national exploration and exploitation.

These findings support the prominent stream of research on the dark side of inter-organisational relations in ecosystems (Bizzi, 2013; Oliveira & Lumineau, 2019) and the impact of orchestration mechanisms set by an orchestrator for value capture by ecosystem actors (Nambisan & Sawhney, 2011). Specifically, this study takes a retrospective view on the co-evolution of the national technology programmes for BIM R&D run by TEKES and the design and construction industry, thus depicting the evolution of the knowledge ecosystem run by TEKES. Despite ideal conditions for the emergence of business ecosystems in the Finnish design and construction industry, there are distinct factors related to the context of the co-evolution of innovators, competitors, their complementors and the environment in which they operate. This study explains why, in some cases, ecosystem members can fail to capture value from the open-system orchestration.

2.2 OPEN-SYSTEM ORCHESTRATION

Ecosystems offer multiple benefits and opportunities to their participants in terms of access to resources, knowledge and learning (Ahuja, 2000; Powell et al., 1996). While some ecosystems are organised without a central network orchestrator (Håkansson & Ford, 2002; Kilduff & Tsai, 2003), recent studies emphasise that intentionally organised ecosystems for innovation can be successful and long-lived (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013). Literature suggests that there must be an anchor organisation to facilitate the connection between dispersed organisations with conflicting goals (Clarysse et al., 2014; Powell & Giannella, 2010). Such organisations are crucial in bridging value creation with value capture (Thomas, 2013) and in coordinating the tension between cooperation and competition (Hannah & Eisenhardt, 2019; Hoffmann, Lavie, Reuer, & Shipilov, 2018). As Nambisan and Sawhney (2011) indicated, although the important role of orchestrators is recognised, there is limited understanding of how ecosystem orchestrators should facilitate value creation and value capture. To date, little empirical support exists to provide such an understanding (Batterink et al., 2010; Jacobides et al., 2018). Furthermore, organisational leadership research on networks and regional clusters is also scant (Sydow, Lerch, Huxham, & Hibbert, 2011).

Scholars have different definitions for the anchor organisation that performs as an ecosystem orchestrator. Scholars refer to such organisations as "*bridging organisations*" (Berkes, 2009), "*open system intermediaries*" (Dutt et al., 2016), "*innovation broker[s]*" (Winch & Courtney, 2007) or *"matchmaker[s]"*. This study adopts the term "*open-system orchestrator*" which aligns with the theory by Giudici et al. (2018: 1370) on open-system orchestration. Giudici et al. (2018) proposed two types of orchestration - closed-system and open-system.

Closed-system orchestration is largely considered by Dhanaraj and Parkhe (2006: p.659) who state that closed-system orchestrators tend to involve "*deliberate, purposeful actions … to create value … and extract value … from the network*". Closed-system orchestrators intentionally design their ecosystems to preserve control and power by providing incentives to members in order deliver collective value around a focal value proposition (Adner, 2017). Ecosystem actors typically have self-interests when participating in such ecosystems (Nambisan & Sawhney, 2011). The perspective of closed-system orchestration is taken almost exclusively from the view of a single private firm and is typically linked to the orchestration of business ecosystems. Such closed-system orchestrators have been referred to as "*hub firms*" (Dhanaraj & Parkhe, 2006), "*keystones*" (Iansiti & Levien, 2004c), "*network administrative organisations*" (Human & Provan, 2000), "*kingpins*" (Jacobides & Tae, 2015) and a "*strategic centre*" (Lorenzoni & Baden-Fuller, 1995). According to Giudici et al. (2018), public organisations can also engage in closed-system orchestration, such as "*government-sponsored programs"* (Levén et al., 2014) and "*R&D consortia"* (Sydow, Windeler, Schubert, & Möllering, 2012). Although, the studied case is a government-sponsored programme, the orchestration processes established in the Finnish national programmes resemble open-system orchestration according to the definition offered by Giudici et al. (2018).

Open-system orchestration functions are similar to those of close-system orchestration; however, rather than aiming at value capture, the mechanisms aim at value creation, open network membership, voluntary participation without contractual obligations, and to "*support members' decentralized and mostly independent entrepreneurial efforts… [this] typically revolves around network-specific criteria that members have to meet to access events and use facilities*" (Giudici et al., 2018:p.1372). Open-system orchestrators support value creation by ecosystem participants in order to help realise their business ideas.

With increased interest in ecosystem orchestration processes, the role of open-system orchestrators in facilitating and accelerating the development of innovation and the emergence of business networks across different industries has become more important (Adner, 2006; Adner & Kapoor, 2016; Autio & Thomas, 2014; Clarysse et al., 2014; Oh et al., 2016; Russell, Huhtamäki, Still, Rubens, & Basole, 2015; Sydow et al., 2011). There is little empirical and theoretical understanding of open-system orchestration processes or the effects they produce (Giudici et al., 2018; Jacobides et al., 2018; Nambisan & Sawhney, 2011). For example, open-system orchestrators are regarded as having positive effects on innovation outcomes and yet there is little knowledge as to their effectiveness (Sapsed et al., 2007). Levén et al. (2014) argued that there is little understanding of how innovation is orchestrated when several industries collaborate. The role of government and public agencies in nourishing innovation contexts for business ecosystem emergence also remains empirically and theoretically underexplored (Rinkinen & Harmaakorpi, 2018).

Public agencies try to play an active role in stimulating the environment for economic growth. There is an interplay between the governance models of public organisations and participating actors which shape the contours of the relationships they hold (Armstrong, Giordano, & Macleod, 2015). This study aims to explore the role of a public funder in orchestrating national programmes for ICT (e.g. BIM) R&D to support the competitive growth of firms in the Finnish design and construction industry. Although literature emphasises the positive role of public agencies in supporting the SMEs' innovation efforts and the commercialisation of research (Clarysse et al., 2014), only a few studies present failure cases and the unintended consequences of orchestration processes. This study presents a case where open-system orchestration manifested in the unintended dark side of the ecosystem orchestration. The questions posed in this chapter also align with the study by Rinkinen and Harmaakorpi (2018) whose research was sponsored by TEKES following their experience of leading the national programmes in Finland. These questions are: "*How did the design and construction industry co-evolve with the national efforts for ICT (e.g. BIM) R&D in Finland? How did the dark side manifest in open-system orchestration led by TEKES? What is the role of the public organisations in orchestrating ecosystems?*".

2.3 DATA AND METHODS

In viewing social interactions for value creation and capture as socially constructed phenomena (Pfeffer, 1993), this study adopted an inductive interpretivist methodology based on the study by Gioia et al. (2013). Gioia et al. (2013) offer a methodology to capture the meaning of people experiencing the phenomenon and to scientifically theorise about their experience (Gehman et al., 2018). An interpretivist approach gives voice to the interviewees to interpret the key issues they have experienced in their journeys while participating in the national programmes.

This study uses qualitative procedures to build a grounded theory of ecosystem orchestration. In particular, it aims to understand how a public funder orchestrated the national technology programmes for value creation, and impacted industry-wide innovation with BIM and the growth of digital services in the built environment sector between 1982 and 2002. A study of the co-evolution of national technology programmes and the design and construction industry requires detailed procedures of a macro-level study and a retrospective view on evolution. To present the evolution of the industry, analysis of the national ICT was extended until 2018 although TEKES's involvement with the design and construction industry stopped between 2002 and 2007. Thus, the study includes historical data collected through the analysis of retrospective interviews and published literature (Langley, 1999; Van de Ven, Polley, & Garud, 2008). To stress and conceptualize the dynamic processes of interactions, complementary data sources were used to generate a comprehensive account of the retrospective evolution of national BIM deployment in the Finnish design and construction industry (Yin, 2017).

2.3.1 Research Procedures and Data Sources

Interviews. The qualitative data comprised primary (interviews) and secondary sources (archives). Professor Arto Kiviniemi, at the University of Liverpool, selected the first round of interviewees. I subsequently applied snowball sampling by asking interviewees for other key interviewees who could contribute to the study. The interviews were conducted in English with the Finnish representatives.

Twenty interviews (31 hours of interviews) were conducted in 2015 with representatives across five key stakeholders and end-user groups, namely: i) public organisations; ii) academia; iii) management and business partners; iv) BIM users; and v) public building and infrastructure clients. Many of the interviewees served in different organisations over time, so most had a wider view of the ecosystem wide efforts to enable digital transformation in the industry.

In 2017, an additional four interviews were collected with new representatives from three levels - CEOs, managers and operations - to validate the analysis derived from the interviews collected in 2015. In 2019, an additional interview with a manager was conducted to obtain results from the KIRA-digi initiatives, a new orchestrator that was established by the Finnish government to enable stakeholder communication in the wider built environment sector. The interviews varied between 30 and 160 minutes. In total, 22 interviews lasted at least 60 to 90 minutes and were recorded and transcribed verbatim.

A total of 24 interviews were collected. **Table 7** presents information on the sectors and occupations of the interviewees. Of the 27 interviewees, 15 actively participated in the national BIM deployment and the remaining 12 did not. The juxtaposition of different viewpoints on technological development brings into focus contrasting views of socio-technical change and development that potentially led practices to today’s level of BIM adoption. Such integration provides contrasting pictures of the same processes without nullifying each other (Van de Ven & Poole, 1995).

Interviews were prepared on the bases of existing case history documentation, such as literature (published in and outside Finland, 1965-2015) on the adoption and implementation of ICT in design and construction. As BIM was an important part of national ICT development, it was important to cover different aspects of BIM R&D. BIM, as a term, did not exist at the time. Finnish experts referred to the Building Information Model as the “*Building Product Model*” (Björk, 1994). The term *'Building Information Model*' first appeared in a paper by van Nederveen and Tolman (1992), but came into wider use after Autodesk started to promote it in 2002 (Autodesk Building Industry Solutions, 2002).

A historical data analysis covered the periods from 1965 (when Tekla was established) to 2015 (when the interviews were conducted) and extended to 2018 with additional interviews and literature review. The collected material helped prepare for the interview process. The semi-structured interview protocol was based on the approach developed by McCracken (1988). The interviews started with the following questions: (1) *How has the Finnish industry evolved in terms of ICT use over the last 30 years?* (2*) How has BIM emerged in the industry?* (3) *What is the current state of industry adoption of BIM?*

Table 7 Selection of Interviewees

Levels	**Sector**	**Occupation**	**No of participants**	**Hours of interviews**	**No of interviews**
Academia	Researchers	Research Scientists	6	10	6
Public clients	Senate Properties (Building sectors)	BIM managers	3	2	2
	Finnish Transport agency (Infrastructure sectors)	BIM manager	1	2	
Public organisations	Governmental funding agency, TEKES	Manager	1	1	4
	Strategic Centre for Science, Technology, and Innovation of Built Environment in Finland	Manager	1	2	
	KIRA-digi	Manager	1	4	
	Intermediary interdisciplinary mediator	Manager	1	1.5	
Business & Management partners	Software developer General Contractor	Manager Innovation & Business Managers	1 3	2 5	8
	Architectural office	Managers	2	2	
	Private Organisation	Consultant	1	2	
	Engineering service provider	CEO, Manager	1	1.5	
	Engineering service provider	Senior Specialist Digital	1	1.5	
Users of BIM at the operational level	General Contractor	Site Manager	1	1	4
	Engineering service provider	HVAC Engineer	1	1	
	Architectural office	BIM technician	1	1	
	General Contractor	Production planning engineer	1	1.5	
TOTAL			**27**	**41**	**24**

As the interviews progressed, open questions were directed to emerging themes and cases. The interviewees were free to highlight the important issues experienced in their practice from their perspective following guidance provided by Corley and Gioia (2011)'s problem-driven theory. The qualitative interviews provided a detailed contextual understanding of the problems experienced by interviewees, thereby revealing hidden motives and beliefs.

Each interview was anonymised, and a transcript was provided for the interviewee's approval. Only after approval were the transcripts used for analysis. Every transcript was labelled with a unique number identifiable only by the author of this thesis. Quotes in this thesis that can potentially identify individuals were eliminated to preserve the interviewees' anonymity.

Archival sources. In addition to the interview data, relevant literature was collected in the form of reports, published articles and internal company documentation to obtain historical evidence of strategic change in the Finnish design and construction industry regarding ICT deployment over the last 50 years. For example, Prof. Matti Hannus provided key reports from national ICT R&D by publishing them on the website, http://cic.vtt.fi/. Prof. Arto Kiviniemi provided all the relevant reports related to the VERA programme on http://cic.vtt.fi/vera.htm. Both websites were accessible in early 2018 but are no longer available. The combination of the archival and interview data provided reliable insights into the complexity of interactions created in national technology programmes.

Triangulation and cross-verification of the collected data - namely the interviews, archival sources and the discussions with key experts - allowed the researcher to validate and eliminate potential biases in the findings (Jick, 1979). The triangulation was beneficial for the generation of theory yielding a stronger substantiation of the emerging concepts (Glaser & Strauss, 1967) and increasing the theoretical sensitivity (Corbin & Strauss, 1990).

This study enabled the researcher to maintain the high-level outsider perspective required for unbiased theorization (Gioia et al., 2013) and to deliver conceptual nonrepresentative insights with the power of a single unique case (Siggelkow, 2007). While I am inexperienced in understanding the critical issues occurring across various disciplines and organisations, I actively engaged in discussions around the findings with knowledgeable actors, industry BIM experts and those who participated in the national technology programmes. This process validated that the results and offered novel insights. I further cross-validated the articulated findings at various workshops, industry events, conferences and through a publication in a peer-reviewed journal.

2.3.2 Data Analysis

Interview transcripts were used as primary data for the analysis while archival sources were used to refine the interpretation of emerging categories, thereby guiding the integration of these categories into an overall framework. First, I aimed to understand and characterize the current dynamics of the industry and the evolving relationship between ecosystem actors. Then, I narrowed the focus of this research to the orchestration processes by a public funder and the effects of national development on industry-wide innovation.

I analysed the collected data by following a methodology provided by Gioia et al. (2013) in which the empirical observations were connected to extant theoretical ideas (Langley, Smallman, Tsoukas, & Ven, 2013). The research progressed through multiple intertwined steps that were repeated a number of times. The following section presents a simplified sequence of these steps that led to the construction of a grounded theory model.

Step 1: Event analysis and open coding. I began by creating a comprehensive case narrative of the evolution of the Finnish national programmes by providing a chronological overview of events and reconstructing a network of activities and actors (Langley, 1999). The narrative resulted in a timeline of historical development, the Finnish Innovation Journey, which depicted the main organisations involved, the programmes established, and the activities and key outcomes of the national programmes. This draft timeline was used to help interviewees trigger their memories about the projects and programmes realised within this national development and to use their insights to accurately complete the timeline. As I continuously engaged in intensive reading of the data (Strauss & Corbin, 1990), I built a large database of in-vivo codes, and distributed these codes according to the emerging timeline as the events occurred and according to the issues related to current state of the industry.

I followed the guidance provided by Gioia et al. (2013). During the first phase of data analysis, a myriad of codes and themes emerged, each containing a sentence or a sequence of sentences (Weber, 1990). I constantly iterated and created mutually-exhaustive, first-order categories (Strauss & Corbin, 1998). When trying to make sense of the data, its abundance and emerging themes eventually became overwhelming (Gioia, 2004). However, it became evident that the evolution of national BIM deployment was connected to earlier phases of knowledge hub formation in the industry from 1965. This understanding later resulted from the inclusion of the additional phase, which presented interesting insights into the evolution of the industry before the emergence of TEKES and the national programmes.

During the analysis process, I continued to communicate with key interviewees by providing preliminary evidence to clarify certain issues. As my understanding progressed, the first results in relation to BIM deployment were published in a paper "*From Finnish AEC knowledge ecosystem to business ecosystem: lessons learned from the national deployment of BIM*" (Aksenova et al., 2018) in a high impact journal "*Construction Management and Economics*". The research results were presented in the UK, Finland, Canada and Spain to industry experts, government representatives and research communities in BIM. The results received a high appreciation, which validated the findings and the relevance of the research.

As the research progressed, it became more focused on the phenomenon observed, namely the co-evolution of the TEKES-run national technology programmes and the efforts made by design and construction industry actors to digitalise the industry. The data showed that the mechanisms set by TEKES were effective in generating knowledge on ICT but also had limited results in supporting value capture by ecosystem members for the systemic qualitative change through BIM deployment in the industry. I found that joint efforts by TEKES and key BIM champions were dependant on the industry context, local organisations (clients, academia, insurance firms, cities, etc) and global technology firms which aimed to preserve their market share and power. National efforts were also limited in changing the existing business ecosystem of the industry as the industry-wide network of actors wanted to preserve the status quo.

Step 2: Axial coding. In the next step, I gradually progressed to axial coding and then to a theory-driven explanation (Strauss & Corbin, 1990). Through continuous iteration between discussions with the supervisors and industry actors, I was able to extract the underlying components of ecosystem evolution by comprising the second-order categories of axial coding (Strauss & Corbin, 1998) while also ordering them according to the periods and phases of national BIM deployment. The evolution of the national BIM deployment resulted in a carefully presented storyline with key events as they occurred. As the study's focus is a longitudinal process of TEKES's orchestration, I continuously refined the emerging second-order categories by reducing and merging them into aggregated themes (Gioia et al., 2013). Since the second-order themes constituted a particular period of development, I have further grouped them into third-order categories comprising periods and then aggregated dimensions comprising the overarching phases of Finnish national ICT deployment from 1965 to 2018. This step was performed iteratively by making extensive use of notes and discussions to interpret the data. The iterative analysis resulted in the data structure shown in **Figure 10** (see **Appendix B** for the full version).

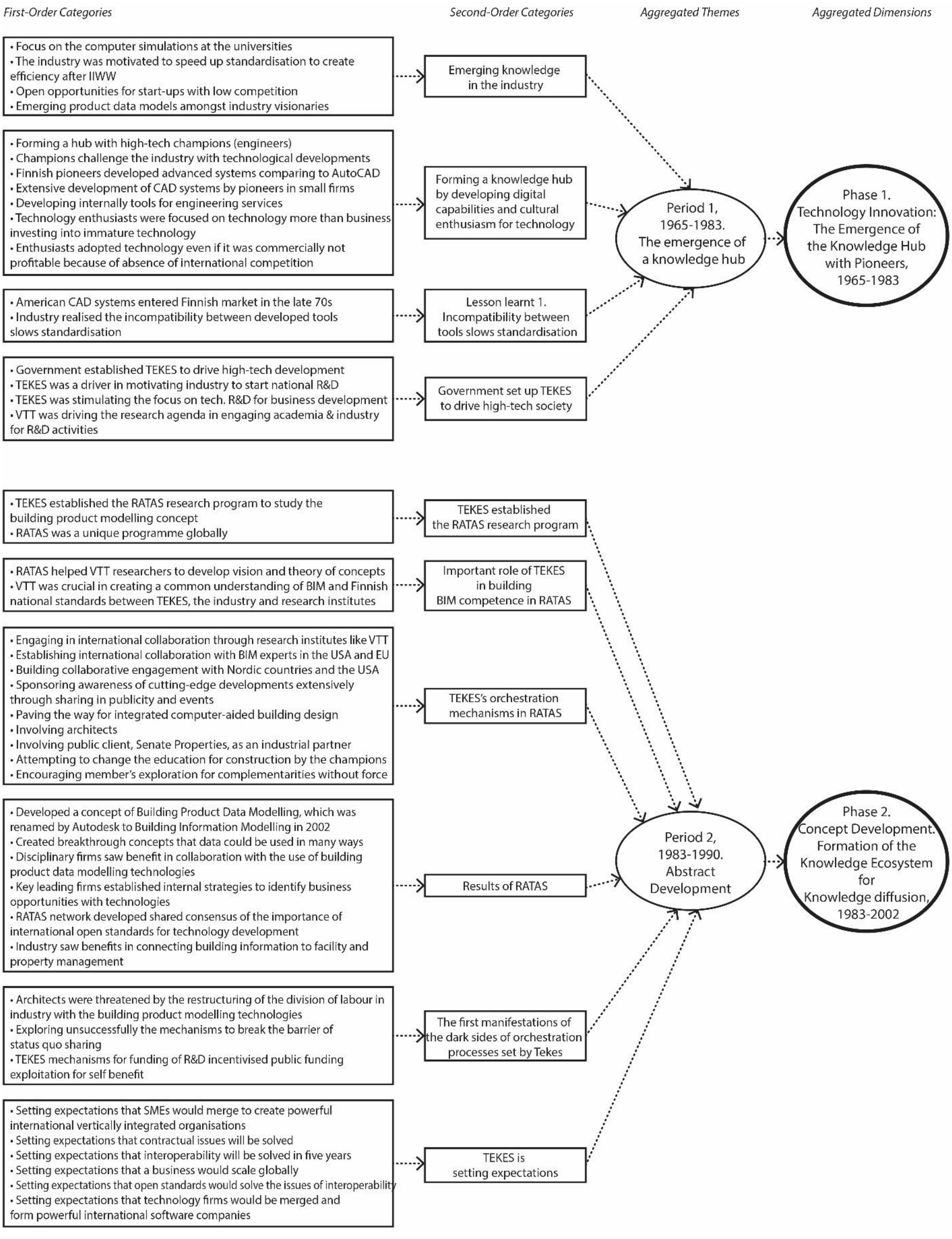

Figure 10 Data Structure

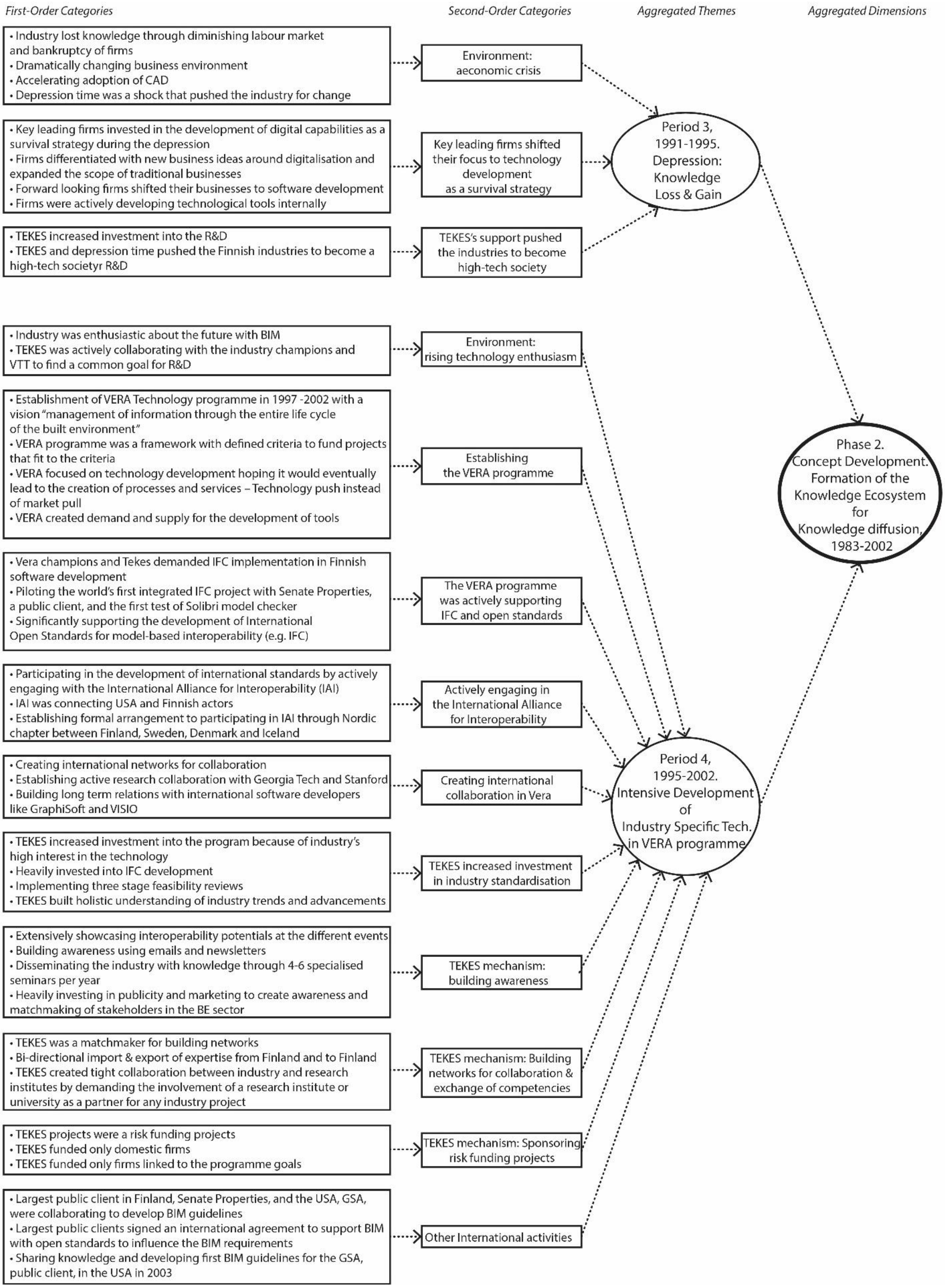

Figure 10 Data Structure Continued

Figure 10 Data Structure Continued

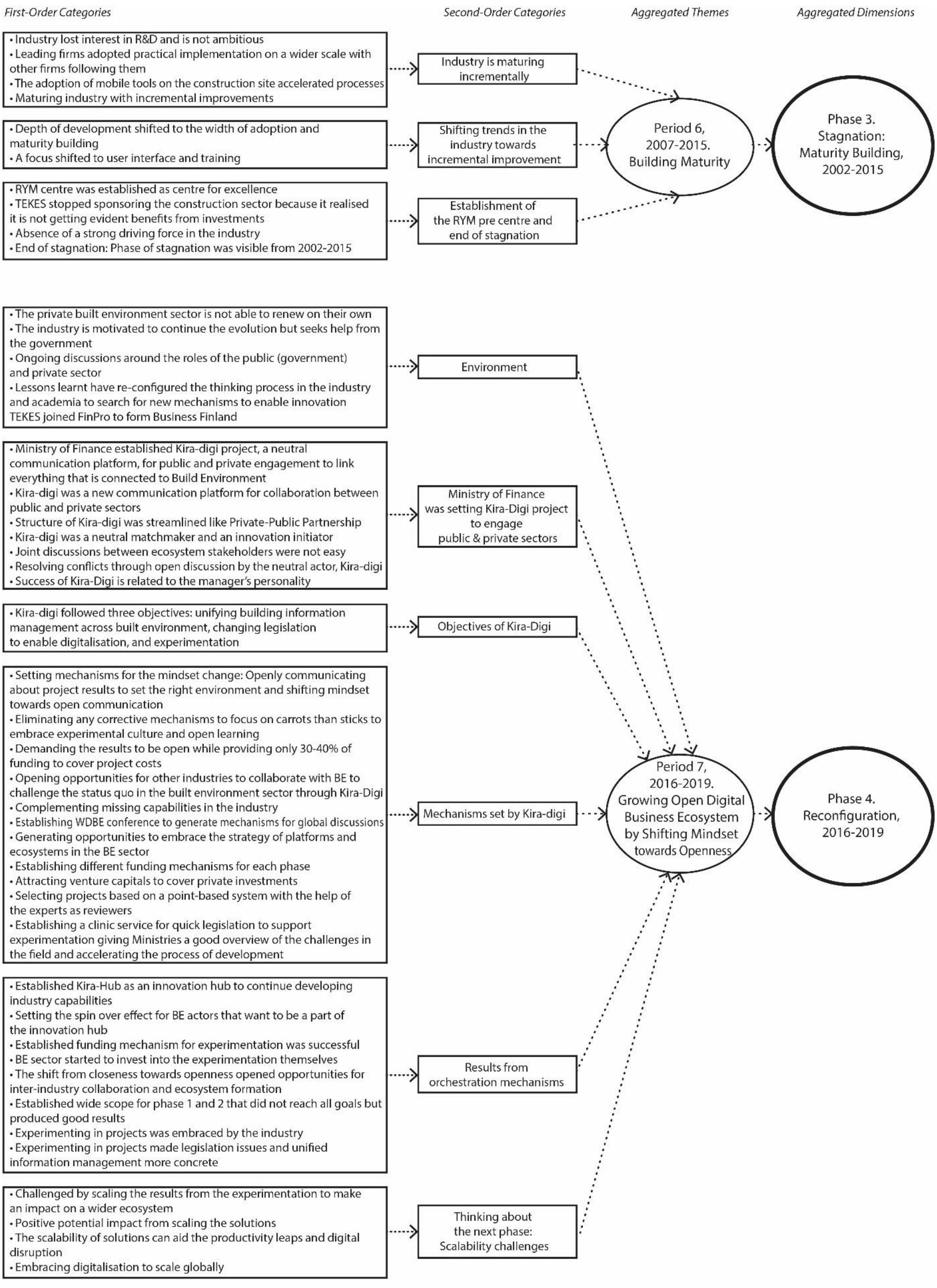

Figure 10 Data Structure Continued

Step 3: Building a grounded model. Finally, I identified the linkages between the aggregated dimensions in order to build a grounded model that explained how the national deployment of BIM was evolving. I not only induced categories but also generated interpretations of orchestration processes and effects, forming a story line between the second-order categories and aggregated themes. Then, I returned to the relevant literature and cycled between the data, the emerging findings and the theory to articulate this study's contributions to the dark side of ecosystem orchestration. The final work was sent for feedback to the manager at TEKES. The feedback helped to refine the focus of this chapter.

2.4 FINDINGS

2.4.1 Case Overview

The case study focused on the role of a public funder TEKES, the Finnish Funding Agency for Technology and Innovation, who supported the digitalisation of the design and construction industry in Finland. Through the TEKES programmes, "*Finland was the first country to adopt the national innovation system approach in its science and technology policy during the depression of the early 1990s"* (Haukka, 2005: p.15). TEKES played a major role in joining research and industry efforts to support R&D into BIM technology for the design and construction industry between 1982 and 2002[9] as well as many other sectors in Finland (Van Der Veen et al., 2012). TEKES has run many other technology programmes for different sectors with a wide-ranging project portfolio. It seeks to promote the competitiveness of Finnish industries and service sectors in the field of technological development. It prepares, funds and coordinates national technology programmes for technical research and high-risk R&D projects, and develops a national technology policy (Tuomaala et al., 2001). Already in the 1980s, TEKES has recognised the importance of

[9] Although, officially, SARA programme finished in 2007, TEKES role in leading the industry, technically, stopped in 2002

innovation in the Finnish design and construction industry as approximately 70% of the national wealth was invested within the real estate and construction cluster and linked to macro-economic development, and societal and demographic changes in Finland (Uusikylä et al., 2003). TEKES saw the potential in establishing several national programmes by linking technology to R&D in the design and construction sector. These programmes acted as platforms for value creation.

In this study, I followed the national R&D of BIM in TEKES technology programmes and its co-evolution from its genesis in 1982 with national efforts for BIM development by the Finnish design and construction industry, which concluded in 2002. Although SARA programme sponsored by TEKES continued until 2007, the involvement of TEKES in leading it has ended after 2002. Hence, this study takes a longitudinal view on the evolution of national efforts for ICT and BIM deployment in the design and construction industry. The analysis incorporates additional information on the RYM pre-programme that was run by the industry to support ICT deployment, and KIRA-digi run by the Ministry of Environment to support the emergence of digital business ecosystems in the built environment sector.

TEKES set exaggerated expectations for the self-renewal of the design and construction industry with emerging technologies, e.g. BIM. Indeed, Finland was the first country to invest in BIM technology R&D as no practical solutions existed in 1982. TEKES's expectations were that public investment combined with existing enthusiasm and technological competence amongst industry champions would lead to a global competitive advantage for Finnish design and construction firms (Uusikylä et al., 2003). National BIM R&D, and particularly the VERA programme, were recognised by TEKES international success stories (Froese, 2002; Haukka, 2005; Uusikylä et al., 2003).

The BIM technology programmes, supported by TEKES, were meant to create new technological know-how by linking research and implementation with cooperation from the industry, research institutes, e.g. VTT Technical Research Centre of Finland (VTT), and universities. In addition to publicly funded R&D, matchmaking and marketing the results, TEKES funded public risk capital projects by providing a seed and early stage capital to innovative start-ups and SMEs. Between 1982 and 2015, the total expenditure on BIM related research in Finland was approx. 80-90 M€ of which more than 50% was spent on the VERA programme (1997-2002). The composition of participants in the national programmes were assembled with a diverse set of private and public organisations including small, medium-size and large enterprises, research institutes, some universities and the largest public client in Finland, Senate Properties. The role of TEKES in the national deployment of BIM was strong as it shaped and conceptualised the content of the programmes with a focus on technology R&D (Uusikylä et al., 2003). As an open-system intermediary (Dutt et al., 2016; Giudici et al., 2018), it had an important role both in the distribution of public R&D funding and in bringing about cooperation between research and practice (Björk, 1994).

The national deployment of BIM in TEKES's programmes included national and international collaborations extending over 25 years and involving hundreds of organisations that piloted dozens of projects between the industry and VTT in the RATAS, VERA and SARA technology programmes. Despite its leading role in guiding the technology programmes, TEKES openly cooperated with industry champions and astutely listened to their advice. Empirical evidence shows that the orchestration process set by TEKES followed the role of an open-system orchestrator with a horizontal approach to cooperation with heterogeneous participants, as opposed to a closed-system approach. The champions had a strong voice in selecting the projects and in leading national deployment with the support of TEKES. However, the expected results did not follow quickly as the new global businesses did not emerge with the support of TEKES despite the initial aspirations. TEKES's interest in the design and construction industry waned between 2002 and 2007 as the exaggerated expectations were not achieved. National ICT deployment was a learning curve for everyone involved. The industry champions continued their negotiations with the government without the involvement of TEKES. The negotiations led to new initiatives by the Ministry of Finance and Ministry of Environment. The reconfiguration focused on a mindset shift and the development of necessary capabilities in the industry to support digital business development. It resulted in the establishment of the KIRA-digi project between 2016 and 2019. This reconfiguration brought about positive results as the new networked type of businesses that cross a variety of industries started to emerge across the Finnish built environment in 2018. Although there are changing dynamics within the built environment sector, further research is needed.

Next, the co-evolution of the design and construction industry with the technology programmes and beyond are presented in the next section.

2.4.2 Evolution of National BIM Deployment Between 1982 and 2002, and Beyond

The analysis of national ICT deployment by the design and construction industry passed four important phases of development: a logic from Abstract Development (theory development in RATAS programme in Periods 1-3), to Concrete Development (VERA programme for technological development in Period 4), to Practical Implementation (in the SARA and RYM PRE-programmes, Periods 5-6), and more recently the reconfiguration of orchestration processes by the KIRA-digi project to enable the growth of Open Digital Business Ecosystems (Period 7). **Figure 11** provides an overview of the key activities executed at the national level. For each phase of development, the periods present key events and national programmes and projects that occurred at that time.

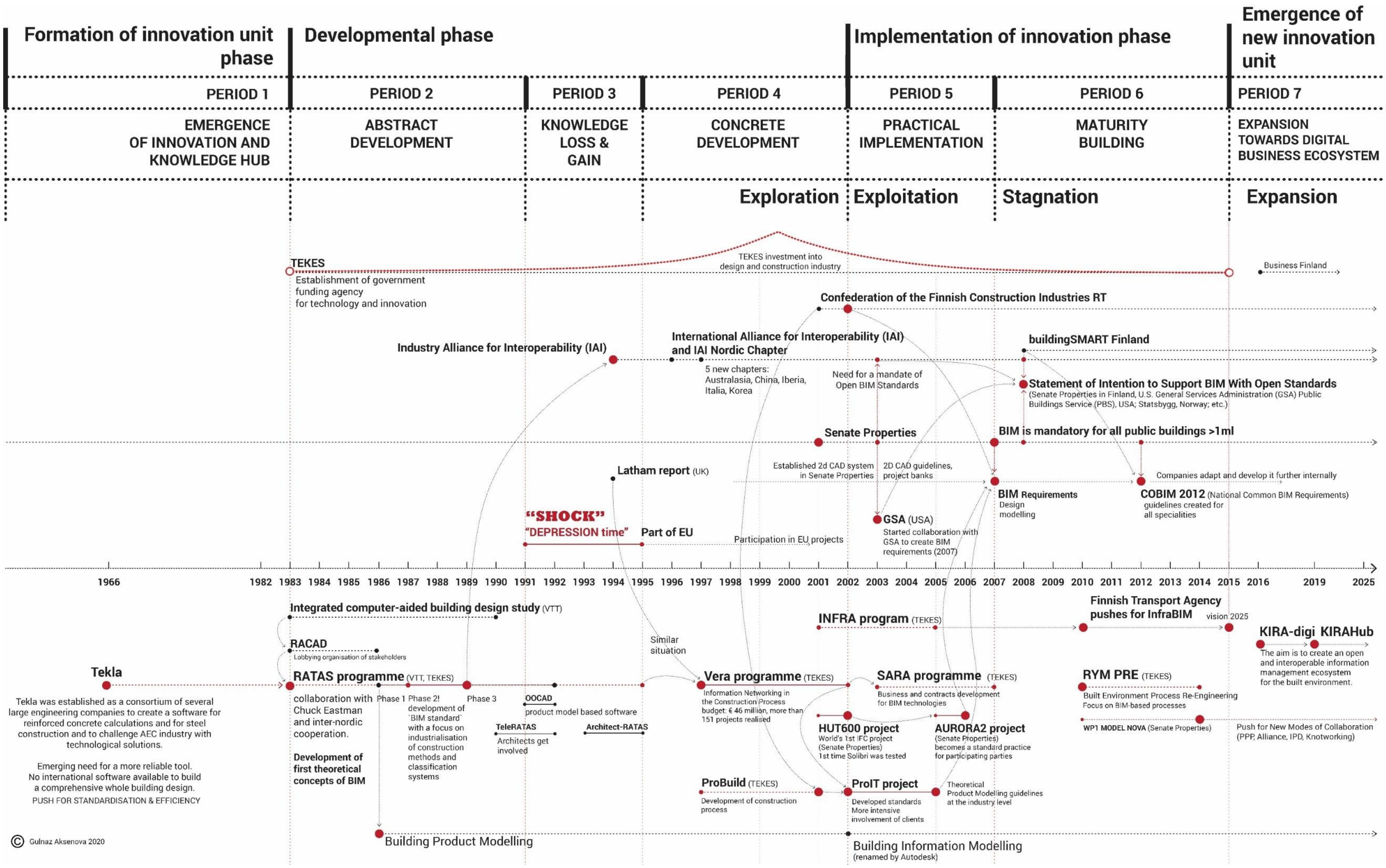

Figure 11 Outline of the Finnish Innovation Journey

The presentation follows a chronological order of the key incidents that occurred and facilitated an understanding of the co-evolution of national ICT deployment and the industry's digital practice.

Phase 1. The Emergence of the Knowledge Hub in the Industry, 1965-1983:

Phase 1 is characterised by the development of digital competence within digital design and construction in Finland. It accumulated the necessary capabilities and interests in the industry to form a fruitful ground for the next phases of national development. Phase 1 constitutes Period 1. Period 1 is characterised by the environment that supported an emergence of the knowledge unit that later participated in the national BIM programmes.

Period 1. The Emergence of a Knowledge Hub

Period 1 is characterised by the emerging knowledge hub in the industry that consisted of the technology champions. The establishment of Tekla in 1966 exemplified the knowledge hub that aimed "*to challenge the industry with new technological solutions*" (Researcher, FIN17). Tekla was a unique case that constituted an emerging interest in the technology and design within the construction industry.

In 1980s, Finnish universities were ill-equipped to provide physical laboratories for simulation while physical laboratories were common in other universities across the European Economic Community (EEC). Due to the lack of facilities, some students started to use computers for engineering simulations as early as the 1970s and the use of computers in universities became widespread in the 1980s. The focus on computer simulation at university led to the development of digital competences amongst engineering students. Graduating engineers had skills to develop software for their own use. It was a period of innovation, as researcher (FIN18) suggested:

> We did not have any laboratories, so, in order to do exercises. Instead of doing laboratory exercises and tests, we did computer simulations from the early on. I have done my first computer graphics program in 1968, which generated 3-D stereo images. I did everything with computers from the very beginning. […] We were getting better and better. Not, of course, all the time. […] At least some of us, I was one of them. […] Maybe before 1985 we had a period of innovation. New ideas, people with great ambitions, setting up new companies. That was a period of pioneers. (Researcher, FIN18)

Due to the low rate of market competition, the opportunities for software development by start-ups were open. Small scale software development flourished amongst engineers. Champions in the design and construction industry recognised the need for standardisation to create efficiency whilst rebuilding the country after the Second World War. Standardisation and efficiency were at the core of technological development even when technology was not commercially viable. As a result, the technology champions invested in immature technology. As they were involved in the same networks, these champions developed a shared understanding that the incompatibility between developed tools slowed standardisation and there was a need for more reliable technology to support the digital information exchange and management between disciplines. In 1982, this led to ongoing discussions on the need to standardise information and improve interoperability (Björk, 2009).

In 1982, the government established TEKES to drive technology development in the country, hoping that newly developed technological know-how would be captured in the industry to support business growth. The establishment of TEKES "*shows how much importance technology has been given in Finland*" (Researcher, FIN05), and as a result "*the discussions about the integration of IT applications in construction started in Finland in 1982*" (Björk, 2009: p.386). TEKES was recognised by this study's interviewees as the driving force for commencing national R&D, stimulating the focus on technology R&D for new businesses and facilitating research and industry networks. The interviewees of this study recognised that public funding was a major motivator in the design and construction industry to engage in technology R&D which otherwise would not have happened due to the industry's reluctance to invest in innovation (Uusikylä et al., 2003).

> Setting up of TEKES caused turmoil in Finland. […] There was a lot of money coming in because people have read in the newspaper that TEKES has a budget for that. It was brilliant. No one really knew what it is going to do, but the budget was X million FIN mark to support technology development in Finland. It was not totally new because previously [the] Ministry of Trade Industry did provide resource funding also for institutes. But TEKES was something more visible, so this first innovation type of enthusiasts, including people like myself and other guys, got very enthusiastic and started to see money in that. (Researcher, FIN18)

This was paradoxical as there was a network of champions investing their own time and resources in technology development due to their enthusiasm, while the industry-wide culture was risk-averse with low levels of investment in R&D:

> TEKES was providing funding for R&D, but they never fund anything 100%, so the companies must use also their own money or borrow it. As the R&D culture in the industry is very weak, very few companies used that possibility. (Researcher, FIN20)

The separation between a small group of interested enthusiasts for technology and the traditional industry was already visible in this period. This emerging technology knowledge hub in conjunction with establishment of TEKES led to the next development phase for the BIM concept at the national level.

Phase 2. Developmental Phase. Formation of the Knowledge Ecosystem, 1983-2002:

Phase 2 is constituted by the start of the national BIM R&D in TEKES's technology programmes. This resulted in the emergence of the knowledge ecosystem led by TEKES. It comprised Periods 2, 3 and 4 between 1983 and 2002.

Period 2, 1983-1990. Abstract Development.

Period 2 started with the establishment of the first national BIM project, named the RATAS-project. The RATAS-project was a theoretical exercise for thinking about the possibilities of *Building Product Modelling*, e.g. *Building Information Modelling* was called *Building Product Modelling* at that time. It aimed to resolve the problems of technological integration, thereby eliminating information incoherencies between various industry specialists. The RATAS-project was initiated as a construction Information Technology (IT) roadmap project in 1985 (Björk, 2009) and laid the foundation for the following phases:

> I think this was the main breakthrough period and everything else was building on this. I do not see major steps forward. It is thinking. […] It was more like specific concepts. So, it was more about clarification to everybody that you can use computers in an intelligent way not just [the] creation of drawings but to create data which you could use in different ways. (Researcher, FIN18)

TEKES actively collaborated with VTT experts in RATAS. VTT was crucial in creating a common understanding of the BIM and Finnish national standards between TEKES and the industry and research institutes. Many industry experts who participated in the RATAS-project were interested in adopting these concepts in their organisations. This willingness arose because of a widespread awareness of technology R&D in Finland, as researcher (FIN18) explains:

> Some people would present their developments for those who were able to follow up these developments. Even during [the] 80s, if you would go to any place in Finland, or consultancy organisation, they would know all the news about these technologies. This is quite exceptional comparing to other countries. So, 20 years ago a consulting engineer or architect would know in this country. They did not have a deep knowledge, but at least they knew something. And I can't think how it would have happened unless TEKES was showing some money. (Researcher, FIN18)

TEKES used the following mechanisms to orchestrate the national programmes and RATAS-project: (1) *built collaborative international engagement* through research institutes like VTT with BIM experts in the EU and the USA; (2) *sponsored technology development* in private & public networks; (3) *created awareness* of these developments through publicity and events, and (4) played the role of matchmaker *encouraging members' exploration* for complementarities and research & industry R&D; (4) *built a trust-rich environment and horizontal relationship* with the industry actors, and (5) *selected industry champions* to lead the national technology programmes, determine the *criteria* for the project selection and the *focus* of the technology programmes. It is important to note that industry champions had a strong voice in influencing TEKES's decisions although TEKES was the final decision maker.

With the help of TEKES, project participants of the RATAS-project created breakthrough concepts concerning the intelligent use of building data. The benefits of disciplinary collaboration underpinned with technology were recognised early. Already in the 1990s, RATAS project participants saw that the benefits of connecting building information to facility and property management could potentially be disruptive for established businesses. This led to a shared consensus of the importance of international open standards for technology deployment because "*the software market is international*" (Researcher, FIN20).

Although the RATAS-project did not fulfil participants' expectations (Björk, 1994), TEKES set great expectations that participating technology-oriented SMEs would eventually become powerful international software companies, as explained by researcher (FN18):

> I think, we were expecting that in the 80s, the small companies … were focusing on different subdomains of the construction industry, like heating and so on. They gradually would be merged and gradually become powerful international software companies. This has never happened which is quite amazing. […] It would be possible with the knowledge, which we have in this country, but that all these companies, which are software developers in the small market, some of them sell abroad, but they are not major players at the international market. (Researcher, FIN18)

The expectation of TEKES was that, with existing competences and public funding for national R&D for ICT, the design and construction sector would renew itself and become an international service and technology provider.

Period 3, 1991-1995. Depression: Knowledge Loss & Gain

Interviewees referred to Period 3 as a "*depression time*" that lasted between 1991 and 1995; this period represented a devastating crisis for the entire Finnish financial sector and hit the whole country. The design and construction industry was largely affected by this crisis, which saw the bankruptcies of several large construction companies. Some foreign companies took over Finnish companies (Laitinen, 1998). The labour market also diminished as the industry lost the expertise developed in the previous periods. All these led to the loss of knowledge and the need to re-develop lost industry expertise. However, this crisis also served as a shock to the industry, which accelerated the adoption of Computer-Aided Design (CAD) technologies. TEKES recognised that this period presented an opportunity for private firms to develop digital capabilities as "*the depression time was expected to end eventually*" (Researcher, FIN21). While the disappearance of firms and downsizing were common, TEKES increased investment in national R&D for ICT. As a result of TEKES's initiatives, Finland was the first country to implement a national innovation system in the early 1990s (Haukka, 2005). As suggested by the researcher (FIN20), the established national system "*was the best innovation system in the world. […] it worked very well. [While] the main survival strategy [of industry] in the early 1990s was to reduce activities and lay off people*". Some leading firms used TEKES funding to develop digital capabilities and engaged early in technology R&D. According to the interviewees, this was a crucial factor that enabled leading firms in the industry to become a high-tech community over the next periods. Period 3 generated a positive ground for the next period.

Period 4, 1995-2002. Intensive Development of Industry-Specific Technologies

Period 4 was characterised by the formation of a new knowledge hub with shared motives to realise the potential of the BIM concept and open standards. TEKES recognised the enthusiasm for technology in the industry. It started negotiations with industry champions and VTT to define common goals for serious R&D for BIM technology at the national level. These negotiations led to the establishment of the VERA programme with a vision of the "*Management of information through the entire life cycle of the built environment*"

(Kiviniemi, 2002)[10]. It is important to note that, although TEKES was orchestrating the VERA programme, it had a horizontal approach to ecosystem orchestration and the definition of common goals for all participants where a shared strategic cognition (de Mol, Khapova, & Elfring, 2015) is developed:

> There were really close relations, [a] network of some peers was close in sharing ideas and discussing things. It is difficult to put a border between TEKES and champions, because there were constant interactions between them, like business and friendship interactions. It was not so that TEKES was totally inventing the idea of VERA, but it was collaboration with the industry. We made a lot of interviews, we tried to find the common goal that the industry could agree about. So, it is not one side would be doing things, it was all sides were trying to find the common goal, it was heterogenous. It was TEKES, champions and VTT who also had a very strong role in that. (Researcher, FIN20)

TEKES heavily sponsored the VERA programme; the total budget for VERA was 46.7 M€ (22.2 M€ (47.5%) from TEKES and 24.5 M€ (52.5%) from the industry). Indeed, today's equivalent would be approximately 60 M€. VERA's aim was to develop technologies that were based on the theoretical concepts of the RATAS-project. The VERA programme was established as a framework to enable collaboration between industry & research institutes, as explained by researcher (FIN20):

> VERA's outcomes were projects. […] The whole concept of this technology programmes is complex and unique. It is like a framework and you are funding projects that fit to your overall goals. Programmes defined criteria. But all the proposals were coming from industry. […] Projects were directly related to IFC […]; the basic rule was, if it is an industry project, you must have a research institute or university as a partner. […] So, they were reinforcing each other. It was one of the main effects of TEKES funding, creating this tight collaboration between industry and research institutes. (Researcher, FIN20)

The VERA programme served as a platform for knowledge co-creation amongst complementors, the technology pioneer network, VTT experts and industry actors. TEKES actively supported activities run at VERA through the following mechanisms: (1) *built awareness through heavy investment into marketing* using emails, specialised seminars and newsletters and by extensively showcasing the interoperability potential at different events;

[10] The quote is from the official website of VERA programme http://cic.vtt.fi/vera.htm (accessed in 2018) is no longer available

(2) *built networks for collaboration and the exchange of competencies*, such as serving as a matchmaker between research and industry, between the import and export of expertise to and from Finland, and built all kind of networks for R&D; (3) *sponsored high risk projects* that were linked to the core goals of the programme; (4) *built a trust-rich environment and a horizontal relationship* with the industry actors; (5) *selected industry champions* to lead the national technology programmes, the *criteria* for project selection and the *focus* of the technology programmes.

Through project-based R&D, "*TEKES had a holistic understanding of what was happening in industry*" (Researcher, FIN21). TEKES managed to create a sustainable supply and demand for the development of technology in the design and construction industry:

> We were able to create demand and supply, basically hand in hand. One of the problems is, for example, if somebody makes a software product too early, there is no demand for that, there are no users. The company is dying because nobody is buying the product, because people do not really see the value of that. On the other hand, if people are interested but you do not have the tools, people very quickly give up, because they think that `this is a very good idea, but I cannot do it, because there is no practical way to do it`. And providing the balanced development of these two things was very crucial in the VERA program. (Researcher, FIN20)

The VERA Programme is recognised as the most successful technology programme in the construction cluster (Uusikylä et al., 2003) due to the wide-ranging technological support provided by key leading industry actors:

> A very positive aspect of the VERA-related work is the very widespread support for the idea that model-based interoperability is the way forward for the AEC/FM industry in Finland. […] many key industry leaders are among the strongest and most active supporters for the technology [IFC]. This degree of acceptance of the value proposition offered by the technology has been an important factor for success in the VERA programme. (Froese, 2002: 11)

Leadership of the VERA programme is recognised as an important driver in propagating technology change across the industry and the achievement of international success by BIM R&D (Froese, 2002). Following VERA's early success, TEKES doubled its budget due to the industry's interest in technology:

> When the Programme started in 1997 the planned total volume was expected to be 28 M euro, of which 12 M euro was planned to be funded by TEKES and the rest by the industry. However, the industry interest [in] the R&D projects on this area was so strong that the final budget increased during the Programme to almost 47 M euro, of which about 22 M euro was funded by TEKES. […] I do not know any other TEKES programs which were in such situation that the budget would increase so dramatically. (Researcher, FIN20).

It had a heavy focus on technology R&D and strong support for open standards and interoperability. The projects realised in TEKES technology programmes in VERA were mandated to support the Industry Foundation Classes (IFC). IFC is an open format for data exchange. The technologies and standards developed in the VERA programme led to the evolution of BIM technologies. The newly developed technological solutions were tested in pilot projects in the VERA programme. TEKES envisioned that IFC, as an open standard, would serve as a platform for information exchange by different disciplines in the industry. It hoped that, if open standards were offered to the industry, the industry actors would be able to create new business services and processes upon open platforms and eventually become a world leading service provider of BIM technology. VTT and TEKES strongly supported Finnish involvement in the development of international open standards in the International Alliance for Interoperability (IAI) (renamed buildingSMART in 2008) in 1996.

The VERA programme piloted the world’s first integrated IFC project, HUT-600. The project pioneered collaborative practice with newly developed BIM technologies between different disciplines including a public client, Senate Properties. They also performed the first test of the Solibri Model Checker, a start-up that is now one of the world leading BIM software (Fischer & Calvin, 2002).

In 1996, leading actors in the VERA programme established formal arrangements to participate in the International Alliance for Interoperability (IAI) through a Nordic Chapter between Finland, Sweden, Denmark and Norway for the development of international standards. This arrangement connected the global experts in BIM. However, the VERA programme members' engagement in the IAI was not easy; interviewees gave the impression that leading software vendors did not agree on the goals for open standards. For several years, the practical usability of IFCs suffered from insufficient implementation quality. The researcher (FIN18) explained the dynamics behind the lack of support for open standards by leading software vendors:

> There are some drivers against it; market-leading information technologies companies do not want their customers to change a system, because all of it for this work is locked into specific system, so you do not see these software companies like [software vendor 1] to be supporters of interoperability. This is natural, because they are the market leader. Why would they support standard when their system cannot be a standard?! If they would support the standard, they would lose clients. […] Actually, it makes the perfect business sense. You never seen market leader to support the standard in the industry sector. (Researcher, FIN18)

Overall, the VERA programme created the following positive results:

- Fostered and supported the "chicken and egg" cycle of creating demand for technology development;
- Contributed to the development of knowledge and expertise in technology;
- Created a positive technological environment for the development of new, globally competitive products;
- Finland gained an international reputation as a world leader in technology and left a positive impact on the progress of IAI's IFC;
- The confederation of Finnish construction industries adopted BIM as a part of the technology strategy in 2002;
- Finland achieved the widespread adoption of the product model concept as part of the AEC/FM industry's processes and strategy; large leading firms included BIM internally as part of business strategy;
- The VERA programme produced leading software, such as MagiCAD and Solibri, which were later sold to international software companies;
- Finland became the earliest adopter of BIM technology on a nationwide and global scale.

Despite its success, there were critical challenges that impacted industry-wide innovation with BIM. The dark side of national BIM deployment manifested in a disconnect between

R&D and implementation as “*there is too much invention and too little innovation in the construction industry*” (Researcher, FIN20). The interviewees pointed to a systemic disconnect between the needs of the researchers and the industry, as explained by researcher (FIN20):

> [A bridge between value creation with value capture] is the biggest challenge in any national system. For some people, making applications and getting research money is the main business. I can see it also at the EU level. **Loads of professionals are making money from R&D.** It is not always about results. If I am genuine, it is seldom about the results. It is true almost anywhere. Mostly, researchers are interested to get good results for publications, but they are not interested in helping companies to implement the results. […] It is almost impossible to start controlling that **the research money should be risk funding.** If you start measuring results and require all projects should get results, you are moving into a bad area. You have to accept that some projects do not get good results. **The problem is how to bridge the gap between the research and implementation. Because research is never creating innovation, or it is very seldom. It is usually business that is creating innovation**. (Researcher, FIN20)

On the other hand, some industry firms avoided taxes by subsidising R&D as researchers (FIN18, 20) explained:

> And I can’t think how it would have happened unless TEKES was showing some money. The money itself is not a key thing, but people would do anything to avoid paying some taxes or get some public funding. It is not really proportional to the money itself, but it has some kind of impact, but this legal support would get them far. You can see that people can avoid a lot of trouble paying these taxes. (Researcher, FIN18)

> TEKES was strict, they were not paying for pilot project or any project cost, they invested only in documentation of the results but still money given for R&D can lead to the situation that companies do it for the money and not for the results. […] Even though research funding is a partial funding, it is never 100% but I know that some companies are misusing the system again so they can be recording hours to do research project at the same time. Again, it is something difficult to prove because no one speaks about it. […] People would go far to avoid some taxes […] Taxing has nothing to do with TEKES, companies did tax reports, but it was an incentive. By putting money in TEKES project, I can reduce tax. (Researcher, FIN20)

TEKES had no effective mechanism to capture a collective body of knowledge by the industry (Froese, 2002). Unfocused project selections with loose connections to the programme’s objectives (Uusikylä et al., 2003) and limited cross-fertilisation between programmes and projects have proved to be a shortcoming of the TEKES mechanisms (Froese, 2002). Project identification mechanisms were informal and provided a great deal of flexibility for companies to define projects to fit their own business needs and opportunities without targeting specific work that was highly important strategically. These informal communication networks between the TEKES organisers and interested parties created a situation where participants were not aware of the overall objectives of the programmes (Froese, 2002). While not all participants configured themselves towards public funding, motivated champions piloted BIM projects and implemented BIM technologies, mainly intra-organisationally. BIM became part of a company strategy for productivity improvement. As a result, a small group of visionary champions distanced themselves by virtue of their traditional industry networks, as clearly indicated by researcher (FIN20):

> The development started from knowing each other and trusting each other and not so from friendships. In that sense, it was leading to this small group of people that are moving much faster than the industry and the gap was increasing. It can be a problem; you have small group of champions that support each other. It can also be dangerous […] when you have a group of enthusiasts, of course everyone wants to move as quickly as possible. People are not necessarily thinking or recognising risks. In that sense it is the dark side [of the inter-organisational relationships]. (Researcher, FIN20)

While a heavy focus on technology R&D in the VERA programme created positive results in connecting technology demand and supply, national BIM deployment was a technology push rather than a market pull. TEKES struggled to secure involvement from universities, insurance firms and private owners. Some champions struggled with the implementation of BIM because of a lack of support from their top management. Overall, following the success and challenges of the VERA programme, the industry entered a maturity building phase.

Phase 3. Maturity Building, 2002-2015:

Phase 3 is characterised by the industry's development of mature BIM practice, incremental improvement, the absence of a driver/vision and the visible stagnation of the design and construction industry that lasted between 2002 and 2015. This phase constituted Periods 5 and 6. The national deployment of ICT and BIM R&D supported by TEKES stopped between 2002 and 2007.

Period 5, 2002-2007. Practical Implementation. Failure of Business Models to Evolve

Period 5 signifies the practical implementation of BIM technologies under the old system and the failure of the SARA programme to generate new business, and contractual and procurement models to support this practical implementation. Although, national efforts for the digitalisation of the sector continued, the active role of TEKES in orchestrating and supporting national BIM R&D ended during the SARA programme.

As the international efforts to support international open standards continued, in early 2000, one of the leading software vendors was about to abandon their support for open standards; however, in 2006, they started to change their mind due to the mandate from major clients to support BIM with open standards – GSA's Spatial Program Validation (United States General Services Administration, 2006). It was an influential driver for the use of open standards. In 2008, to further resolve these tensions around interoperability, the GSA in the USA and Senate Properties in Finland were supported by other countries which signed an *International Statement of Intention to Support BIM with Open Standards* (Winstead, Jensen, Kohvakka, Lie, & Jagers, 2008). This aimed to influence the commitment of software vendors to open standards. Later, this agreement was supported by the largest public clients, which represented other countries in the EU and around the world. However, the software vendors never stated the extent to which they would support open standards. To date, the interoperability improvements have been rather modest (Howard & Björk, 2008).

Projects that started as part of the VERA programme continued after its completion. For example, in 2002 project ProIT (2001-2005) resulted in the adoption of BIM as a core element of the Confederation of Finnish Construction Industries. In 2006, the AURORA project (a continuation of HUT-600) had become standard BIM practice. After that an important development was the world's first industry level general BIM guidelines, which were published in 2007 and sponsored by Senate Properties. In 2007, BIM use became mandatory in all Senate Properties' projects above €1million, and in 2008, the Finnish forum in IAI was transformed into BuildingSMART Finland.

In 2003, TEKES established the SARA programme, which continued until 2007. Although the VERA programme generated recommendations for the SARA programme to focus on the change of business models and contractual relationships to support the adoption of BIM (Penttilä, 2005), the programme failed to meet these objectives:

> SARA wanted to continue development on business models, but I really do not think that SARA was successful [to] the same extent as VERA. […] The development in Finland was slowing down during SARA program. (Researcher, FIN20)

> I guess the driver in the early days was that we must improve the productivity of the industry. […] but the culture and the business processes have not been developed. (Consultant, FIN04).

Following the failures of the SARA programme, TEKES lost interest in the industry, as explained by innovation manager (FIN21):

> TEKES has been actually quite critical towards the Built Environment sector in Finland. They kind of have given a lot of resources for these different BIM-based projects and, at some point, they felt that there are not enough results coming from the given resources, so they lost hope in the construction industry. […] TEKES's focus was shifting more and more to global growth to support companies that have global visions. They did not see those kinds of players in BE. (Manager, Innovator, FIN21)

TEKES questioned the results from the national BIM deployment, as a manager from TEKES (FIN12) explained:

> But when you look at the history you have here, I don't think we are in position right now to say that we have been successful. I would say that we haven't been successful. […] We have been very powerful. There have been success stories, the use of BIM is growing but it has been very slow. We missed key companies who would run the business; it should be a way of work in everyday life in Finland, but it's not. After 30 years it's not. […] I would say that now only 5% of projects are done by BIM. […] What I am saying is that BIM is not a key area of the business at the moment. Thirty years of development, why is BIM not used as it was planned? I would say that the main drivers were idealists, people which believed in it, but really the business drivers, they were lacking. […] Where is the customer value? End-users? Scalability? It was 100% technology push instead of market push. (Manager, TEKES, FIN12)

In 2003, TEKES's technology programmes shifted their focus from specific fields of technology and industry towards a thematic approach for cluster-specific programmes (Uusikylä et al., 2003). However, competition was based on the same criteria ignoring the nature of the industries concerned, as explained by the researcher (FIN20):

> The system has been changing a lot many times. […] They did not think about different natures of the industry. Partly, I understand that because some of the results in the construction industry were not that encouraging. It was difficult to defend them inside TEKES. Partly, some big companies did it just because of TEKES's money. And they were never really implementing results in practices. And when you see it from TEKES's side, it is a waste of money. (Researcher, FIN20)

Consequently, the Finnish design and construction industry stopped evolving during the SARA programme. Its stagnation was visible between 2002 and 2015. Although the Finnish industry made technological changes within large individual firms, thereby improving productivity, the vision for the management of information through the entire lifecycle of a building (proposed by the champions during Periods 2-4) had only been partially realised. The conception of BIM's potential business value for clients remained unclear. Interviewees (FIN01, FIN02, FIN07, FIN08, FIN16) perceived that, at this stage, technology had reached its maturity and champions accelerating the maturity of developed practices had overcome the technical challenges.

Period 6, 2007-2015. Industry Stagnation

Period 6 is characterised by the industry's loss in R&D and a lack of significant results. Although the industry associations initiated RYM shock, these established the RYM PRE (Process Re-Engineering) programme in 2010 that continued until 2014. However, the programme management had no decision-making power.

During this period, leading companies in the industry matured BIM practices through incremental improvement following the AURORA project. Nevertheless, the focus on productivity improvement and technology R&D has not led to business development, as suggested by FIN04, 05, 08, 14 and 19. Throughout the history of national BIM deployment, new business models were not mentioned by interviewees as the industry continued to operate in a traditional way. However, the long-established incumbent, the leading building services company Granlund Oy, and a challenger, general contractor Fira Oy, have both become successful examples of Finnish companies developing service-dominant logic and client-centric business models based on BIM, even though the external environment did not support such developments. They are widely recognised exemplars of innovative firms in Finland.

The industry was not able to renew itself without the financial support provided by TEKES but was motivated to continue its digital development. The interviewees recognised that national BIM deployment was a learning curve and without a business model development, the industry could not achieve a qualitative digital transformation:

> It was a focus on technology. Businesses have not been a driver. Now we have to look at the business model and a change of business thinking. […] We have been the thought leaders in Finland, but it has been very private, and company driven. It is not anymore about technology; it is the question of innovation. (Manager, Public Agency, FIN14)

The industry actors called for organised innovation and support from the government to continue the industry's evolution:

> I see too little organized innovation taking place within the industry. Tools and information management have evolved profoundly over the last 10 to 15 years, but business processes have remained the same. That leaves doors wide open for outsiders to radically change the business. (Metsi, 2018)

> In Finland, the field is ready, because we started earlier […] We cannot go further if the government does not help us. We are now at a level that we cannot evolve anymore. (Manager, HVAC firm, FIN11).

Lessons learnt from national BIM deployment between 1982 and 2015 led to a shared understanding of the need to address business development. This understanding served as a foundation for the next phase.

Phase 4. A New Wave of Exploration, 2016-Present:

Phase 4 represents a new wave of experimentation with new orchestration mechanisms to enable digital business ecosystem emergence in the built environment sector. From 2016 to 2019, this was led by the Ministry of Finance and the Ministry of Environment in the new KIRA-digi project. This phase is built on a new understanding amongst industry actors and the government that the next phase of development must include support for capability development in the built environment sector to enable value capture by the sector.

Period 7, Reconfiguration: Emergence of Open Digital Business Ecosystem

Period 7 is characterised by a reconfiguration of the thought process in the industry to search for new mechanisms that enable innovation and business ecosystem emergence in the built environment sector. Since BIM practice is established in the industry, industry actors look for further evolution with the support of the government.

Following continuous discussions on the role of the government in stimulating the digitalisation between the government and the design and construction industry, in 2016 the Ministry of Finance established a "*neutral communication platform*" (Innovation Manager, FIN21), known as the KIRA-digi project. This was the public and private engagement streamlined as Public-Private Partnership (PPP). Led by the Ministry of Environment, it has employed new mediators to coordinate discussions between the Ministries of Finance and the Environment, cities, and various inter-industries, while "*The €16M programme's vision is to develop an open, interoperable information management ecosystem for the built environment*" (Törrönen, 2017). KIRA-digi facilitated open negotiations as a matchmaker between various stakeholders in the built environment sector. Previously, negotiations between institutional stakeholders were not easy due to conflicting goals and stakeholder interests. A neutral coordinator was expected to resolve any possible conflicts that arose. It followed three objectives: unifying building information management across the built environment, changing legislation to enable digitalisation, and experimenting in the built environment sector. A Clinic Service was established by the government to support experimentation projects through legislation, whilst also giving ministries a good overview of the challenges in the field and accelerating the process of development. KIRA-digi project acted as an effective open-system orchestrator.

KIRA-digi project had a different mechanism compared to TEKES. It extensively focused on shifting the mindset from siloes towards openness by demanding open communication about project results to set the right environment. It eliminated any corrective mechanisms "*to focus on carrots rather than sticks*" (Manager, Innovator, FIN21) in order to embrace experimental culture and open learning. The funding mechanism was similar to TEKES as it provided only 30-40% of the project costs but attracted venture capital to help start-ups. Matchmaking activities by KIRA-digi opened up opportunities for complementary industries to enter the built environment sector and challenge the status quo. It complemented the industry's missing capabilities by educating project participants with the necessary skills. For instance, it provided support for the development of marketing, business and communication skills. In 2018, the World Summit on the Digital Built Environment (WDBE) was established to attract global experts and to generate discussions around the opportunities to embrace the platforms and ecosystems in the built environment sector.

The mechanisms deployed by KIRA-digi produced a spin-off effect amongst participating firms, thus forming a community. Experimental projects produced new disruptive business models with a service-dominant logic (Lusch & Nambisan, 2015). According to the manager (FIN21), design and construction actors have started to invest into R&D by embracing experimentation. The manager (FIN21) further explained that a shift in mindset towards openness allowed for the emergence of new ecosystems with inter-industry collaboration for cutting-edge technology development.

Following the success of KIRA-digi and its completion in 2019, a KIRAHub was established to scale solutions created on a global level and to impact the developed business models on a wider ecosystem. Although the initial results are very promising, at this point it is too early to know what impacts KIRA-digi and KIRAHub will have on the Built Environment sector.

2.5 DISCUSSION

The analysis of the evolution of national ICT and BIM deployment orchestrated by TEKES have deepened the understanding of open-system orchestration and its effects on industry-wide innovation. Findings of this study point to similarities amongst TEKES's orchestration mechanisms with organisations, such as business incubators whose main purpose is to support the growth of new businesses. TEKES supported this growth *by financing the advancement of technological knowledge, disseminating R&D outcomes,* and *building collaborative engagement* (matchmaking) between universities, research institutes and industry, and by and *building trust-rich horizontal relationships* with industry champions who had a strong voice in co-leading the national technology programmes. These activities demonstrated that TEKES's role as an open-system orchestrator differed from the self-centred motives of closed-system orchestrators. However, TEKES's orchestration mechanism produced unintended effects that also indicated its closed-system nature. The case of TEKES enriches the description of open-system orchestrators provided by Giudici et al. (2018). The mechanisms set by TEKES closely adhered to open-system orchestration mechanisms, but empirical evidence highlighted a more mixed picture. TEKES does not fall exactly in the category of open or closed-system orchestration. TEKES's characteristics in relation to open and closed-system orchestration is depicted in **Table 8.**

Table 8 Closed-System Orchestration vs. Open-System Orchestration of Innovation Ecosystems (Adapted and Updated from Giudici et al. (2018: p.1371))

	Closed-system orchestration (Giudici et al., 2018: p.1371)	**TEKES orchestration in technology programmes**	**Open-system orchestration (Giudici et al., 2018: p.1371)**
Core reference	Dhanaraj and Parkhe (2006)	Tuomaala et al. (2001)	Dutt et al. (2016)
Orchestration orientation	Directed, self-interested	Pro-social, aiming at public good, support and matchmaking	Pro-social, other-oriented
Value creation and capture	Centralized coordination of innovation efforts, and negotiated distribution of the benefits of the collective output	Centralized coordination of innovation efforts and support of independent entrepreneurial efforts	Facilitation of decentralized and independent entrepreneurial efforts, with local appropriation of their benefits from members
Centre vs. periphery interaction	Harness (exploit) distributed resources and capabilities of network members along a centrally coordinated innovation effort	Provide shared resources and nurture capabilities of network members to support dispersed entrepreneurial efforts	Provide shared resources and nurture capabilities of network members to support dispersed entrepreneurial efforts
Members' admission	(Relatively more) restricted: selection based on network needs and member-specific evaluation	Semi-Open: Selection based on potential members meeting network-specific criteria with **partially** predefined criteria for selection of projects	(Relatively more) open: selection based on potential members meeting network-specific criteria
Members' engagement	Expected commitment to collective innovation efforts, typically enforced contractually	Voluntary ad hoc participation in network activities. Expected voluntary commitment to collective innovation efforts, **enforced contractually** with voluntary participation (The engagement was contractually required from the research institutes (VTT) and universities, but not from the private companies)	Voluntary ad hoc participation in network activities
Examples	*Hub firms* (Nambisan & Sawhney, 2011) *R&D consortia* (Sydow et al., 2012) *Government-sponsored industrial programs* (Levén et al., 2014; Paquin & Howard-Grenville, 2013)	*TEKES technology programmes* (RATAS, VERA, SARA) (Valtakari, Roininen., Riipinen., & Nyman., 2014)	*Incubators* (Dutt et al., 2016) *National and regional agencies* (McEvily & Zaheer, 1999; Sapsed et al., 2007), *SME associations* (Arıkan & Schilling, 2011; Lee, Lee, & Pennings, 2001)

TEKES's orchestration processes resulted in an effective knowledge ecosystem that failed to translate into new businesses in the design and construction industry. Despite the good intentions of the knowledge ecosystem's core hub, findings also revealed the dark side of inter-organisational relations (Oliveira & Lumineau, 2019).

The critical issue was that national BIM R&D involved a technology push rather than a market pull. These conditions contributed to the failure of qualitative digital business transformation in an industry that was heavily involved in the development of technological know-how.

What follows in this section is the articulation of findings into theoretical underpinnings. To highlight the contribution of this research, the findings are juxtaposed with current assumptions on the challenging role of open-system orchestrators in navigating knowledge ecosystems and supporting value capture in the industry. **Figure 12** and **Figure 13** present the orchestration models set by TEKES and KIRA-digi respectively. Next, a grounded model of open-system orchestration led by TEKES is discussed together with the implications for a theoretical understanding of open-system orchestration.

2.5.1 A Grounded Model of Open-System Orchestration

Open-system orchestration enhances the network's capacity to assess and use knowledge and resources by managing the network with a light touch (Giudici et al., 2018). Open-system orchestrators manage their ecosystems without assertive actions allowing participants to join based on free will (Dutt et al., 2016). The empirical evidence in this study suggests that, although the mechanisms deployed by the open-system orchestrator, TEKES, supported the creation of an effective knowledge ecosystem, the design and construction industry failed to capture value from the created knowledge. The expectation that participating SMEs would eventually become powerful international firms did not happen.

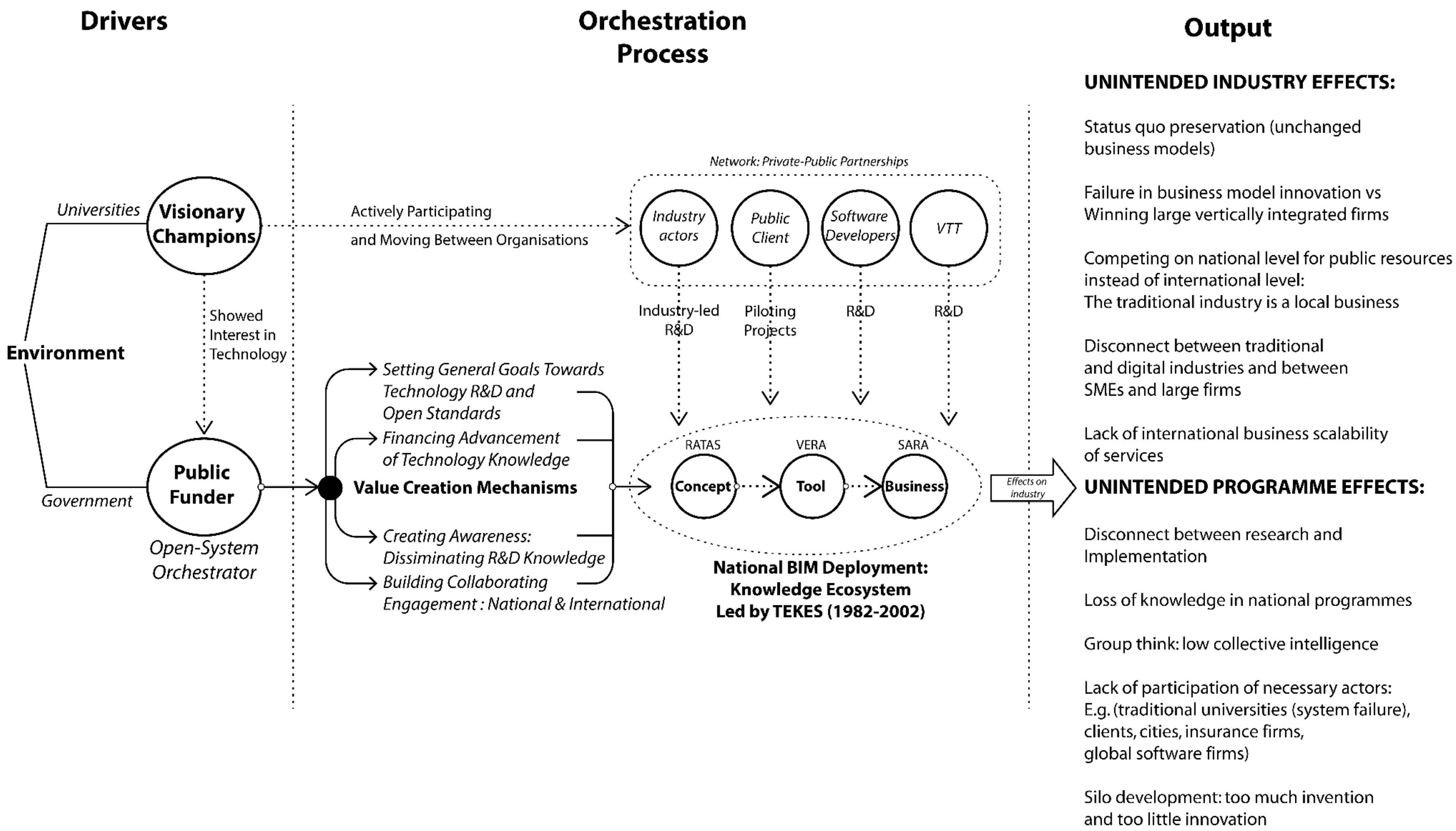

Figure 12 Grounded Model of Open-System Orchestration Set by Open-System Orchestrator, TEKES 1982 – 2007

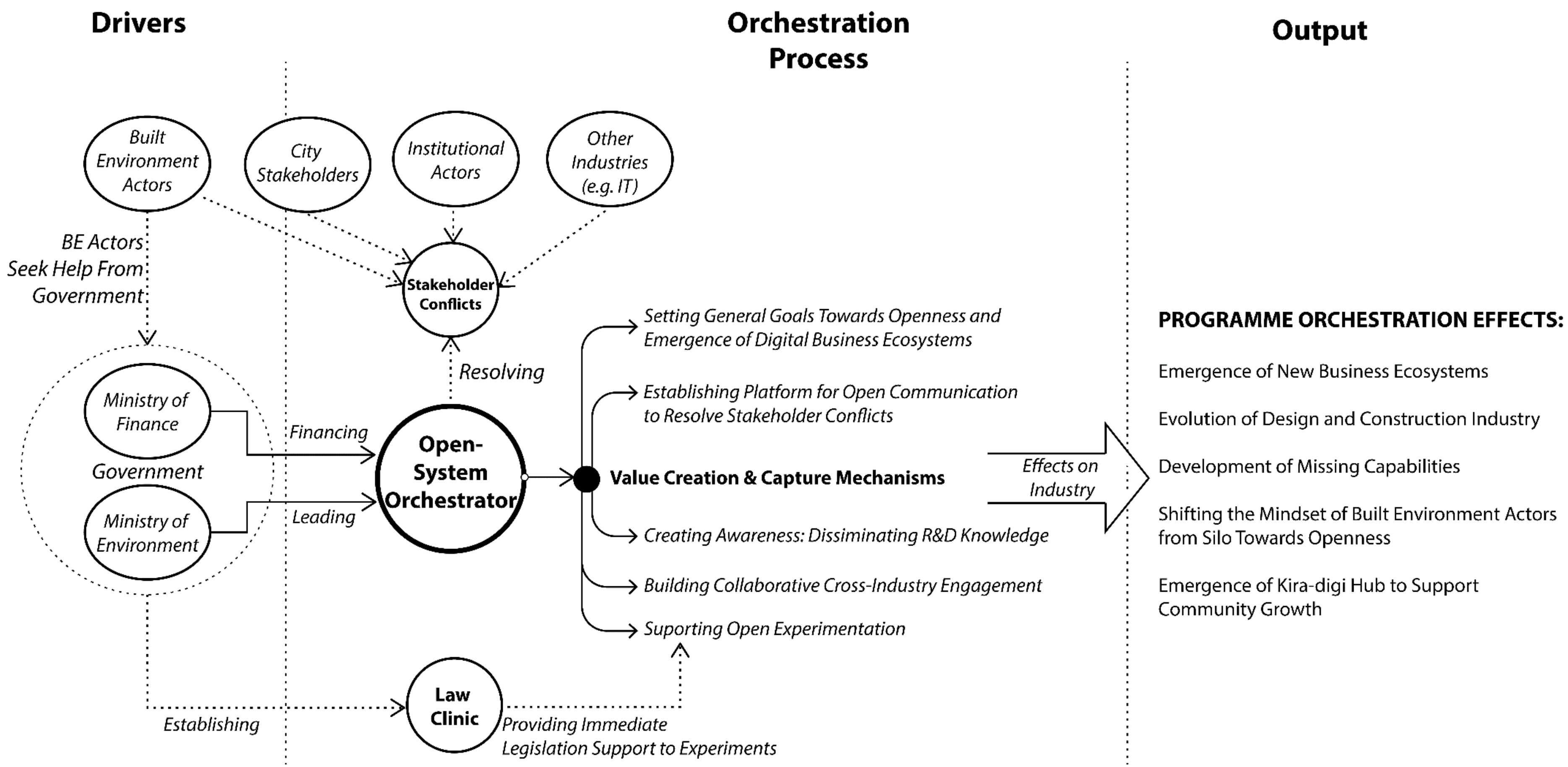

Figure 13 Grounded Model of Open-System Orchestration Set by Open-System Orchestrator, KIRA-digi 2016-2019

An evolutionary process of national BIM deployment that developed thought and understanding based on technology did not lead to the development of business models and digital transformation in the industry. Overall, TEKES relied on the goodwill of actors to capture value from their national technology programmes, thus constituting the dark side of the orchestration processes.

The dark side of open-system orchestration manifested in various ways and contributed to the failure to bridge value creation with value capture. First, researchers were preoccupied with the publication and not the implementation of results; second, some industry actors used public funding for self-benefit and not to implement results; third, some industry actors intentionally preserved the status quo as industry actors did not agree on the division of labour amongst emerging technologies; fourth, there were no incentives to attract necessary complementors, such as technology suppliers; at the international level, complementors, the software vendors, did not agree on the goals for open standards and data sharing; fifth, the results from R&D were often lost during the process as there was no effective means for knowledge capture; six, although the knowledge hub had good intentions, it largely operated in silos, generating biases and a reliance on the goodwill of actors; seven, national BIM deployment was a technology push instead of market pull; eight, the system failure, as academia did not have necessary competence and capabilities to become involved in the national technology programmes despite its crucial role in the development of the mindset. Finally, since TEKES started to support national industry-focused technology R&D very early, it did not have any mechanisms for start-up funding seeds or an aim for disruption; nor did it develop an understanding of venture capital. Only recently have such mechanisms became widespread. Business ecosystems were not considered at the time of these national technology programmes because the concept was not well established. Neither ecosystem thinking nor the know-how to orchestrate an ecosystem across the sector were considered.

Despite this, the empirical evidence derived in this research confirms the findings of Clarysse et al. (2014) that value creation in a knowledge ecosystem does not necessarily lead to value capture in the business ecosystem. Thus, open-system orchestrators should deploy additional mechanisms to connect value creation with value capture. The next section articulates a theoretical explanation of the dark side of orchestration processes set by TEKES in supporting the national technology programmes for BIM in the design and construction industry. The dark side contributed to the systemic disconnect between value creation and value capture in ecosystems.

Incentivising necessary complementors. The empirical evidence highlighted a paradox (Smith & Lewis, 2011) between the need for an open-system orchestrator to offer a light touch in support of value creation (exploration) and the concurrent need to incentivise ecosystem actors to exploit the created knowledge for value capture (exploitation). Ecosystem participants can fail to capture value if necessary complementors are not incentivised in value creation, whilst others do not recognise the opportunity in value capture. While the hub firm in a closed-system incentivises network participants to participate in a collective goal (Dhanaraj & Parkhe, 2006), the literature on open-system orchestration suggests that setting an incentive system to direct behaviour is less important than supporting the efforts of participants to search for their own business opportunities (Giudici et al., 2018).

Open-system orchestrators do not force the complementors to join the ecosystem unless they are willing to join it freely. Instead, this study's empirical evidence suggests that the participation of necessary complementors is necessary for value creation. For example, interviewees suggested that the participation of universities was critical in shifting the mindset of the whole built environment sector. However, universities were neither actively involved in the projects, nor were the developed technologies adopted as part of a university strategy (Froese, 2002). The critical issue concerning universities was the lack of technological competencies, such as professors in relevant fields or researchers specialising in technology R&D. As a result, academia was not able to bid for proposals and actively participate in national BIM R&D until the end of the VERA programme. TEKES was not able to influence the activities of the universities in Finland because of their independent roles and the threat that new knowledge could displace established competence in academia. Overall, TEKES did not have any specific mechanisms to incentivise participation amongst the necessary actors, e.g. universities, international software vendors, clients, city stakeholders and all the other necessary complementors in the built environment sector.

System exploitation. Theories on inter-organisational networks suggest that firms are willing to cooperate around value propositions and exploit the opportunities for combining complementary assets in order to stay ahead in rapidly developing technological fields (Iansiti & Levien, 2004c; Powell et al., 1996). It is assumed that ecosystem participants "*are self-motivated to pursue their own entrepreneurial opportunities* […] *in trust-rich contexts*" (Giudici et al., 2018: 1393). Instead, this study suggests that trust-rich contexts are important for exploration but the availability of resources to support exploration can result in the exploitation of the system for individual self-benefit under the established way of doing business. Both opportunistic behaviours by individuals and system exploitation manifested in several ways, which are discussed next.

First, in some cases, system exploitation took the form of researchers **using public funding for publications and not for the implementation of results**. The empirical evidence shows the dark side of the conflicting objectives of research-industry cooperation. The existing business models around public funding for R&D limit researchers' interests in implementing their results. What these insights highlight is that open-system orchestrators have to recognise the business incentives of ecosystem actors by setting mechanisms to ensure that the knowledge created is effectively relevant to, disseminated amongst and captured by the industry at an ecosystem, rather than individual, level. Indeed, established players relying on the strong ties with the orchestrator to obtain the resources were involved in incremental innovation. This network falls within a category of network evolution (Elfring & Hulsink, 2007).

Second, system exploitation amongst some **private firms means that public funding was sometimes used for self-benefit and not to implement results**. The study's findings showed that some individual firms used public funding and R&D opportunities for "*money and not for results*" (Researcher, FIN20), e.g. tax reduction schemes that were not directly related to national R&D. Some organisations aimed to use the funding for state tax reduction benefits and not for the implementation of results. To prevent this, TEKES invested into mitigation mechanisms against freeriding by setting a review board. This mechanism was limited in nature, as it did not address how the firms captured value from R&D. The mechanisms of public funding configured individual firms to rely on public funding instead of seeking business opportunities on a global scale (Spencer, Murtha, & Lenway, 2005). Consequently, ecosystem participants competed for public funding and not for value propositions. Public funding created false expectations amongst SMEs, as explained by the researcher (FIN20):

> Very often, when small firms first contacted the programme, they expected that they did not have [to] pay [a] salary. They thought that they could just estimate their salary and TEKES would pay half of that for SMEs, but they were told that, unless they pay that salary, they will not get money from TEKES. And, **you must pay first to be able to get funding** from TEKES. You will need to cover 100% of your salary and other costs before you will get funding from TEKES. **That was shooting down a lot of proposals. People had the wrong expectations**. (Researcher, FIN20)

TEKES typically sponsored only 40% of a project budget. Although it encouraged SME participation, it was mostly large organisations who were able to afford the match funding for R&D. This contributed to a disconnect between SMEs and large organisations concerning long term industry-wide innovation.

Third, system exploitation took the form of industry actors intentionally preserving the industry's status quo and established business models. The system exploitation happened at both industry and international levels.

At the industry level, the innovation network experienced two issues. The first issue was that BIM implementation would require a **restructure of the industry's division of labour and profit.** The business models represent a critical issue in the industry as they impact value capture from R&D and were a key issue in the RYM Shock programme. For example, the early discussions between architects and champions led to an understanding that the implementation of BIM should address the fee structure of designers. However, restructuring the industry's division of labour and profit would mean the restructure of institutional power relations. For example, architects traditionally lead projects institutionally. When BIM was proposed as an industry-wide innovation, architects were anxious about a power restructure in the industry, as explained by the researcher (FIN18):

> I participated under the confidentiality agreement for the strategic agreement with some architectural associations in the early 80s. They got anxious about their role with this technology: is it beneficial to them or is it dangerous, and so on! If there are any doubts of [the] benefits from this technology, companies usually do not do that, because they would rather stay in something they always done. It takes a lot of courage to change how the system works. (Researcher, FIN18)

Consequently, the industry actors could not agree on the division of labour. The preservation of established business models is therefore the dark side of the national BIM deployment, as explained by researcher (FIN20):

> Main thing that did not happen was changing business models and contractual models. VERA was creating processes and technologies and SARA was expanding business models. **So, these are the dark side of national development, that business models are unchanged**. […] Probably, it is more difficult to change businesses and contracts than changing technology as people see more risks in that and, if the clients do not see the benefits of having different contractual models, they are not willing to change their procurement methods to buy services. Unless you do it on a wider scale, you cannot prove the benefits. […] how to prove that something is useful if no one ever used that?! It is almost impossible! (Researcher, FIN20)

Another example is that general contractors and sub-contractors profit from established business models as they create money from existing inefficiencies within construction processes, as researcher (FIN20) noted:

> The dark side of [the] status quo is that the industry creates money from waste and some people do not want that to change. […] The culture of industry is another dark side. People are not motivated or do not have capabilities or desire to change. (Researcher, FIN20)

While some actors intentionally preserved established business models, built environment stakeholders struggled to find a BIM value propositions that would unite all ecosystem stakeholders, as indicated by the manager (FIN12):

> There are people which are very keen on BIM and sustainability. But how to put them together? It seems impossible! […] I do not know why the owners were not involved. All the participants in this value chain. It is natural. They look at their own businesses. So, what was developed here did not fit to the business model of the owners. There was mismatch. This is really a key question. (Manager, TEKES, FIN12)

The mechanisms set by TEKES did not take into consideration the existing business culture and business models of the industry. They extensively relied on the enthusiasm and goodwill of ecosystem participants. The intentional preservation of the status quo by ecosystem participants is the dark side of open-system orchestration. Even today, business models for the design and construction industry remain unchanged and thus constitute the dark side of the industry.

At an international level, TEKES supported the involvement of champions in IAI activities by promoting the development of open standards and interoperability between technology systems. Whereas the Finnish champions envisioned open modular structures with open interfaces to enable BIM practices, their desire coalesced with the established power of international software suppliers. There was an opportunity for software vendors, as complementors, to support the growth of inter-organisational practices by establishing a common open platform for interoperability. This meant that stakeholders could set the necessary international mechanisms to coordinate technical standards, e.g. IFC, and thereby enable effective processes and the reduction of uncertainty (Laakso and Kiviniemi, 2012). However, the study's evidence suggests that, due to a history of dominance and existing competitive dynamics in the software sector, these open standards were not fully implemented. There is limited evidence that open standards are supported by the leading software suppliers (Howard & Björk, 2008; Laakso & Kiviniemi, 2012). This evidence echoes the results presented in the work of Ozcan and Santos (2015). It shows that national open-system orchestrators have limited power at an international level to incentivise the necessary global complementors to participate.

Silos: The collective intelligence of social networks and network ties. TEKES had a horizontal relationship with the champions, who in turn had an active role in the decision-making processes. For example, TEKES and the industry champions collectively defined the goals of the national technology programmes for BIM R&D and the project selection criteria for funding. Programmes typically had steering groups consisting of key industry actors to strategically navigate the focus of technology programmes. The industry champions were invited to lead the programmes. Indeed, ecosystem orchestrators advised that, to allow network members to play important roles in innovation leverage, they should be included in decision-making processes, and the dynamic participation of network members should be facilitated (Nambisan & Sawhney, 2011). Small communities, however, are susceptible to biases and predisposed cognitive frames (Porac et al., 1989). These biases manifested in several ways.

First, while participating in the technology programmes, the network of champions developed digital capabilities much faster than the rest of the industry. The empirical evidence shows that the silo of this network led to an increasing gap from traditional industry. The literature on networks and competition suggests that this condition would offer a strategic competitive advantage for champions leading the industry to create new markets (Powell et al., 1996;

Santos & Eisenhardt, 2009). However, the empirical evidence suggests that a small group of champions fixated on technological development. Consequently, they distanced themselves from the traditional actors:

> I would say that **the main drivers were idealists** - people who believed in it, like [hidden] - but really the business drivers, they were lacking. This is my feeling at the moment […] They have done this together in different positions. Like me, I have been a very strong insider. (Manager, TEKES, FIN12)

> **People were interested in technology because of their personal interest**. It is, of course, true. Especially in Nordic countries like Finland. **People can get easily carried away** with the technology. (Researcher, FIN20)

The knowledge created in BIM R&D was mostly utilised by the champions (Froese, 2002). Although the mechanisms to disseminate the results in the VERA programme were effective to some extent, these mechanisms were not widely utilised across all programmes. In fact, mechanisms for knowledge capture, management and reuse represent a key issue for national technology programmes. The publication of the results was not demanded by TEKES and therefore reports were not published at all or published in Finnish. The marketing of activities and results is another key issue that would have positively contributed to the Finnish industry internationally. As a CEO of the software vendor firm indicated:

> I think we didn't make much noise out of it, sort of internationally. We did some but not very much. It was more like okay, let us just do that. (CEO, Software Vendor, FIN17)

The size of the country (Finland's population is 5.5 million) and local culture had created certain conditions where the network of champions was too tightly interlinked within the institutional structures, as explained by researcher (FIN18):

> We are a small country and I think Finland has a very critical size, and I have seen the same happening on many different occasions and different industry sectors. **In Finland, we always gather around like five people around the table like this and those five people would decide what is going to happen in the next 10 years.** This really happens. […] Here, it was always possible in many cases to find a consensus. […] I have seen this myself in the building sector, nuclear engineering, and mechanical engineering industry. […] This is one of the funny things in this country, people go around. So, once you get to know the full team, they may move to other jobs. But you still keep meeting them in different jobs for very long time. […] It is a small community always. (Researcher, FIN18)

The literature suggests that success arises when intermediaries primarily support - institutionally and commercially - business groups and family firms because of relational ties in place of contractual ties (Miller, Lee, Chang, & Le Breton-Miller, 2009). The strong ties were important for the emergence of the ecosystem network, but, perhaps, the entrepreneurs struggled to engage the weak ties to expand and create markets outside of Finland (Elfring & Hulsink, 2007). Instead, the empirical evidence in this paper suggests that relational ties in innovation networks can also lead to false perceptions and biases if the choices made by the innovation network core are grounded in what was perceived (by them only) as benefits or advantages derived from technological innovation. The members of an innovation network were entangled in common beliefs and passions for technologies in a trust-rich environment with available resources, digital competencies and support by the orchestrator.

The interviewees suggested that the built environment sector was a closed community, although one informant reported that it is opening nowadays. The afore-mentioned conditions defined competitive and cooperative relationships allowing the ecosystem actors to adopt technologies due to their technological enthusiasm and not because of the need to compete at an international level:

> This is a small country, we are not afraid of international competition, **it is possible to adopt technology enthusiasm even if it is commercially not profitable in the short term**. […] But this technological enthusiasm can be dangerous. […] If you invest in the technology, which is not yet mature, you might suffer from competition. […] **In the 80s, we had a number of big brave software companies in a very small market like Finland.** I assume if people had a little bit more sense, they would not have established these companies for such a small market. They were more interested in IT rather than business. (Researcher, FIN18)

The literature suggests that ecosystems emerge from the interactions between multiple heterogenous organisations that create new structures for value propositions (Jacobides et al., 2018; Jacobides et al., 2006). Instead, the findings in this research further suggest that ecosystems do not necessarily emerge in some conditions. The study illuminated that open-system orchestration is a complex issue and its success depends on many reasons, such as the consideration of business drivers for technology, the industry context (division of labour, capabilities, business model, culture and nature) and the capacity to capture value. In such contexts as the design and construction industry, open-system orchestration can be a challenging task to bridge value creation with value capture.

2.5.2 Implications of the Dark Side of Open-System Orchestration

The current theory on open-system orchestration emphasises the important role of open-system orchestrators on the development of institutions by "*building loosely coupled communities of actors, rather than designing and enforcing a set of contractual relationships*" (Giudici et al., 2018:p.1395) and helping firms to create their own "*entrepreneurial identity*" (Navis Glynn 2011). Yet, it has a positive angle in promising to aid the development of a firm's capabilities, which would lead to the emergence of new markets. Instead, the findings presented in this research show that open-system orchestration can create a positive influence on innovation exploration but can fail to yield conclusive evidence of the promised benefits of value capture and exploration. In other words, the current theory of open-system orchestration provides processes to support value creation but is ill-suited to explain how value is captured by ecosystem participants.

The empirical findings illuminated the dark side of open-system orchestration. The manifestations of the dark side observed in this study aligned with the propositions by Oliveira and Lumineau (2019). First, the dark side manifested in the mechanisms for public funding that incentivised new members to configure to public funding expectations, thus generating system exploitation. This allowed for opportunistic behaviours amongst some of the participants. However, these incentives coalesced with the notion that the traditional design and construction industry is always local. Second, the dark side manifested in the disagreements related to the division of labour and market share both at the industry and international technology supplier levels. The “*powerful players from different industries have difficulty in reaching agreement on the new market’s architecture due to their history of dominance in their respective industries*” (Ozcan & Santos, 2015: p.1986). Third, the dark side manifested in the business culture that exists in the context of the built environment. Individuals intentionally preserved the status quo because of industry-rooted practices that drive potential opportunism amongst industry participants (Gu, Kim, Tse, & Wang, 2010; Poppo, Zhou, & Zenger, 2008). Indeed, it is widely known that managers of construction projects exhibit opportunistic behaviours, thereby damaging innovation practice (Korczynski, 1996). The failure of business networks to emerge can be attributed to competitive dynamics, which are oriented towards the exploitation of established business models with little incentive for cooperation for business model innovation. The opportunities provided in knowledge ecosystems will not necessary be used to search for new business opportunities. Open-system orchestrators are advised to consider the development of missing capabilities and mindset shifts by ecosystem participants and offer effective mechanisms for knowledge capture, management, and reuse.

However, the fourth manifestation derived in this research contributes a new understanding of the dark side of inter-organisational relations. While the dark side is typically associated with opportunistic behaviours and ill-suited intentions (Bizzi, 2013; Oliveira & Lumineau, 2019; Poppo et al., 2008), the findings show that the good intentions of an open-system orchestrator and its ecosystem can manifest the dark side. While the commitment, trust and engagement of ecosystem participants were present, the silos of the core hub can manifest in biased decisions even if the network of champions extensively cooperate or is open for cooperation in a not-for-profit way. The trust of an on-going team has a direct impact on the motivation and performance of champions (Elfring & Hulsink, 2007). A desire to aid the common good by fixating on technological development due to cultural enthusiasm and heterogenous horizontal interactions between the orchestrator and network members can also limit the innovative potential of ecosystems. This can also clash with the conflicting goals of complementary actors. The results of the dark side of open-system orchestration highlighted the need for strategies to tackle the collective intelligence of ecosystem participants.

The finding draws attention to the role of the open-system orchestrator in guiding value creation. The role of the orchestrator in only requiring R&D for technology development but not imposing what technology should be created, could be usefully coupled with the development of dynamic capabilities and mindset shifts for openness. Collaborative learning and engagement can generate positive outcomes (Berkes, 2009), but without knowledge management mechanisms these activities can be fruitless in terms of the value capture by ecosystem members. Furthermore, open-system orchestrators are encouraged to have a "*subtler role, by helping members clarify their understanding of own goals and distinctive resources*" (Giudici et al., 2018: p.1395). In the design and construction sector, actors are more likely to preserve the status quo and individual value capture which can limit the potential value creation for industry-wide innovation overall. As such, it can naturally lead to vicious cycles in the industry when ecosystem members search for the benefits from their own established ways of conducting business. This finding indicates that the open-system orchestration mechanisms proposed by Giudici et al. (2018) are well suited for individual entrepreneurs and not for established industry actors. Thus, this chapter contributed, to some extent, to the call made by Giudici et al. (2018: p.1398) *"future research may also extend our efforts to examine the implications of open-system orchestration on the design of new business models (e.g., Baden-Fuller & Haefliger, 2013)".*

Finally, the case of national BIM deployment in Finland between 1982 and 2018 resonates with the case of Scottish knitwear, which also suffered from maturity and cognitive biases (Porac et al., 1989; Porac, Thomas, & Baden-Fuller, 2011). Thus, cognitive consensus (Ng, Westgren, & Sonka, 2009) across the managerial level may be an exception (Porac et al., 2011) that makes the Finnish design and construction industry case and the Scottish knitwear case interesting.

2.5.3 Limitations and Suggestions for Future Research

No study is without its limitations, and the efforts to analyse national BIM deployment in Finland is no exception. Several limitations were identified within the study that could offer future areas of research.

Timing. The data collected in Finland in 2015 was followed by five follow-up interviews between 2016 and 2019. When the researcher entered the field, 2015 was a difficult time for the industry in Finland. This was the end of the stagnation period when champions were exhausted from a long and intensive journey towards digital innovation in the construction industry. The collected interviews were more negative than positive as expectations had not been met and industry champions were questioning the history of national BIM deployment. Although this paper presents the dark side of open-system orchestration, there were multiple positive effects created by TEKES, such as the development of a theoretical and technical basis that constituted modern BIM technologies, which consequently led to higher quality design and construction processes in Finland, in-depth technological competence amongst the champions and the early adoption of BIM in Finland on a global scale. Finland is a profound example for other countries that are going through BIM deployment on a national scale.

A limitation of the data collection is that the data was not collected extensively about RYM shock, which was initiated by industry associations and data analysis from the KIRA-digi project, rests on the two interviews conducted with the same manager over the course of three years. The KIRA-digi participants were not interviewed which offers an opportunity for future research. Therefore, future research could revisit the outcomes of KIRA-digi and the following initiatives to complete the industry evolution and study the effects of KIRA-digi mechanisms on the emergence of business ecosystems. Furthermore, other programmes were included in the analysis. As most data was published in Finnish or not published online at all, this created a challenge in deriving more in-depth analysis.

Single case. National BIM deployment in Finland is a unique case as there are no globally documented cases that focus on the renewal of the design and construction industry in national innovation systems. While this study articulated the role of TEKES as an orchestrator and its national ICT technology programmes as a knowledge ecosystem, when it was established, TEKES did not consider an ecosystem and saw its role as a public funder for technology R&D. The business ecosystems only recently caught the interest of the government. This study considers the evolution of thinking about ecosystems and its importance for sectors. Future research could usefully explore the implications of open-system orchestration on business model innovation in the sectors, which go beyond individual entrepreneurs towards sector-wide innovation. The renewal of mature industries with open-system orchestration mechanisms could be a challenging and interesting topic. The national mandate and efforts made by the UK since 2016 (HM Government, 2015) on the orchestration processes set by the government would be a good case to follow in future research.

Orchestration mechanisms. Several conceptual questions remain open for future studies. First, additional research is needed on the orchestration mechanisms that bridge the disconnect between knowledge and business ecosystems. Future research could explore the nourishing mechanisms for business ecosystem orchestration from a policy maker's perspective (Rinkinen & Harmaakorpi, 2018) and an ecosystem member's perspective. Second, the orchestration mechanisms are set to renew mature industries, as opposed to industries operating in constantly changing environments; this could expand the existing literature on ecosystem orchestration. The implication is that innovating firms can be constrained by cognitive and institutional biases that create impediments for self-renewal; however, they can also be constrained by the international power relations of complementors and the industry context. Third, the concept of context in ecosystem literature can provide new insights in grounding relevant mechanisms for the purposes that orchestrators aim to achieve. Finally, this research identifies an emerging field that can be usefully researched in the future, namely the dark side of open-system ecosystem orchestration.

2.6 CONCLUSION

This chapter examined the role of open-system orchestrators in enabling industry-wide innovation with ICT R&D (e.g. BIM technologies). Based on a case study in Finland, the role of open-system orchestrators is similar to intermediary organisations, like business incubators and matchmakers. Despite similarities in the orchestration mechanisms, the role of the open-system orchestrator in this research was also inclined to a closed-system approach. The insights highlighted the difficult role of the public organisation as an open-system orchestrator in bridging the disconnect between value creation and value capture and incentivising the participation of necessary complementors. A government organisation can have limited power to direct and incentivise the necessary behaviours and be challenged by following the approach of an open-system orchestrator. It is possible that combining the mechanisms from open and closed-system types of orchestration (e.g. Dyer and Nobeoka (2000)) can potentially bridge value creation and capture, but such orchestrators might still have limited power at the international level.

Whereas open-system orchestration is expected to create a positive environment for the organisation to capture value for the development of networks, the findings also suggest that the orchestration processes can incentivise organisations to exploit the system for individual value capture favouring silos and opportunism. This failure constitutes the dark side of open-system orchestration. The dark side of open-system orchestration can also pose challenges related to the good intentions of actors leading to the failure of value capture and industry-wide innovation. Ecosystem participants can fail to capture value from the technology push. A stronger consideration of industry context, capabilities and business model innovation is necessary for value capture. Assuming that the role of the open-system orchestrator is critical for the emergence of new business networks, empirical evidence shows that contextual conditions can contribute to a disconnect between value creation and value capture. An open-system orchestrator can fail to assess the industry's capabilities while setting exaggerated expectations. This work has set a new scene to investigate the dark side of open-system orchestration in ecosystem research.

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CHAPTER 3

Chapter 3. CLOSED-SYSTEM ORCHESTRATION: THE DARK SIDE OF ORCHESTRATING BUSINESS ECOSYSTEMS FOR INDUSTRY PLATFORMS

ABSTRACT

Research on business ecosystem orchestration has been the subject of increased scholarly interest. Successful examples of business ecosystem orchestration have resulted in extensive research on the role of central hub firms and their success stories in value capture; this forms a selection bias. In this chapter, I examine the under-theorized failure of a hub firm in orchestrating a business ecosystem in the digital built environment sector operating in northern California. The analysis reveals that the orchestration processes, with the use of the marketing power set by the hub firm, negatively affected sector-wide innovation with Building Information Management. Promising directions for future research on the corrective mechanisms and the dark side of ecosystem orchestration are discussed.

KEYWORDS

Business ecosystem, platform, orchestration mechanisms, the dark side, BIM

3.1 INTRODUCTION

The nascent literature on ecosystem orchestration, an emerging stream, has focused on hub-based models where a dominant hub firm successfully leads a business ecosystem to bring an innovation to the market (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011). The success of business ecosystems is often achieved with *"network effects"* (Katz & Shapiro, 1985), which are created by hub firms on top of the platforms they own. Network effects can magnify advantages to the platform owner because the value to customers on one side of the platform increases with the number of participating complementors on the other side thus creating a mutual benefit for everyone in the business ecosystem (Gawer & Cusumano, 2014; Iansiti & Levien, 2004c; Jacobides et al., 2018). Typical success examples are Facebook, Uber and Google.

While there is a growing understanding of how these hub firms successfully orchestrate their business ecosystems (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011), scholars may have overlooked several related critical issues. First, scholars extensively focus on the successful examples of long-lived business ecosystems. The focus tends to be "*lopsided […] and directed at "the few*" (Jacobides et al., 2019), thus creating "*a selection bias*" (Aldrich & Fiol, 1994: p.665). This study recognises the need for empirical research to strengthen the emerging stream of failed ecosystems (Jacobides et al., 2016; Ozcan & Santos, 2015; Tee & Gawer, 2009). Second, current debates on inter-organisational networks further emphasise the dark side of inter-organisational relations (Oliveira & Lumineau, 2019), which is a nascent stream within ecosystem literature. Third, the orchestration mechanisms described in the literature (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011) derive from the Business-to-Customer (B2C) contexts of successful examples, while the orchestration processes in Business-to-Business (B2B) contexts remain underexplored (Aarikka-Stenroos

& Ritala, 2017). An open question remains as to the extent to which the theories of business ecosystem orchestration developed in B2C contexts can be applied to B2B contexts.

To address these shortcomings, this study presents empirical evidence of orchestration processes set by a global incumbent software vendor. The software vendor successfully orchestrates business ecosystems for individual value capture but fails to orchestrate value creation and capture by customers in a Business-to-Business (B2B) context. The software vendor particularly fails to play a key role in ensuring an equitable value distribution and mitigating value appropriability by B2B customers (Dhanaraj & Parkhe, 2006). Thus, the orchestrated ecosystem is a case of "*ego-system*" (Jacobides et al., 2019). A specific context for the study of orchestration processes set by the software vendor involves the implementation of Building Information Management (BIM)-related technology innovation (Eastman et al., 2011; Sacks et al., 2018) in the Digital Built Environment (DBE) sector in northern California. The software vendor runs Software as a Service (SaaS) business model in a B2B context. It offers a platform that incorporates various proprietary software, including BIM software, to support design and construction practices to business owners, and design and construction service providers in the DBE sector. Thus, it owns a platform but also orchestrates a business ecosystem around its platform to increase its membership.

The literature on ecosystem orchestration assumes that opportunistic and joint benefits from the use of platform technologies will open up new business opportunities. By tapping into business ecosystem formation, ecosystem participants are expected to shape opportunities and gain benefits through joint sensemaking (Nambisan et al., 2017). The case presented in this study clearly indicates a limitation of the theory as the opportunistic behaviour by the software vendor offers inadequate opportunities for value capture by the complementors, particularly by B2B customers.

It looks as if this orchestrator is different from the successful examples of Google and Intel. Successful orchestrators are effective at individual value capture while also offer mechanisms for value capture by complementors and consumers. For example, Intel was researched as a case by Gawer and Cusumano (2014); it was initially a component maker but became an architect that changed the computer sector from a fragmented siloed environment to a modular ecosystem. This opened up the ecosystem to enable the creation of innovation by complementors and prompted the evolution of the sector. Google offers an open platform by first focusing on engagement, which drives value creation to achieve a critical mass amongst the platform membership. Then, it uses network effects to drive a distributed monetization model. For example, Google allows complementors to use third party tools to create apps that connect through APIs to an Android platform while also accepting most of the apps (Greene & Shilton, 2018).

Instead, it seems that the software vendor offers a platform with limitations while indirectly but effectively enforcing the customer's adoption of the platform through marketing power. Indeed, the orchestrators influence the formation of the ecosystem through their recruitment strategies (Kenis & Knoke, 2002). The software vendor uses marketing strategies to recruit customers and increase the membership size in order to maintain its power and status as a dominant software provider in California and around the world. The use of marketing strategies has a disproportional negative effect on the value capture by customers in the DBE sector. It contributes to a restructure of the division of labour by serving those who already have power and resources. It therefore favours large, vertically integrated firms whilst limiting the potential emergence of ecosystems in the sector. Consequently, its strategies reinforce the status quo feedback loops in the sector. It defines value propositions for the use of BIM in the sector, thus limiting the sector's innovative potential. It sets exaggerated expectations amongst the sector's clients, which inhibits the development of trust between the sector's clients and B2B customer, and the service providers. The platform offered does not act as a platform and has limitations in connecting design to construction practices. This evidence constitutes the dark side of ecosystem orchestration by a closed-system orchestrator (Oliveira & Lumineau, 2019). Consequently, the orchestrator follows an uneasy transition from a vertically integrated firm to a platform-based business ecosystem. As such, the business ecosystem orchestration context can potentially influence what, how and by whom value is created and captured.

By examining the case of business ecosystem orchestration by a software vendor and its impact on the value capture by complementors and customers, this study develops a theoretical understanding of the orchestration mechanisms set in B2B contexts while describing the contextual nature of such processes. To arrive at a theoretical understanding, a theory is built on the work of, and addressed the call by, Nambisan and Sawhney (2011: p. 55) who stated: "*another research implication relates to the characteristics of the hub firm and their impact on network orchestration. […] the nature of the processes and their implementation likely vary with the structure and power of the hub entity, indicating another promising line of future inquiry*". This chapter offers an empirical basis for the grey areas of ecosystem orchestration literature, such as failed ecosystems, while contributing to current debates on the dark side of interorganisational relations (Oliveira & Lumineau, 2019). In the remainder of this chapter, I first describe the theoretical background pertaining to the questions, then discuss the findings, their contributions to literature, and finally provide concluding remarks.

3.2 ECOSYSTEM ORCHESTRATION

Over the last twenty years, Dyer and Singh (1998) proposed interfirm networks as a unit of analysis for understanding competitive advantage. Since then, successful governance mechanisms by Toyota have been understood from a relational perspective that proposes mechanisms to manage a network of suppliers in one private automotive sector. While the Toyota case represents relationships between the hub firm and its complementors, it remains an alliance type of orchestrator (Dyer & Nobeoka, 2000; Jacobides et al., 2019). The digital economy calls for extended mechanisms on orchestration, which are aimed at value capture in ecosystems when technological and innovation complementors are present (Teece, 2018b).

As a result, the orchestration mechanisms set by a hub firm have become a prominent topic in the literature on digital innovation and business ecosystems (Dhanaraj & Parkhe, 2006; Gawer & Cusumano, 2014; Jacobides et al., 2018; Nambisan & Sawhney, 2011). Orchestration by a "*hub firm*" (Dhanaraj & Parkhe, 2006) is also known as a "*strategic center*" (Lorenzoni & Baden-Fuller, 1995), "*anchor firm*" (Wang et al., 2014), "*kingpin*" (Jacobides & Tae, 2015), "*keystone*" (Iansiti & Levien, 2004c) or "*organisational leader*" (Sydow et al., 2012). As mentioned previously in this study, I refer to the hub firm as an orchestrator. Moreover, Nambisan and Sawhney (2011: p.40) recognize two types of orchestrators - an "*innovation integrator*" and a "*platform leader*". A platform leader offers a "*platform or a foundation for other network members to build on through their own complementary innovations"* while an innovation integrator *"defines the basic architecture for the core innovation and then invites network members to design and develop the different components that make up this core innovation"* (Nambisan & Sawhney, 2011: p.41). Thus, the software vendor falls into the "*platform leader wannabe*" category (Gawer & Cusumano, 2008).

Orchestrators usually remain central decision makers by occupying bottlenecks (Hannah & Eisenhardt, 2019) and managing value creation through cooperation and value capture through competition. They set a system goals or collective value propositions, and coordinate, influence and direct the ecosystem actors in value creation and capture

(Nambisan & Sawhney, 2011). The ecosystems build on unique mechanisms for value creation and value capture. "*Greater value creation, in turn, depends on the firms' ability to innovate successfully. To capture the returns from innovation, many firms strive to be technology leaders in their industry by being first to introduce new innovations to the market*" (Adner & Kapoor, 2010: p.306).

An orchestrator can lead with an open or a closed-system approach. The software vendor in this study is categorised as a closed-system orchestrator, which is reflected in its self-interested orientation. This contrasts with an open-system orchestrator that supports network members in search of their own business opportunities (Giudici et al., 2018). However, despite the significance of an orchestrator's role, the way in which an orchestrator facilitates value creation and capture remains empirically underexplored (Nambisan & Sawhney, 2011).

Nambisan and Sawhney (2011) further recognise that the orchestration processes occur in a dual context, platform design and ecosystem design in B2C contexts. Network design is the bridge between platform design and ecosystem design (Nambisan & Sawhney, 2011). Orchestration, or network orchestration, refers to the capability to purposefully build and manage inter-firm innovation networks "*without the benefits of hierarchical authority*" (Dhanaraj & Parkhe, 2006: p.659). As such, the software vendor designs the platform as well as the innovative business ecosystem around the platform. Therefore, a platform designed by a software vendor falls into a category of an industry platform; this is a technology that is offered to the DBE sector as a foundation upon which external innovators can develop their complementary services, technologies and building products. It is thus organised as an innovative business ecosystem (Gawer & Cusumano, 2014). An innovative business ecosystem can be characterised as "*a community of interdependent heterogenous actors coordinated through a co-alignment structure who collectively deliver an ecosystem-level output*" (Thomas & Autio, 2020: p.28).

Platforms offer several benefits for the orchestration processes. First, platforms play an indirect and supportive role in innovation orchestration, thus allowing complementors to create their innovative solutions by using the platform as a foundation (Gawer, 2014). As such, the platform orchestrators rely on complementors to supply complementary products and services that enhance the core of the platform in order to provide better benefits to users (Parker et al., 2016a). Second, platforms offer a considerable promise in terms of improved value creation and value capture by a heterogeneous network of ecosystem complementors through combining knowledge, resources and capabilities to provide value that is bigger than any single firm can provide (Dhanaraj & Parkhe, 2006; Jacobides et al., 2006). Third, an orchestrator inverts the production from in-house to outside through the "*network effects*" (Katz & Shapiro, 1985). In the context of platform-based ecosystems, the orchestration of network effects is critical to platform survival as complementors are essential to a platform's success (Ozalp, Cennamo, & Gawer, 2018). Network effects occur between two and more cross-groups of platform users and complementors through mutual symbiosis. The value of the platform increases with the number of complementors, which drives the increase of customers and drives more value to the complementors (Hagiu & Wright, 2015).

The growth of platform-based ecosystems depends on the orchestration mechanisms deployed by the orchestrator (Paquin & Howard-Grenville, 2013). Ecosystem orchestration refers to the capability to purposefully build and manage an inter-firm innovation network (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011). Dhanaraj and Parkhe (2006) theorized about managing knowledge mobility, innovation appropriability and network stability. Nambisan and Sawhney (2011:p.42) extended the work of Dhanaraj and Parkhe (2006) by theorizing about orchestration mechanisms that "*perform several orchestration processes, including managing innovation leverage, managing innovation coherence, managing knowledge flows, managing network membership, managing network stability, and* *managing innovation appropriability"*. Nambisan and Sawhney (2011) focused on three mechanisms: *managing innovation leverage, managing innovation coherence, and managing innovation appropriability*. A process of *innovation leverage* allows members to reuse and redeploy the assets of other members to facilitate innovation output (Iansiti & Levien, 2004c). Managing *internal innovation coherence* allows for the coordination and alignment of members' output processes while *external innovation coherence* relates to the alignment of goals and outputs in relation to external technology and the market environment. *Innovation appropriability* relates to the key processes by the orchestrator that ensure equitable value appropriation amongst members by participation in the ecosystem (Dhanaraj & Parkhe, 2006). Their studies offer useful foundations for the development of grounded theory on ecosystem orchestration.

By presenting the software vendor's strategy, new empirical knowledge is added to the orchestration mechanisms theorized by Nambisan and Sawhney (2011). In particular, this study adds new knowledge to the ecosystem orchestration mechanisms that manage network membership, manage innovation coherence, and manage innovation appropriability. The management of network membership is of particular interest to this study because of its significance for complementors. Orchestrators manage the size and diversity of network membership through recruitment strategies, which preserve its centrality and status (Dhanaraj & Parkhe, 2006; Doz, Olk, & Ring, 2000; Kenis & Knoke, 2002). The formal arrangements used by an orchestrator to motivate members depicted in the literature were intellectual rights and contractual forums (Brusoni & Prencipe, 2013; Ritala, Agouridas, Assimakopoulos, & Gies, 2013), standards and interfaces (Baldwin & Woodard, 2009; Teece, 2018b), and platform dominance and newness (Venkatraman & Lee, 2004). Very few scholars researched the rules governing membership and relationships (Jacobides et al., 2018). By presenting the orchestration processes on how the software vendor recruits its members and manages innovation coherence and appropriability, this case constitutes failed orchestration process.

Evidence shows that the process of orchestration can be complex as ecosystems can fail for various reasons. For example, ecosystems can fail because of power reorganisation in the market (Ozcan & Santos, 2015); a short-sighted agency and blindsided actors with their own conception of reality (Porac et al., 1989); power actors intending to retain control of their market share (Jacobides et al., 2016), and entrepreneurs who face resistance from incumbents (Gurses & Ozcan, 2015). These studies on failed ecosystems offer useful insights to ecosystem orchestration. The case explored in this chapter offers new insights on how one powerful incumbent can represent a paradoxical case of simultaneous success and failure that has not yet been empirically explored in existing ecosystem literature. The case of a software vendor contributes new insights to the emerging debate on how and why ecosystems can fail while projecting individual success. The incumbent is widely and globally considered one of the leading software vendors in succeeding both in business and innovation. This study presents a different perspective in demonstrating that the process of successful individual value capture does not always lead to the successful value capture by complementors and customers. In fact, the orchestration mechanisms set by an incumbent can have serious implications for the business of complementors and customers.

The process of orchestration can be even more challenging when the orchestration process is taking place in specific contexts, like the DBE sector. The DBE sector is infamous for failing to innovate beyond the intra-organisational boundaries and investing in innovation activities (Egan, 1998; Morrell, 2015; Winch, 1998). However, while theorizing a failure by a software vendor, it is important to note that the sector holds particularities that influence the strategy adopted by such vendors. The issue of context and sector particularity is explored in detail in Chapter 4.

Furthermore, ecosystem literature tends to focus on a few examples of success in the B2C markets while there is ongoing debate regarding the role and value of the ecosystem concept in B2B contexts (Aarikka-Stenroos & Ritala, 2017). The software vendor fails as an orchestrator because, as a firm, it is successful in individual value capture; however, when operating in B2B contexts, its orchestration mechanisms disproportionately influence the value capture by platform customers in three distinct ways. First, its recruitment strategies are based on the marketing power to increase platform membership and, as such, sets exaggerated expectations between the sector's clients who demand the use of the platform to create that value. Second, as mentioned earlier, the platform offers value that does not match the exaggerated expectations set by the software vendor, and thus hinders the process of innovation creation by customers who are service providers in the DBE sector. Third, the software vendor articulates the value propositions for the use of the platform, which hinders the innovative potential of SMEs, namely the B2B customers. While an orchestrator defines the use of their platform, they limit the customer's innovative potential and capabilities by imposing value propositions on the supply chain in the DBE sector.

These arguments suggest that ecosystem orchestration is a challenging process that is under-researched (Ozcan & Santos, 2015). First, orchestrators are challenged by the environment in which they operate and are forced to focus on selfish value capture to survive. Second, the process of value articulation is largely taken for granted within ecosystem literature. The dominating role of the software vendor in articulating the value on behalf of the sector in a B2B context offers critical implications for the legitimacy of ecosystem members and for the orchestrator's role (Aldrich & Fiol, 1994). Third, through the use of marketing power and identity-claiming strategies to become a cognitive referent in the sector, the orchestrator's recruitment strategies appear to be critical to the value capture by complementors and B2B customers. This chapter will provide specific empirical knowledge on how an orchestrator recruits prospective members by effectively utilizing marketing power while failing ecosystem members.

Thus, an empirical study on the failed ecosystem by a software vendor can positively contribute to the call by Aldrich and Fiol (1994: p.646): *"Because only a few theorists have examined failed industries […] we believe that legitimacy is a more important issue than previously recognized."* However, Aldrich and Fiol (1994) specifically called for industries that failed completely, this chapter presents the case of an individual orchestrator that has succeeded to gain dominance and control but failed the ecosystem members thus presenting a case that has simultaneously succeeded and failed while contributing to ongoing debates on the dark side of interorganisational relationships (Oliveira & Lumineau, 2019). In order to contribute to ongoing debates concerning the success versus failure of orchestrators, I ask: *how and why did the software vendor fail the ecosystem orchestration? To which extent can the theories derived from the successful orchestration mechanisms in B2C contexts be applied to B2B contexts?* In addressing these research questions, I articulate the orchestration mechanisms deployed by a prominent global incumbent that strives to win the "*design to make*" market while presenting the specifics of its failure in one region.

3.3 DATA AND METHODS

New theories can explain the creation of new value propositions when multiple actors are involved with complex power relations and are centred around platform innovation (Adner & Kapoor, 2016). Thus, this research pursues an inductive interpretivist methodology based on the study by Gioia et al. (2013) in order to understand how a software vendor failed the ecosystem member's innovative capabilities through the deployment of orchestration mechanisms for individual value capture. Gioia et al. (2013) offers a methodology that captures the meaning made by people experiencing a given phenomenon and theorises this experience scientifically (Gehman et al., 2018). The methodology applied by Gioia et al. (2013) was chosen for its reference to grounded theory (Strauss & Corbin, 1990) that allows the use of a single case to capture, interpret and model an informant's meanings in order to build a process model that fills a research or practice gap (Langley & Abdallah, 2015). The interpretivist approach gives voice to interviewers while also interpreting the key issues they experience on their journeys towards value capture from the use of the platform. As per Strauss and Corbin (1990), interviewees' interpretations were further structured to construct the theoretical perspective grounded in and emerging from the data.

3.3.1 Case Overview

This case study is based on an incumbent software vendor who has scaled up based on its CAD design drafting technology, which it developed in the 1980s. Since then it has expanded its business by acquiring new software for the design, engineering and entertainment industries. With the emergence of the BIM acronym in 2002, the software vendor has started a new marketing strategy around BIM technologies in order to expand in various ways and thus target various supply chain specialties. It markets itself as a platform that connects design to construction allowing a frictionless data flow that promises to improve collaboration between various disciplines by connecting design and construction practices and enabling the digital business transformation of the sector. In the last decade, the software vendor made the transition from a traditional, perpetual licensing model with diminishing profits to an Internet Software as a Service (SaaS) subscription model that enables increased profits. Nowadays, it designs its own SaaS-platform products that are easily deployable by customers.

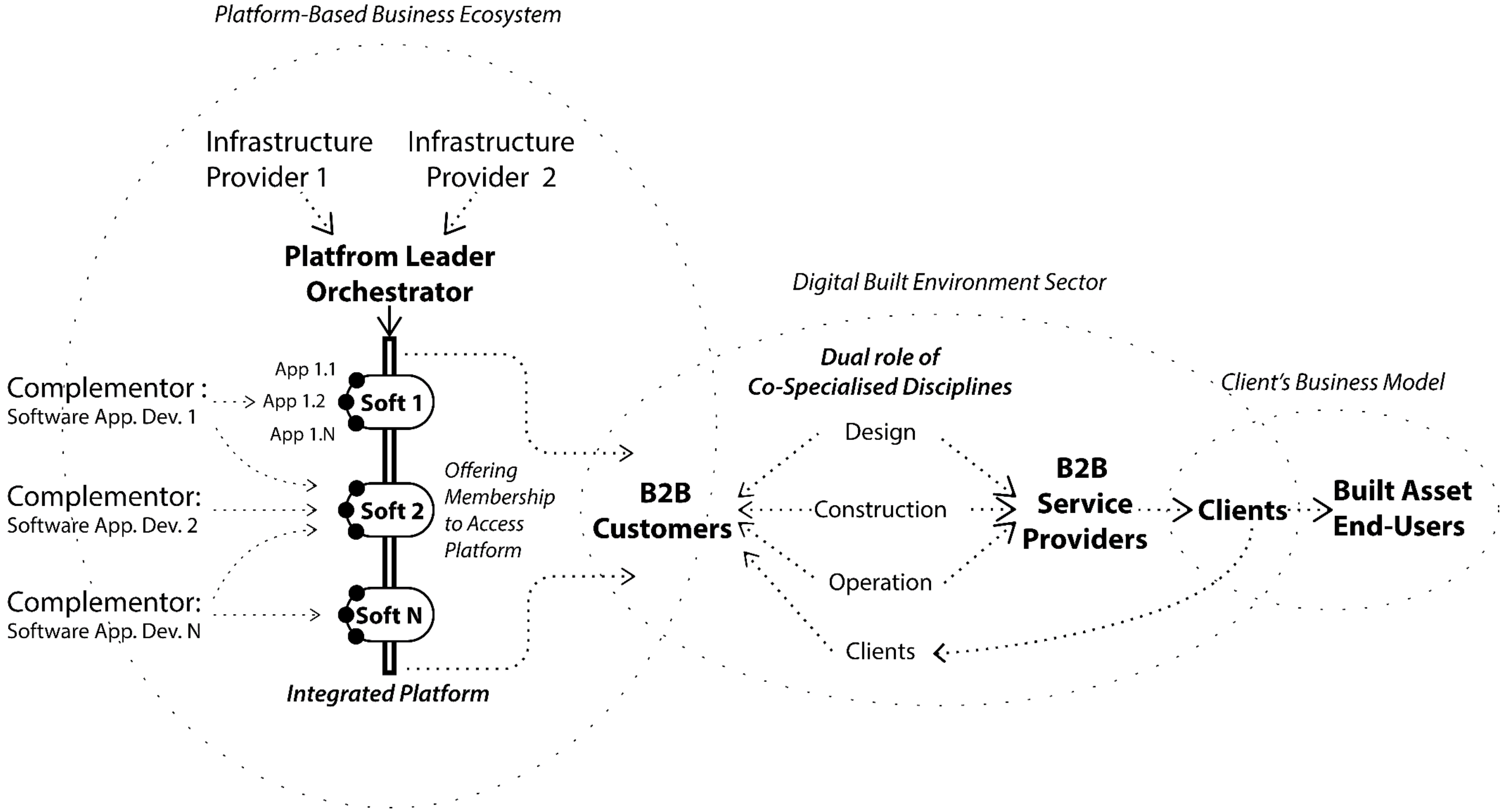

Figure 14 Generic Schema of Roles in the Platform-Based Business Ecosystem of Software Vendor

It is also important to note that the software vendor is a complementor to the DBE sector while it acts as an orchestrator. **Figure 14** depicts the roles and relationships created in the software vendor's business ecosystem.

This case is particularly interesting because the digital built environment sector – the software vendor's market segment – is infamous for its slow adoption of technologies and innovation (Bygballe & Ingemansson, 2014; Linderoth, 2010; Pries & Janszen, 1995), low rates of innovation (Winch, 1998) and was blamed for inefficiencies favouring a short-term perspective for sub-optimization (Gann, 1996). DBE incorporates the supply chain of Architecture, Engineering, Construction and Owner Operators businesses. BIM technologies were offered to the DBE sector to solve the inherent issue of lack of productivity in project networks (Björk, 1994; Eastman et al., 2011; Eastman, 1975). One of the promises of digitalization with BIM is that it provides mechanisms for collecting, managing, visualising and consuming knowledge collectively by the supply chain. BIM offers a set of processes underpinned with digital tools that are meant to support these mechanisms (Eastman et al., 2011). However, despite the widespread adoption of BIM technologies and the regional advantage of the case study, its proximity to Silicon Valley and its active involvement with the network of top universities, the northern Californian DBE sector suffers from inertia and low productivity. The promised benefits of BIM implementation have generated modest results.

This observation of the ecosystem surrounding technological innovation using BIM in this sector highlights the importance of the orchestration processes set by a software vendor. The software vendor's platform is a dominant technology in the region. Hence, the dominance of the software vendor in the region meansthe orchestration processes it deploys to win the market and preserve its power disproportionally influence the sector's business development and innovation. Empirical data was collected to support these observations.

3.3.2 Research Procedures and Data Sources

Interviews. The qualitative data comprises interview data as a primary source and archival data as a secondary source. A total of 38 interviews were conducted with leading experts spreading across six key stakeholders and end-user groups: i) academia; ii) clients; iii) supply chain: business & management; iv) supply chain: technology operation; v) start-ups and challengers; and vi) the software developer (see **Table 9**). These 31 interviews were conducted in person and seven interviews were conducted over the phone. The first round of interviewees was selected by a professor at Stanford University. Subsequent interviewees were pinpointed and recommended by these initial interviewees.

Table 9 Conducted Interviews

Levels	Sector	Occupation	N of participants	N of Interviews
Academia	Academia	Researchers	3	3
Clients	Silicon Valley	Project manager	2	5
	Health Care	Project manager	2	
	School	Superintendent	1	
Supply chain: Business & Management	Architecture	Architect	2	13
	General Contractor	Business management	2	
		CIO	2	
		Innovation manager	1	
	Engineers	Mechanical	2	
		Structural	1	
		System engineering	2	
	Sub-trades	CIO mechanical	2	
	Consultants	Practice expert	1	
	Facility management	Manager	1	
Supply chain: BIM operation	General contractor	Pre-construction manager	1	9
		Superintendent	2	
		VDC managers	2	
		Project manager	1	
		VDC integrator	1	
	Architecture	Architect	2	
Start-ups & challengers	Ai technology	CEO & CIO	5	5
Software Developer	BIM technology	Product management	1	1
Small scale renovation	Builder	CEO	2	2
TOTAL				38

The semi-structured interview protocol was originally based on the approach developed by McCracken (1988) that proved to be ineffective in the northern Californian context. Some interviewees were reluctant to speak unless specific questions were asked. "*Floating prompts*" (Dohrenwend & Richardson, 1956) were used to repeat the key terms of the respondent's last remark, which proved to have a negative result as the interviewees were annoyed by hearing a repetition of their own words. The researcher had to abandon the use of "*floating prompts*" during the process.

Interviewees were free to highlight important issues experienced in their practice from their perspective, as suggested by Corley and Gioia (2011)'s problem-driven theory. The following questions were explored: 1) *How has the sector evolved over the last 30 years in terms of BIM innovation?* 2) *Who are the ecosystem actors that drive the sector and influence sector innovation?* 3) *What issues are the ecosystem actors experiencing in relation to BIM practices?*

As the interviews progressed, open questions were directed to emerging themes and cases. During the process, key interviewees were interviewed twice, at the beginning and the end of the data collection phase, in order to explore and validate the emerging themes. The interviews varied in duration but ranged between 30-160 minutes. In total, 30 interviews lasted at least 60 minutes and were recorded and transcribed verbatim. Each interview is anonymous, and a transcript was provided for interviewee approval; furthermore, every transcript was labelled with a unique number identifiable only by the first author of this report. Quotes that could potentially identify individuals were eliminated to preserve the anonymity of the interviewees.

Archival sources. In addition to the interview data, relevant literature on the northern Californian DBE sector was collected in the form of reports, published articles, news articles and internal company documentations to obtain historical evidence of strategic change in the sector over the last twenty years regarding BIM implementation.

During the data collection, I was a visiting scholar at CIFE, the Centre for Integrated Facility Engineering, Stanford University. I kept observational notes to complement the transcribed interviews. Moreover, I asked additional questions during the sector-related events at CIFE to recursively understand the emergent findings and to modify the interview protocol for the subsequent interviews. This process allowed me to engage in "*gestalt analysis*" (Gioia & Thomas, 1996) to make sense of the collected data.

The collected data allowed for triangulation in various ways (Jick, 1979) - by circulating between the validated transcripts, archival sources and the discussions with key experts - thereby eliminating potential biases and validating the results. During the process, the researcher continued to communicate with key interviewees by providing preliminary evidence to clarify certain issues. As this understanding progressed, a private report was written with findings and circulated among key interviewees to correct any factual errors and validate my interpretations.

Once the data collection process was completed and to maintain the high-level outsider perspective required for unbiased theorisation (Gioia et al., 2013), I had ongoing discussions with my multidisciplinary supervisory team that circulated between the the collected evidence and my observations. Although I have limited sector experience, I collected and performed the first data analysis, which was supported by my second supervisor, Martin Simpson, who is a structural engineer and familiar with the context of DBE sector. Furthermore, Prof. Arto Kiviniemi, who is an architect and my third supervisor, is a knowledgeable agent and familiar with the Californian context. He did not participate in the data collection or analysis but rather contributed to, and offered clarification during, the discussions. Lastly, the sector context was new to my first supervisor, Prof. Tom Elfring, who is a knowledgeable actor in strategic management.

3.3.3 Data Analysis

The collected data was inductively analysed as it adhered closely to the guidelines provided by Gioia et al. (2013) and to constant comparison techniques (Corbin & Strauss, 2015). Interview transcripts were used as primary data for the analysis while field notes were used to refine the interpretation of emerging categories thereby guiding the integration of these categories within an overall framework. First, the aim was to understand and characterise the current dynamics of the DBE sector and the evolving relationship between the ecosystem actors. Then, I narrowed the research focus to the orchestration processes used by the software vendor. Next, I explain how the data analysis process moved from open coding to axial coding to grounded theory building.

In my initial rounds, each interview was coded separately on the basis that each phrase was labelled according to the informant's interpretation. A myriad of codes and themes emerged during this process, with each containing a sentence or a sequence of sentences (Weber, 1990). Then, I reread each interview several times to discern similarities and differences between their interpretations. I continued discerning codes by collapsing them into the first-order categories, employing the language used by interviewees. The abundance of data and emerging themes eventually became overwhelming when making sense of them (Gioia, 2004). As a result of this iterative process, first-order categories were created (Strauss & Corbin, 1998). I iterated between the emerging themes to distil distinct conceptual patterns. This process allowed me to create mutually exclusive, collectively exhaustive, first-order categories. Organised first-order categories illuminated a complex relationship between the DBE sector and its environment. Various actors and factors in the environment drive the sector's dynamics and the use of BIM. The actors and factors that influenced this sector are depicted in **Figure 15.**

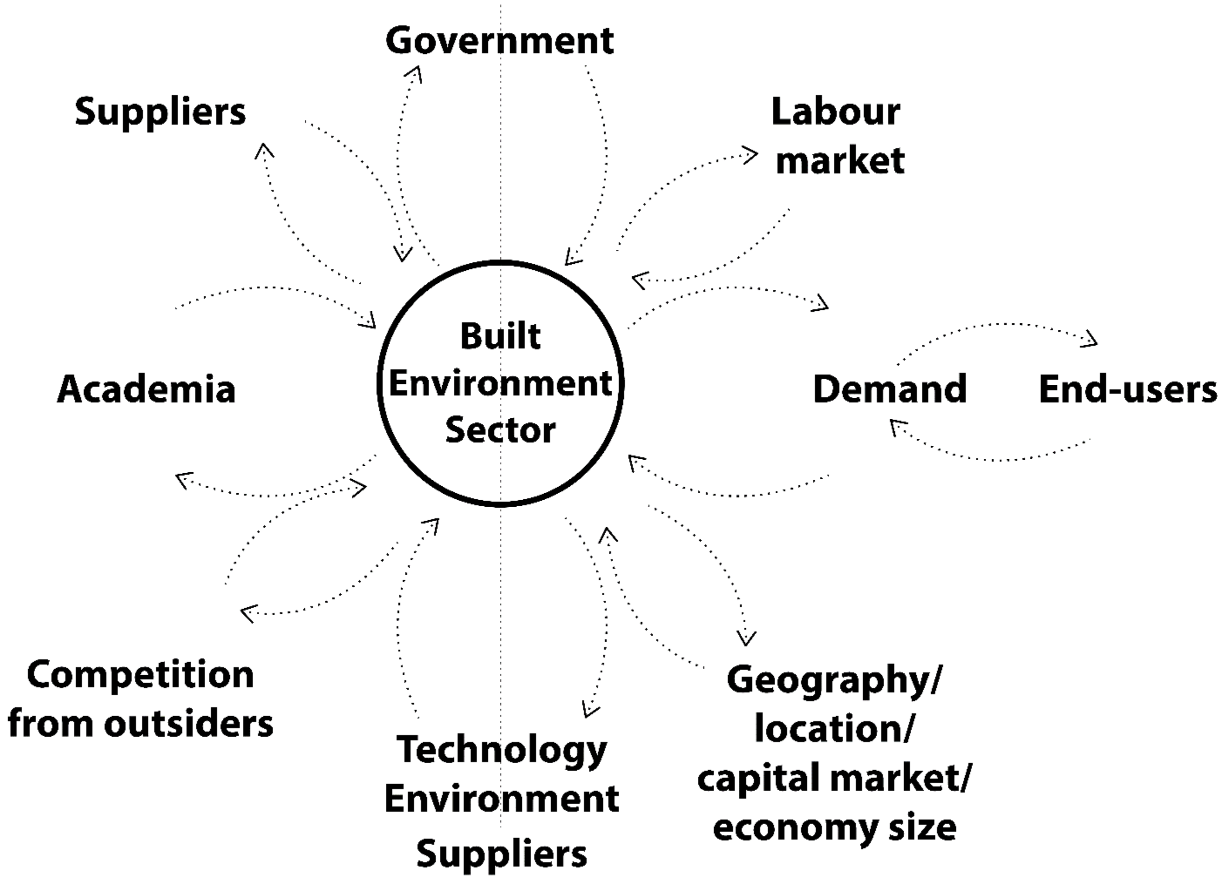

Figure 15 Reciprocal Relationship Between the DBE Sector and the Co-Evolving Actors and Environments

Alongside my observations of these complex relationships and the development of first-order categories, the links between them were identified. To ground the knowledge gained and the coding, I reread key interview transcripts to further validate my observations. I was able to identify the drivers that influenced BIM practices, such as the labour market, increased demand, clients' requirements, increased costs as an industry-wide issue, and the marketing power of software vendors. The interviewees highlighted several issues that they experienced in using the software vendor's platform; these concerned its dominance in the area. The dominance of the software vendor's orchestration processes and its links with Silicon Valley clients evidently had an impact on the built environment sector-wide innovation using BIM technologies and were present across most interviews. At this stage, the research gradually progressed to axial coding and then to a theory-driven explanation (Strauss & Corbin, 1990).

The axial coding was dedicated to an analysis of the strategies employed by the software vendor, at which point I identified a number of issues. One large, first-order category was dedicated to the technology environment where the software vendor was the main actor. I further iterated once more across all codes; this meant distilling all relevant codes by adding them to the selected first-order category of the technology environment. The first-order category became a pool of data in which I iterated the open coding process by distilling the emerging themes and conceptual patterns dedicated to the software vendor's activities. New, mutually exclusive, collectively exhaustive first-order categories and aggregated themes were created related to the software vendor's activities.

Through continuous iteration between this discussion and the data related to the software vendor, it was possible to extract the underlying orchestration processes set by the software vendor comprising a second-order of axial coding (Strauss & Corbin, 1998). Through iterative refinement, the first-order categories were reduced to 32. This was further reduced to the emerging 15 second-order categories while merging them into the aggregated themes.

Finally, the linkages between these aggregated dimensions were identified in order to build a grounded theory model to explain how a software vendor orchestrates DBE for self-benefit using a platform-based business model and marketing power. While damaging the innovative potential of the specialists in DBE, the use of marketing to recruit members manifested very clearly across key interviews and comprised the key findings. The software vendor acts as a driver of technological innovation in a mature sector. The iterative analysis resulted in a data structure, see **Figure 16** (see **Appendix A** for the full version). The categories were not only induced but also generated interpretations of orchestration processes and effects, forming a story line between the second-order categories and aggregated themes. Then, the researcher returned to the relevant literature and cycled between the data, the emerging findings, and the theory to identify the novelty in these findings and to build the final grounded model.

3.4 FINDINGS

The competitive advantage of business ecosystem orchestrators rest in how they interact with their environments (Piepenbrock, 2009). The research finds that the case study is a very successful firm that aims to capture value by interacting with an environment that is "*privately profitable but socially inefficient*" (David & Greenstein, 1990: p.21). Indeed, the interviewees have detailed marketing strategies that are effectively used to create perceptions amongst decision makers – their clients – in order to push the sector towards their desired direction. At first, the research was concerned primarily with the effects of platform orchestration on the sector; however, it soon became apparent that marketing strategies have negative influences on inter-organisational dynamics between the sector actors and clients. This research finds that the exploitative dynamics created by the software vendor

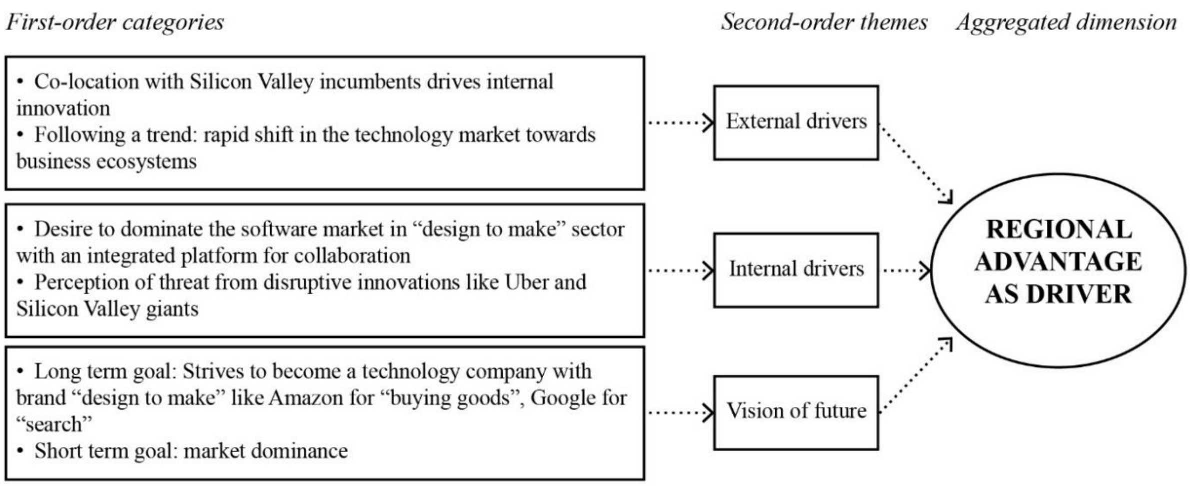

Figure 16. Data Structure

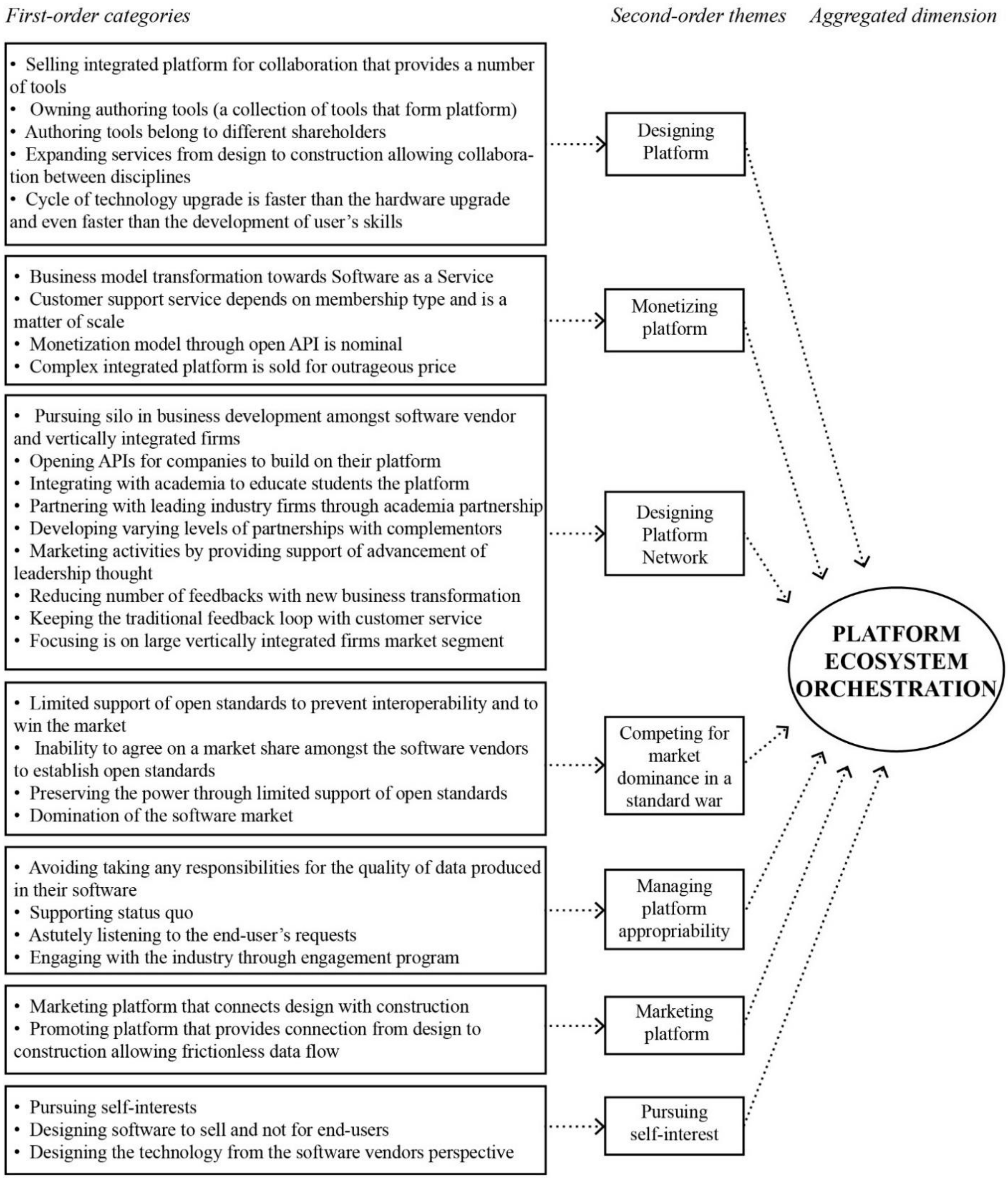

Figure 16. Data Structure Continued

damage sector-wide innovation. This study also finds that the northern Californian DBE sector is a self-organised entity with no identifiable mechanisms to correct the behaviour of self-profiting firms. As suggested by Nambisan and Sawhney (2011), the orchestration processes happen in dual contexts, in *platform innovation* and *the interfirm network*. The

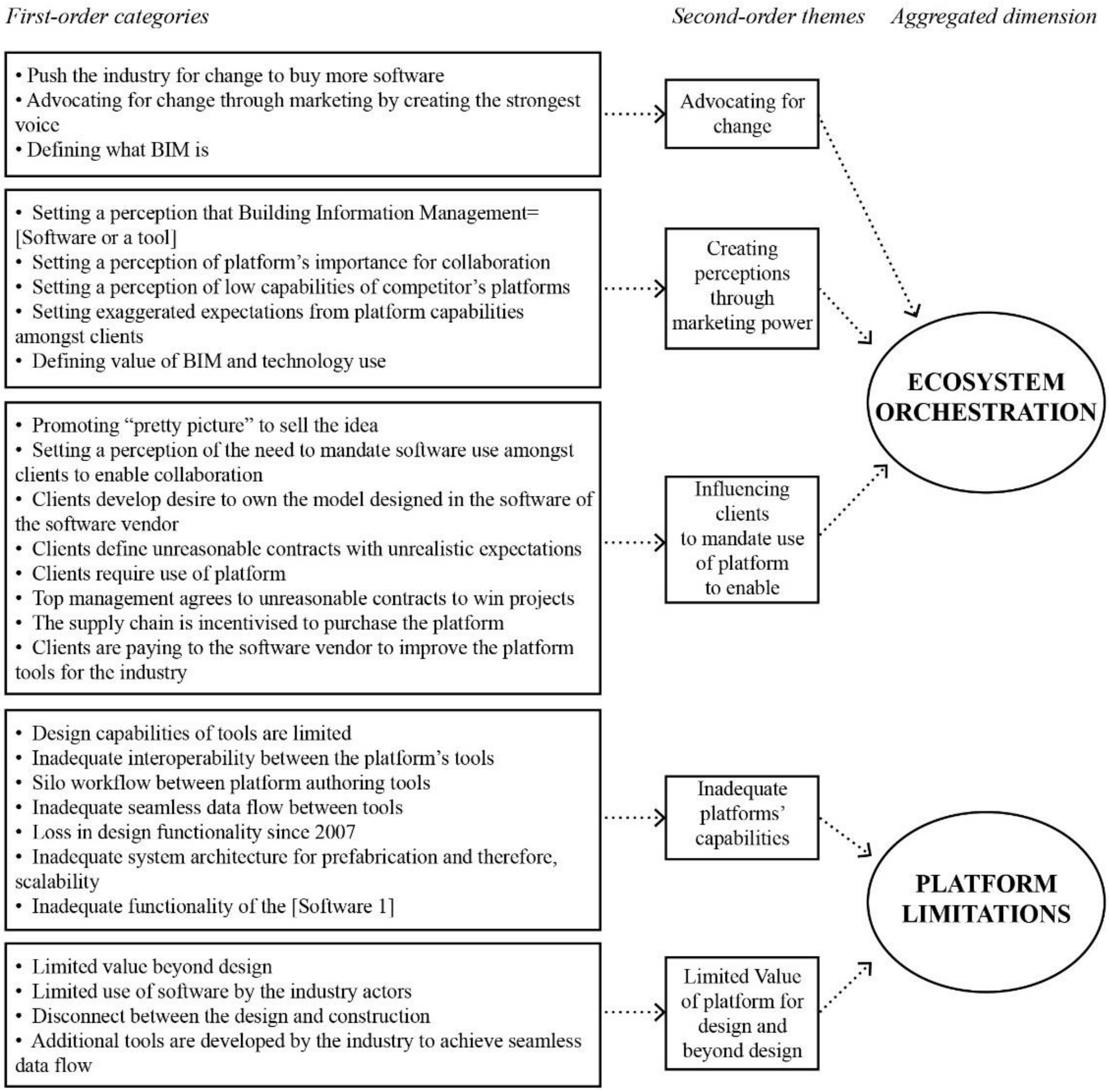

Figure 16. Data Structure Continued

analysis suggests that the software vendor achieves its success through two main orchestration processes: 1) an evolution towards *an orchestrator of a platform*; 2) *the orchestration of the environment* to build a robust business ecosystem around the platform. In this section, a narrative of these strategies is presented, following which the effects of the orchestration processes on sector-wide innovation are illustrated.

3.4.1 Regional Advantage as an Innovation Driver

The software vendor's embeddedness, proximity and co-location within Silicon Valley (SV) means successful business ecosystems represent important **external drivers for innovation**. Silicon Valley has an important role in influencing the behaviour of the firms by setting certain trends. There is a rapid shift in the technology market towards business ecosystems, from "*building it all to partnering to provide it all*" (Manager, Software Vendor, CA30). Following the example of Uber, which has challenged the traditional taxi sector by creating new rules, the power and resources of SV firms pose a serious threat to the position of the software vendor. This accelerates the desire of the software vendor to dominate the technology market in the "*design to make*" sector with an integrated platform for collaboration that acts as **an internal driver for innovation**. Internally, the software vendor pursues two goals: *the short-term goal* is to dominate the construction market with the platform which, according to a manager, means that "*the sector buys more [software vendor's] software*" (Manager, Software Vendor, CA30); *the long-term goal* is to become a technology company with a "*design to make*" brand, like Amazon for "*buying goods*" and Google for "*search*", as noted by manager (Software Vendor, CA30) (see selected quotes in **Appendix C**). The firm is currently pursuing market dominance that defines its accelerated value capture through orchestration processes; these are described in the following sections.

3.4.2 Closed Platform Orchestration

Following certain trends in Silicon Valley, the software vendor is going through a business model transformation, by moving towards a platform strategy by integrating with complementors, opening an API for start-ups and adopting the SaaS model. Despite such integration practices, the software vendor falls into the category of a closed platform ecosystem with an imposed approach to orchestration (Giudici et al., 2018). The platform orchestration process unfolds via two main streams – by designing a platform and by designing the platform's network (see selected quotes **in Appendix C**).

Designing Platform

The software vendor designs a platform that allows external innovators to build complementary products, technologies and services (Gawer & Cusumano, 2014). Its platform integrates authoring design tools that belong to different shareholders; meanwhile, there is inherent competition between these shareholders as 80% of revenue is still derived from the old CAD technologies that it continues to sell. Following its success in the design sector, the software vendor is currently trying to expand its platform offerings towards the construction sector, otherwise known as the "*make*" sector. It aims to achieve its long-term goal of becoming a dominant technology provider in the *"design-to-make*" sector and eventually become like Google and Amazon by occupying its distinct niche amongst the Silicon Valley giants. To achieve this, it is prospecting new business areas that are adjacent to vertically integrated construction firms, as these firms contain large resources and can make large investments, unlike SMEs.

Several years ago, it was going through a business model transformation and transitioned towards selling subscriptions as 'Software as Service' following the example of the computer software company, Adobe. This business transformation was not easy as it previously operated as a vertically integrated firm. The transformation has essentially changed the feedback loop with its buyers. Although as a minimum, the firm has maintained a traditional feedback loop with the sector, a new subscription SaaS model allows for more incremental engagements with their customers and provides support that depends on customers' membership subscriptions. The customer support service depends on the membership type and considers the scale of the customer. An integrated platform is sold for an "*outrageous* *price*” (as frequently pointed out by some interviewees) given the scale of SMEs; therefore, the latter typically do not have access to the premium support service. The same interviewees emphasised that the software vendor rarely addresses their requests for improvement. Indeed, empirical evidence shows that the software vendor favours large, international, vertically integrated firms so they can allow the purchase of premium memberships. There is a reciprocal relationship between the two “*ecosystem species*” that maintain silos, namely the software vendor and large vertically integrated firms as B2B customers. As an innovation manager (CA11_1) explained:

> Speaking of silos, just one last observation that I saw. One of the most advancements that we have seen in technological work and methodologies in this sector are from two separate most silo groups. One is the software vendors there; they are very siloed. The other is either at the front line of construction. You mentioned [vertically integrated firms], all those folks, […] they're doing a lot of advanced stuff, innovative stuff, but they are also siloed. (Innovation Manager, GC, CA11_1)

An interesting fact is, since its transition towards the SAAS-platform, the profits of the software vendor have risen in the last decade while the DBE sector in northern California report a sector-wide problem of increased costs and diminished profits since the recession in 2007:

> Profits in the US before the recession from 2007 to 2009 were probably between 4 to 5%, do not quote me the exact numbers, but after the recession, it was dropped to between 1 and 2%. So, you would be building 100 million dollars for 1% fee, right? And then after the recession, that number did not move up. (Manager, Software Vendor, CA30)

Managing the Platform

The software vendor is actively designing its business network by integrating with academia, partnering with leading sector firms through academic partnerships, and developing varying levels of partnership with complementors that are not in direct competition with the platform. They actively organise conferences and workshops to propagate their legacy and knowledge and are providing support to the sector through leadership activities and projects with advanced viewpoints. Strategically, the software vendor uses the identify-claiming mechanisms to become '*a cognitive referent'* (Santos & Eisenhardt, 2009: p.649) for the "*design to make*" market and the dominant software provider in the DBE sector. The presence of the software vendor in the USA across a diverse set of organisations is significant. Through contextual embeddedness and by interacting in the technology network's social structures, over time they have achieved a cognitive embeddedness (Dacin, Beal, & Ventresca, 1999) to the extent that network members have adopted the vocabulary and value propositions propagated by the software vendor.

Research by Aksenova et al. (2018) has provided evidence that software vendors compete in a '*war of standards'* thus providing limited support for open standards to prevent interoperability in order to win the market. The initial attempts to establish open standards at the international level resulted in an inability to agree on goals for data sharing between the incumbent international powerful software vendors in the DBE sector as indirectly inclined by the key industry BIM experts (Aksenova et al., 2018). Howard and Björk (2008) argue that software vendors are a key element in BIM and that they should state their real commitment to the implementation of open standards. A similar situation has been observed by Ozcan and Santos (2015). By limiting support to open standards, software vendors destroy a customer's trust in the interoperability, and by offering an integrated platform they create an incentive for customers – in this case design and construction firms – to buy integrated solutions to avoid interoperability issues. In this way, the software vendor preserves its established power and dominance in the software market but hinders the open standards development and interoperability needed amongst SMEs and start-ups. For example, an architect (CA09) explained the difficulty of transitioning from CAD, the traditional practice, to BIM, the modern practice, for architects and SMEs in general:

> But there’s a big barrier to entry. Because for some reason, [the software vendor] is not made it possible for details to transfer from [the platform’s CAD software] to [the platform’s BIM software], you can import them and explode them, but then you pretty much a reworking all of them. So, there's a huge gap, a huge transition period that's actually really difficult for architects and I imagined it would be the same for small construction firms. The switchover is that they would have this challenging transition period and that's actually something I see a lot of in California, not through any of my own work but through a lot of my colleagues who called me to ask about BIM, who are working in smaller firms, and not. And they all suddenly have projects where the clients are requiring that they deliver the building in [the platform’s BIM software], regardless if it’s necessary or not. And a lot of these companies are in the struggle where they’re kind of stuck between the original CAD world and the [platform’s BIM software] world. (Architect, CA09)

A CEO of Ai start up (CA16) explained the frustration of developing separate workflows for each platform for their technology start-up:

> What's going to be the Holy Grail for me is that if there was an IFC, and it had a standardised way of sorting 3D information and had a standardised way of having metadata in it. […] The problem is these guys [software vendors] don't talk to each other. […] One of the biggest issues with the IFC standardisation is that these geographic limitations that you have, [the software vendor] would want to cater it just to the American market very well, they don't want to get at the others. (CEO, Ai Start Up, CA16)

An orchestrator has a central role to play by setting the mechanisms for network members to appropriate value for their value capture (Nambisan & Sawhney, 2011). The empirical evidence indicates that the software vendor does not hold any responsibility or liability for the data created in their software. Indeed, a PM (GC, CA20) reported, “*software vendors are not responsible and do not want to take any responsibility*”. For example, by denying their liability concerning the data’s technical quality, thereby increasing the risks that clients take on, the software providers act as inhibitors and dilute the benefits of BIM adoption (Mosey et al., 2016). This is a critical issue as successful platform owners are accountable for platform functions that fail to fulfil their promises (World Economic Forum, 2017).

Fierce competition between the shareholders of authoring tools inside a platform also has consequences for customer productivity. Consequently, by pursuing self-interest, the software vendor contradicts the sector’s needs, thus damaging customer innovation appropriability and capabilities. Meanwhile, interviewees report that technologies created at the heart of Silicon

Valley are designed from the software vendor's perspective without understanding the design and construction process. The cycle of technology upgrades is faster than hardware upgrades which also creates certain challenges in relation to the design of complex products. This process is also much faster than the development of skills and competencies in the DBE sector.

3.4.3 Business Ecosystem Orchestration: Leveraging Marketing Power

The platform leverage relates to value generation and rapidly increases with the number of ecosystem members who use the platform thus creating the network effect. An orchestrator is central to the creation of opportunities for innovation leverage in the ecosystem (Nambisan & Sawhney, 2011). A key strategic activity of the software vendor is how it interacts with the environment. The construction sector is infamous for the slow adoption of technologies and inherent inertia at the sector level. Uusers typically receive traditional technical skills in CAD while BIM implementation requires a substantial learning curve as the transition from a 2D environment to BIM practice can be challenging in terms of changing mental models, cultures, routines, and processes (Paalova & Miettinen, 2013). The interviewees reported that the low margins of business processes (between 1-10%), "*outrageous software prices*" (for the size of SMEs), and "*expensive training*" also hinder platform adoption. Therefore, the sector's actors are reluctant to try new digital technologies. To accelerate growth, the software vendor has developed an ingenious recruitment process to push the sector towards an accelerated adoption of the BIM software offered in the platform. It orchestrates a business ecosystem for the "*industry platform*" (Gawer & Cusumano, 2014) by leveraging marketing power and "*selfishly, [the software vendor] is pushing their agenda*" (Manager, Software Vendor, CA30). The process that the software vendor adopts to achieve an increase in platform sales is outlined next.

Advocating for change. It is important to note that marketing is the core capability of the software vendor who uses it effectively for its own advantage. The software vendor is astutely listening to its customer's requests and the trends in the sector. It is actively engaging in various activities to market the platform's capabilities and advocate for change. In addition, while it creates a strong marketing campaign by capturing value, it also creates the strongest voice in the sector by defining the value propositions for the use of BIM technologies. The marketing strategies deployed by the software vendor have damaging consequences for the sector's innovation, as a project manager (CA11_1) explained:

> BIM is something that absolutely needs to be **revisited… […] Maybe academics and the sector should stop listening to the software vendors** and make a big revision of what BIM is. But I guess the practitioners are not ready to listen to this from me or anyone else. **The problem as I see it is the influence that the software vendors have had and are having in defining what is BIM and how it should be used, both at the academic level, but also, and maybe mainly at the practitioners' level.** I believe that the software vendor's voice should be just one among different voices (and definitely not the most important) that need to be heard when trying to define, and mainly implement, BIM. When this is not the case, I believe then that something is going wrong. […] the blame is on those advocating for the change. […] I think that the strategies from those advocating for change to reach the people with their proposals have not been there the best ones. […] So, there is some gap there between those advocating for change, the strategy that they use to reach the people. […] usually the gurus and experts and consultants, whoever has the technology and the software vendors, **especially [the software vendor].** (PM, GC, CA11_1)

Creating perceptions through marketing power. Using marketing strategies, the software vendor encourages the perception that BIM equals the BIM software offered in the platform. This is a false proposition, as the BIM concept is not defined by specific technology but rather as a set of processes and methods that are underpinned by BIM technologies. Various software vendors offer digital technologies to support BIM practices in the sector.

Another inhibiting factor can be attributed to the oligopolistic nature of the software market in DBE sector, which is dominated by a small number of vendors. The software vendor encourages a perception that competitors' products have low capabilities, even if they offer competitive prices and quality levels. Because of the resulting monopolisation, consumers are usually reluctant to try and use software that is incompatible with mainstream products, even if they offer competitive prices and quality. Large software companies have "*a disproportionate control over the terms of market competition, by not only setting prices but manipulating product quality in ways that are privately profitable but not socially efficient*" (David & Greenstein, 1990: p.21).

Influencing clients to mandate use of the platform to enable collaboration. The software vendor markets a "*pretty picture*" (Manager, subtrade, CA21) of 3D models to sell the idea to the clients of DBE sector, and the clients are hooked by the marketing trick. As one manager (GC, CA01) pointed out, "*some people call this Hollywood BIM*". As a result, clients develop the desire to own the software model designed by the software vendor even if "*they do not know what to do with this model*" as manager (Sub-Trade, CA21) explained. Several interviewees suggested that the BIM concept has become a "*buzzword*", as explained by the architect (CA09):

> The owners see BIM as this buzzword that they think is going to make the project better, but they aren't highly involved with the knowledge of BIM. […] so, they set exaggerated expectations. (Architect, CA09)

The software vendor further generates a perception of the platform's importance for collaboration. The sector has struggled for a very long time with collaborative practice and innovation due to high levels of fragmentation and an established culture derived from a short-term project-based environment (Egan, 1998). Furthermore, clients are recognised as important drivers of innovation in the sector (Brandon, 2006). The software vendor markets its product to clients by setting "*exaggerated expectations*" of the platform's capabilities and propagating the need to mandate the use of BIM technology to improve collaboration in projects. The practitioners find this practice frustrating, and, as an CEO (Structural Engineer, CA07) describes, "*extremely damaging and counterproductive*". The same engineer further states that the marketing power is damaging sector-wide innovation because sector leaders and software vendors are intentionally preserving the current status quo as it allows them to keep the market share:

> It is forcing the sector into a technological dead end by defining the future in terms of what current software products are capable of, perpetuating current limitations, aided and abetted by sector leaders who also want to maintain market share without having to change or evolve. (CEO, Structural Engineering Firm, CA07)

The interviewees report that the sector has started to recognise the importance of collaboration and that collaborative practice can happen with or without the use of software. The use of BIM software is not a determining factor that influences collaborative outcomes. Following the value propositions set by the software vendor, clients mandate the use of BIM software and offer unreasonable contracts with unrealistic expectations. For example, architects report design schedules cut in half although with BIM processes, the design phase requires more time than in the traditional CAD environment.

Silicon Valley is marked by a distinctive collection of people and institutions with overlapping associations and with tight links accumulated by networks of interacting individuals (Lee, 2000). The interviewees shared that the top management of DBE firms is typically involved with clients in informal relations and agree to unreasonable contracts to win projects without checking with the operational level whether exaggerated expectations can be delivered. The interviewees reported a contradictory culture and power imposition by Silicon Valley client representatives in the construction sector. As a result, supply chain firms are forced to purchase the platform and agree to unreasonable contracts to win projects as sector firms are afraid to lose clients. Considering that Silicon Valley is a privately-driven and self-organized microcosm, its culture and goals contradict its adjacent and dependent industries, such as the conservative design and construction industry.

3.4.5 Platform Limitations Contradict the Marketing by the Software Vendor

Converging evidence from the interviews suggests that the marketing strategies set by the software vendor directly contradict the platform's capabilities in terms of delivering the value promised. While top management and clients make the decisions, people at the operational level report several issues related to the platform's capabilities. It is important to note that the marketing strategies for platform leverage have damaging consequences for sector-wide innovation and, while the platform provides value, it leaves a lot of room for improvement in terms of meeting the expectations set by its marketing. Several issues related to the platform limitations, as reported by the interviewees, are outlined next.

The platform's inadequate capabilities. While the platform has been designed to provide value to designers, it has limitations in terms of interoperability, rigidity, the lack of a user-intuitive interface, an inability to deal with complex geometry and a disconnect with construction practices. Surprisingly, interviewees have also frequently reported inadequate interoperability and siloed workflow between the platform's authoring tools, despite marketing by the software vendor promising a seamless data flow. The interviewees report:

> [The platform's CAD software] did not directly integrate with [the platform's BIM software]. […] So rather than being just a disconnected program […], you can do some things, but it's a silo workflow. (Manager, Software Vendor, CA30)

> There is a big barrier to entry. Because for some reason, [Software vendor] is not made it possible for details to transfer from [the platform's BIM software] to [the platform's CAD software]. […] The interoperability, as much as they say it is, it's not!" (Architect, CA09)

Some of the interviewees reported a loss in design functionality in the BIM software since 2007. The interviewees further reported that the use of the platform's capabilities by the customers is between 10-50%, as a manual input is required that limits individual productivity, as pointed out by a sub-trade manager (CA21):

> The problem that we've had with [BIM software], we're having problems getting this documentation out of it, fabrication sheets out a [BIM software], they have a lot of manual input to it and it's not automated.(Manager, Sub-Trade, CA21)

The construction sector is urgently moving to prefabrication to address on-site labour shortages. While the software vendor claims that their platform connects design to construction with a seamless data flow, the inadequate system architecture of the BIM software has little value in terms of prefabrication and therefore the scalability of the solutions.

Limited platform value for design and construction. The construction firms that undertake a prefabrication report revert from BIM technology to CAD technology in the same platform because "*CAD technology is broken […] but we know where it is broken"* and the processes are established. There is a disconnect between design and construction although the software vendor claims to connect it. To connect design data to construction processes, firms develop additional tools to aid the functionality of the platform. Furthermore, the platform's BIM software for design is mainly a document production tool and is therefore intended to support the status quo, as explained by a consultant (CA13):

> They are designing software to sell software, they're not designing software for users, for what needs to be used. I didn't see the connection between the productivity and the software that is going to solve it. I didn't really see that connection there. So, the role of this software should be to basically create simple technology that enables people, that is friendly to use, that is intuitive, that really enables people and is a lever to improve productivity. And I do not see that […] I know that it's just to support basically the status quo! (Consultant, CA13)

The way the software vendor interacts with the environment and manages its platform has a disproportionate influence on the sector's dynamics in terms of value articulation, value capture and the sector's architecture. It supports the status quo and serves only those who already have power and resources. For example, a director of a general contractor firm (CA25) picked a team for a new business model innovation with the use of BIM. The team members selected a competitor's BIM software due to its superior functionality and interoperability. This team distinguished itself by a collective discovery of its opportunity and legitimacy which secured its survival and performance. The same team member reported that the self-centred behaviour of the software vendor does not aid value capture in the sector:

> One of the unique things that endeared me to you guys right away was when I met [an architect] for the first time, he told me: "Because I'm not anything… if there's one thing you learn about me if you've known me for any period of time, I hate [the software vendor]! Because they are the antithesis of what we're doing! They're not about trying to make things easier to work with, they are trying to force people to use their product!" (Superintendent, GC, CA25)

The strategy of the software vendor mirrors the system behaviour of the leading vertically integrated firms, which reinforces the status quo and squeezes out SMEs with innovative potential. The reciprocal relationship between two silo groups – namely, the software vendor and vertically integrated firms – creates status-quo reinforcing feedback loops that impact competitive dynamics in the sector.

3.5 DISCUSSION AND CONCLUSIONS

In this chapter I explore *how and why the software vendor failed ecosystem orchestration.* A grounded model shows how the software vendor takes a lead in orchestrating the DBE sector. This forms a business ecosystem around its platform by effectively utilising the marketing strategies, which forces B2B customers to purchase the platform and thus increases its membership. Indeed, the software vendor is successful in capturing value that is "*privately profitable but socially inefficient*" (David & Greenstein, 1990: p.21). This happens when an orchestrator adopts strategies from B2C success examples and applies them to B2B contexts leaving B2B customers as illegitimate actors and hampering their innovative potential. **Figure 17** presents the grounded model.

This in-depth case study shows the self-centred motives of the software vendor who is driven (and at the same time threatened) by the success of giant corporations located in Silicon Valley. It strives to dominate the "*design to make*" market by occupying a complementary niche to firms like Google, Apple, Facebook and Amazon. Therefore, it aims to become a "*winner takes all*" and is a "*platform-leader wannabe*" (Gawer & Cusumano, 2008) type of orchestrator. While the software vendor is driven and threatened by giant corporations, the software vendor articulates value propositions for BIM practices with their marketing power

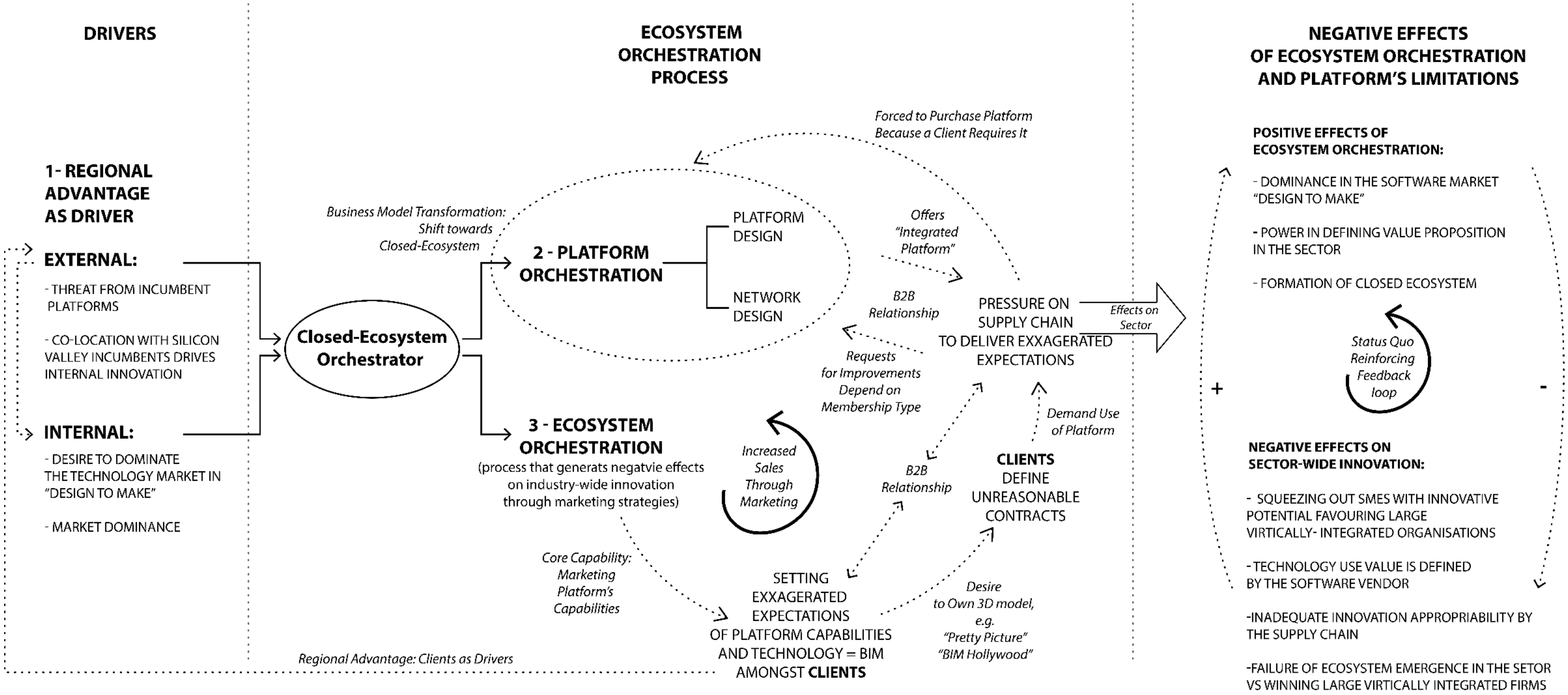

Figure 17 A Grounded Model of Effects of a Closed-System Ecosystem Orchestration on Sector-Wide Innovation

on behalf of sector actors and clients. It also markets the need to mandate the platform use in a project to enable collaboration, whilst clients mandate the use of the platform in projects by putting pressure on the supply chain to deliver exaggerated expectations. This process increases the platform's membership.

The data shows that playing the "*role of an ecosystem orchestrator*" is a directed process in which a firm can capture value through the creation of feedback loops between the dominant ecosystem actors, thus favouring those already with power and resources and extracting value from the small-scale niche members. The orchestrator's role contributes to the failure of the emergence of business ecosystems in the sector by squeezing out SMEs with innovative potential, and thereby favouring large, vertically integrated firms.

The next section discusses the implications of the findings for the theoretical understanding of ecosystem orchestration by a closed-system orchestrator in one specific sector.

3.5.1 A Grounded Model for Orchestrating a Business Ecosystem for an Industry Platform

The ecosystem literature suggests that participation in an ecosystem has mutual benefits for participating actors by combining complementary resources, capabilities and knowledge. Ecosystems are bound and co-evolve around common goals without the need to engage in vertical integration; this suggests the importance of the leading hub in propagating rules to ensure fair value capture (Jacobides et al., 2018; Nambisan & Sawhney, 2011; Teece, 1986). The findings suggest that this potential can be damaged by the mechanisms set by a dominant hub if the ecosystem actors do not have a legitimate status. Legitimacy is perhaps most relevant to B2B contexts where each actor aims to capture value through monetisation, even if monetisation does not happen in the platform per se but that customers rely on the platform to create value in their businesses. However, it is necessary to articulate a theoretical explanation of the failure of the orchestrator’s role in propagating sector-wide innovation.

Not managing innovation appropriability for selfish value capture. The research on ecosystem orchestration has highlighted the importance of managing appropriability by ensuring fair value capture while mitigating appropriability concerns between network participants (Dhanaraj & Parkhe, 2006). In contrast, the case study shows how a leading firm captures value without taking any responsibility and accountability for the impact it has on the business of network members, the quality of the data produced in their software, or its failure to set fair rules for value capture by B2B customers. By not taking accountability for failing functions, it also disrupts trust between B2B customers as professional services struggle to realise exaggerated expectations from BIM practice by clients. It also hinders the trust of B2B customers in the concept of BIM and the potential it offers. This case exhibits the exploitative dynamics of innovation appropriability where a single leading actor profits by capturing value.

According to Iansiti and Levien (2004c), the case falls within a dominator’s role, as opposed to a keystone who is essentially encouraging the health of the ecosystem; this does not match the definition of a system integrator or platform leader offered by Nambisan and Sawhney (2011). The dominators occupy a large number of ecosystem nodes, thus ecosystems become unstable and vulnerable to external shocks. Ensuring the success of an ecosystem’s health is potentially a critical role for an orchestrator (Iansiti & Richards, 2006).

Leveraging the network for individual impact by creating negative sector-wide effects. An orchestrator needs to find a way to incentivise potential members to participate in the ecosystem (Nambisan & Sawhney, 2011). The ingenious mechanism set by the software vendor to incentivise network members is achieved through marketing power, by directing the client's behaviour to force the supply chain to purchase the platform. The software vendor masterfully creates illusions amongst the clients. Clients are considered the drivers of innovation in the DBE sector (Brown, Hampson, & Brandon, 2006). "*Illusion is the use of deception, shielding intentions and exaggerating one's importance to gain advantage*" (Santos & Eisenhardt, 2009: p.633). As marketing strategies are complemented by other activities, the software vendor signals its leadership and dominance in the software market for the DBE sector.

Moreover, the findings suggest that the value propositions for the use of BIM software set by the leading hub hampers the innovation capability amongst B2B customers who are unable to propagate their own visions for the use of the platform. This is because the clients of construction projects are influenced by the marketing strategies set by a software vendor around a platform's value. By leveraging marketing power and defining the value of BIM practice and the use of the platform, software vendors inhibits innovation opportunities amongst B2B clients, particularly amongst SMEs. It does not just hinder innovative potential, but also damages the profits made by B2B customers by offering a platform with limitations.

This contradiction is more obvious in SMEs transitioning to digitalization because their resources are scarce. By favouring large organisations, the software vendor is entangled in a status quo, reinforcing a feedback loop that serves those who have power and resources while squeezing out SMEs with innovative potential. This vicious cycle leads to further status quo preservation in the sector (Hannan & Freeman, 1977). Cooperation between the two most siloed and powerful groups – the software vendor and large vertically integrated firms – signals to other DBE sector actors the ineffectiveness of networked processes, which leads to ecosystem inertia and favours closed ecosystems over inter-organisational cooperation (Jacobides & Winter, 2012).

Network effects emerge in B2C contexts but are they effective in B2B contexts?

Platforms are typically associated with "*network effects*"; thus, the larger the pool of complementors adopting the platform, the larger the value of the platform delivered to customers. Furthermore, larger pools of customers mean that more complementors join the platform. Through mutual symbiosis, a platform owner achieves network effects. Network effects drive diversity amongst the complementary products and services offered to customers (Gawer & Cusumano, 2014). However, empirical evidence shows that an increased pool of B2B customers does not necessary lead to an increase in the platform's value. Instead, interviewees reported reduced functionality alongside the increased popularity of the platform.

The software vendors in the sector are engaged in oligopoly. Historically, they were not able to collude and agree on goals for open standards, thus setting prices to maximize their individual profits (Teece, 2018b). Implementation of digital innovation is expected to allow easy interoperability by integrating products that were previously separated (Teece, 2018b). However, this study shows that the existing standard war on the software market in the DBE sector and inadequate interoperability even between the platform's authoring tools contributes to a significant loss of productivity by B2B customers. Thus, the marketed capability of the platform to provide a seamless data flow is contradicted by this evidence. Even if network effects are achieved artificially, the business ecosystems created in B2B contexts do not necessarily provide superior value to B2B customers. Indeed, adopting ecosystem strategies from B2C contexts in B2B contexts can hinder sector-wide innovation.

3.6 IMPLICATIONS FOR THE DARK SIDE OF ECOSYSTEM ORCHESTRATION FROM MANAGEMENT LITERATURE

The findings suggest that current literature has a positive angle on the outcomes of orchestration processes set by a business ecosystem orchestrator (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011). Although business ecosystem orchestration is more akin to centrally managing network relationships, this study indicates that, if there is no corrective mechanism for selfish value capture, the leading hub can aim to capture value by enforcing its conditions and goals on network members. It does so by controlling the perception of value generated by using the platform and effectively utilising marketing power, regardless of whether the platform has the capability to enable B2B customers to deliver exaggerated expectations. With the use of marketing power, the software vendor effectively interacts with the environment but also, selfishly, directs it towards its agenda. It also signals leadership and thus becomes a cognitive referent for the claimed market (Santos & Eisenhardt, 2009).

This study contributes to theories of power. Resource dependence theories emphasise firm-level strategies to gain control, and by controlling interdependences the network's collaborative activities increase joint action, trust, and the quality and scope of information exchange (Gulati & Sytch, 2007; Pfeffer & Salancik, 1981). This study extends current theories of power to ecosystem orchestration. First, the study shows that the siloed control of interdependence does not necessarily lead to increased collaboration at the system level. The dominance and power of the software vendor and the absence of corrective mechanisms can lead to an egocentric ecosystem orchestration. Second, the case highlighted that control obtained through masterful interaction with the environment and with the use of marketing power can reinforce siloes between complementors and co-specialised B2B members. Third, the software vendor insists on dominating the software market in the built environment sector by engaging in turf wars. By using marketing power and actively interacting with the environment, it preserves control and dominance over one region.

This study offers new insights over previous studies as entrepreneurial firms were able to organise conflicting actors for value creation (Ozcan & Eisenhardt, 2009; Santos & Eisenhardt, 2009). These studies highlight that firms were able to resolve conflicts by inviting necessary complementors to commit to shaping the market. In contrast, the prominent firm, a complementor, contributes to the market by organising the environment around its own selfish agenda in a silo. Innovative SMEs have limited power to create countervailing power, define their value propositions or persuade the software vendor to cooperate with them if their goals contradict those of the vendor. SMEs take two routes: either by adopting a new business model innovation with an alternative platform (which is rare) or by continuing to follow current practice by losing profits (the majority of SMEs).

The study offers an explanation as to why, in some contexts, ecosystems might not emerge. This study aligns with research by Ozcan and Santos (2015), which showed that interdependence and inter-industry collaboration requires prominent firms to collaborate to establish a new market as turf wars between prominent firms can cause market non-emergence. While Ozcan and Santos (2015) illuminated a difficult relationship between prominent firms, which is similar to this study, this study further showed that the context for market emergence can also significantly impact the behaviour of prominent firms. The specific context of the built environment sector coupled with turf wars incentivises competition for selfish value capture. New markets are even less likely to emerge in such contexts. It should be noted that the consideration of the context is an important prerequisite for market and ecosystem emergence. Ironically, the use of marketing power can be necessary for firms in certain contexts, such as mature and traditional B2B sectors, where, historically, actors are reluctant to try new technologies. The practice illuminated paradoxical tensions (Smith & Lewis, 2011) between the orchestrator's efforts to push the DBE sector towards digital transformation through its platform and the simultaneous preservation of the status quo which favours large, vertically integrated firms. This paradox creates vicious cycles (Masuch, 1985) where prominent firms enforce the sector for technology investment. By favouring large, vertically integrated firms and by heavily investing in recruitment with marketing strategies that require the relocation of resources from the development of the platform to the marketing department, the software vendor limits the opportunity to create network effects and innovation by B2B customers who are SMEs. As result, through its deployed mechanisms, it reinforces the status quo and contributes to a lack of business ecosystem emergence by SMEs.

It is important to note that the sector sees value in the digitalization of the built environment sector with BIM technologies. However, two interviewees (CEO, structural engineer, CA08; CEO, architect, CA17) pointed to the inability of actors in the sector to define and articulate a value proposition through the use of BIM technologies because they lack the capacity to sense and seize new technological business opportunities (Teece, 2007). Thus, ecosystem inertia is simultaneously preserved by large and small firms. However, the influence of the software vendor and regional informal relations between northern Californian actors in the DBE sector are profound as this evidence shows they constitute the dark side of ecosystem orchestration. This study highlights the important role of the sector context for ecosystem emergence and orchestration that has previously (and largely) been taken for granted (Jacobides et al., 2006).

This study contributes to literature on closed-system orchestration. Orchestrators have an important role in defining the basic architecture for core innovation and by setting mechanisms for equitable value creation and capture (Nambisan & Sawhney, 2011). In particular, the study presented a unique mechanism of how a software vendor manages a network membership. The concept of value proposition is an important element of a recruitment strategy; however, ecosystem literature takes for granted the value proposition of the platform. Nambisan and Sawhney (2011) did not extensively discuss the role of the orchestrator in defining the value propositions. Indeed, such companies as Intel embrace open innovation by articulating the value of collective value creation at the system level. However, it does not articulate and impose the value of the platform for the customer but rather allows for the discovery of their own business opportunities, thus enabling open innovation creation (Chesbrough, 2003).

Important questions arise as to *who can legitimately define and enforce the value propositions in a B2B ecosystem,* and *do B2B customers have a legitimate status in co-defining and co-articulating value?* The results of this study suggest that the software vendor is illegitimately leading the sector-wide digital transformation with BIM due to its business model and role in the DBE sector. To support interoperability and innovation in the sector, policy makers should address the issues associated with liabilities of data created in BIM software and open standards. As empirical evidence shows, the value proposition is critical to value capture and can direct behaviours towards change. However, the northern California case is a self-organised entity in which policy makers hold a minimal role in driving industries; thus, due to the varieties of capitalism (Hall & Soskice, 2001), the corrective mechanisms in such contexts remain a grey area. Indeed, ecosystems thrive in unregulated markets (Jacobides et al., 2019). The findings draw attention to the critical role of corrective mechanisms and countervailing power relations with policy implications. Perhaps, in coordinated market economies, public clients in the DBE sector can take such a role as their primary task is to ensure the creation of public good. For example, some studies indicate that Norwegian public clients can hold that role (Divella & Sterlacchini, 2018). However, following the results detailed in Chapter 2, public clients can struggle to take such a role and it seems that the legitimacy of orchestrator roles depends on the variety of capitalism. Public organisations are better suited to coordinated market economies while liberal market economies offer opportunities to private organisations, like the software vendor, to take advantage by leading their own ecosystems.

Overall, this study contributes to an understanding of how the strategies deployed in a platform-based ecosystem orchestration can contribute to the non-emergence of business ecosystems at the convergence of industries. The process described in this study resonates with the work of Ozcan and Eisenhardt (2009) and the dialectic tensions noted by Van de Ven (1992: p.178) where individuals and organisations *"exist in a pluralistic world of colliding events, forces, or contradictory values, which compete with each other for domination and control".* In this study, the software vendor adopted a strategy for growth and survival whilst threatened by co-located global giants; however, it also found a niche that does not directly compete with these giants. Moreover, by fiercely trying to survive, it creates siloes and negative effects in the sector by abusing its power for domination and control. It competes by creating the illusion of technological progress in the sector. In doing so, it behaves as a dominator in order to extract value by damaging the health of the sector. In this context, the logic of dominance incentivises prominent actors in the ecosystem to adopt silos and thus, to move away from cooperative behaviours.

3.6.1 Limitations and Suggestions for Future Research

This study has some limitations. Firstly, the data is collected from sector participants, mainly B2B customers, who have both close and distant interactions with the software vendor; through their observations, I understood the profound effect the vendor has on the sector's competitive dynamics, innovation outcomes, and value capture by B2B customers. Through discussion with my supervisors, I managed to understand the orchestration processes of the software vendor by assembling often oddly shaped but interlocking and tessellating pieces of evidence in a jigsaw puzzle while building the grounded model. The original focus on the digital transformation of the sector with BIM has shifted towards a focus on the software vendor's impact on digital transformation in the sector.

The literature review showed that management scholars are increasingly focused on examples of success. However, such examples involve leading firms that orchestrate their ecosystems and platforms without considering the effects on their stakeholders and on sector-wide innovation. Thus, this study contributes to ecosystem literature by offering new insights in highlighting a case of failure. Failed orchestration processes and corrective mechanisms could constitute an emerging field and offer an important contribution to knowledge in this field. Although it is difficult to pinpoint failed industries affected by orchestration processes, this research calls for replicative studies on failed ecosystems. Here, further work should investigate more specific questions for consideration in future research, which could extend these findings. I observed that the current literature tends to focus on how ecosystems are evolving without considering how they, and the environment, co-evolve; this aligns with propositions made by Piepenbrock (2009).

Firstly, this research calls for studies on how orchestrators co-evolve with stakeholders and ask whether there are differences in value articulation, creation and capture. Following this, it is necessary to explore the impact of this co-evolution on society. Secondly, following the argument on value propositions, definition and imposition, and value capture by the software vendor, this study highlights the need for more work to study corrective mechanisms for failed ecosystems. Anti-trust literature previously reported the successful correction of Microsoft's behaviour when the government stepped in (Economides, 2001). There may be a need for new research with new propositions to tackle complex modern global issues. Thirdly, very few scholars have researched the rules governing membership and relationships (Jacobides et al., 2018). This chapter provides specific empirical knowledge on how an orchestrator recruits prospective members with the use of marketing power. The use of marketing power is underrepresented in ecosystem research and requires further research. Finally, the process model presented in this study shows that orchestration processes can cause a failure in terms of sector-wide innovation. It also illustrates how it can slow down the sector's evolution by favouring large, vertically integrated firms in order to pursue self-profit. Assuming the role of the leading hub is a central issue in setting the mechanisms for value capture, therefore, future research could explore the legitimacy of the leading firms in orchestrating ecosystems. This highlights methodological issues around hierarchy, power and agency in a sector's evolution. Inquiries into this possibility should address both the strategic choices set by the leading hubs and the role of feedback loops in relation to industrial evolution, which echoes the call by Jacobides and Winter (2012).

3.7 CONCLUSION

This study contributes to the understanding of failed ecosystem orchestration while illuminating that orchestration processes can manifest the dark side and create negative effects on sector-wide innovation in B2B contexts. In doing so, this research has set the stage for future research on the dark side of ecosystem orchestration (Oliveira & Lumineau, 2019). The results highlight that prominent firms could preserve control and dominance through marketing power was not widely discussed in the ecosystem literature. Through power and dominance, prominent firms can selfishly aim for solo value capture, which abuses their status over SMEs. The study shows that a history of dominance amongst prominent firms can further influence the strategies adopted by incumbents, which contributes to the lack of inter-organisational and inter-industry collaboration. This opportunistic and selfish value capture can seriously damage the innovation capability amongst entrepreneurial SMEs. A nascent market is less likely to emerge as an ecosystem provides the incentives to preserve the status quo. It should be noted that these findings are generalisable to the literature on ecosystem emergence and orchestration.

In terms of the contribution to practice, this study offers useful insights on how the software vendor orchestrates their environment, thus creating awareness amongst executives in the sector. For executives, this study is a stark lesson on the dark side of the marketing strategies deployed by prominent firms in power. By following their lead and not listening to the operational level concerning innovation management, executives can seriously limit value capture by their own firms when making decisions. Thus, by learning about the dark side, decisions makers can make meaningful choices in relation to digital innovation with BIM technologies. It might be that executives develop capabilities to organise the dark side in an effective way (Zyglidopoulos, Hirsch, Martin de Holan, & Phillips, 2017). However, a tension arises if clients impose their views on digital innovation in the sector and the executive's desire to win the project; this leaves executives with a difficult decision on whether to continue with the current status quo or meaningfully apply persuasive capabilities to change a client's views.

Policy makers can address the issue of corrective mechanisms in the sector. The challenge is that prominent global firms have the power and resource to impose their views. For policy makers, these findings serve as a reminder that new ecosystems can fail to emerge if global players are not incentivised to collaborate, and if they perceive any change as a high-stakes game. Policy makers must ensure that the leading firms take responsibility for the data created in their platforms that also largely contributes to the failure in value creation and capture, and thus impact productivity, trust and innovation amongst SMEs. To conclude, this study posits that ecosystems may fail to emerge in certain contexts that are dominated by firms with power and no corrective mechanisms. The findings of this chapter offer a step forward to a deeper understanding as to why and how ecosystems might fail to emerge in certain contexts.

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CHAPTER 4

Chapter 4. CRITICAL CONSTRUCTS AND COMPONENTS OF ECOSYSTEM ORCHESTRATION

ABSTRACT

In this inductive multiple-case study set in the built environment sector, which is going through a digital transformation with emerging technologies (e.g. Building Information Management (BIM)), I investigate how and why the sector is failing to make a qualitative digital transformation with BIM. The failures in this sector were compared to successful transformations in the automotive, taxi and semiconductor sectors while testing the critical components and constructs of the success and failure for ecosystem emergence and orchestration. The comparison illuminated that the components and constructs fall into three categories - *failing*, *enabling* and *building* elements. The findings show the importance of the sector's nature and the context for ecosystem emergence and orchestration. The findings contribute to the emerging field of the dark side of ecosystem orchestration and are potentially important steps in showing how and why ecosystems fail and succeed.

KEYWORDS: sector context, critical constructs and components, ecosystem orchestration, the dark side

4.1 INTRODUCTION

Over the last two decades, scholars have shifted their interest towards the ecosystem as a new way to form interdependent cooperative relations with competitors and complementors in dynamic environments. These cooperative relations displace vertically integrated supply chains and traditional markets (Iansiti & Levien, 2004a; Jacobides et al., 2018; Moore, 1998). As a result, there is an increased interest in understanding the processes of ecosystem emergence and orchestration (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011; Navis & Glynn, 2010; Santos & Eisenhardt, 2009).

Prior literature extensively examined the key orchestration mechanisms of successful firm strategies in established ecosystems focusing on the evolution of technologies, markets and products (Adner & Kapoor, 2016; Nambisan & Sawhney, 2011) with little consideration of the sector evolution (Jacobides et al., 2016). Some success examples of business ecosystem orchestration are Google, Facebook, Intel and Uber. However, most works have discussed the positive effects of ecosystem orchestration mechanisms, partly from a firm perspective and mostly based on the limited empirical analysis of success cases while only a few studies have examined failed sectors and ecosystems (Jacobides et al., 2016; Oliveira & Lumineau, 2019; Ozcan & Santos, 2015). Systematic empirical research in this area also remains limited (Aldrich & Fiol, 1994; Gawer & Cusumano, 2014) while some evidence shows that ecosystem emergence can be a difficult process (Ozcan & Santos, 2015). Indeed, ecosystems and platforms more often fail than succeed (Cusumano et al., 2019).

Debates around the success of ecosystem creation without a rigorous analysis of failed ecosystems suggest a "*serious form of selection bias. […] Indeed, only by comparing the strategies of terminated industries with those that completed their life cycles can we assess* *the relative importance of the forces*." (Aldrich & Fiol, 1994: p.665). Therefore, I extend the prior research by examining one sector in the context of failed business ecosystems and systematically comparing the failures in one sector to successful examples in other industries. Based on the available literature, this is the first research that attempts to compare the empirical evidence of failure in one sector to documented success examples of ecosystem orchestration processes while testing the conditions (e.g. importance of sector context, structure-agency relation and business models as structural innovation) of ecosystem emergence.

These arguments are empirically grounded in the contexts of Building Information Management (BIM) implementation (Eastman et al., 2011) in the digital built environment (DBE) sector, as focused on two geographical contexts - Finland and California. The previous two chapters illuminated the failure cases of orchestration mechanisms for BIM implementation in Finland (Chapter 2) and California (Chapter 3). The Finnish case presented the evolution of innovation ecosystem mechanisms for BIM research and deployment at the national level, as led by an open-system orchestrator and public funder, which was aimed at the public good. The Californian case presented the orchestration mechanisms of a business ecosystem for BIM software innovation in the sector, as led by a closed-system orchestrator - a software vendor - which aimed at selfish value capture. Both cases are contrasted in terms of the orchestration mechanisms and contexts in which they operate. However, despite these contrasts, two distinct orchestration processes resulted in similar outcomes and failures. The failures were the preservation of the status quo by key sector actors while favouring large, vertically integrated organisations and the lack of business ecosystem emergence. Thus, the logical question posed in this chapter is: *how have both contrasting contexts with two different ecosystem orchestration mechanisms produced* *similar results and failures?* Empirical evidence from the two previous chapters suggests that the orchestration mechanisms are not the only reason for failure, pointing to the importance of the sector's context, which has not been explored in the previous chapters. Indeed, ecosystems are shaped by the industry architecture, which defines its division of labour, and through feedback loops between the agency and structure that in turn develops capabilities (Jacobides & Winter, 2012). To investigate this observation, this chapter explores the critical components that contribute to success and failure, with a focus on the sector's context and whether it matters for business ecosystem emergence and orchestration.

Given the limited research on the topic, I use a multi-case, multi-level, inductive theory building approach to identify, generalise and analyse the similarities of failure between two sectors. The focus is on the similarities between the two failures because the differences seem to be implausible drivers of failure. The similarities manifested at three levels: the micro-level focuses on individuals (agency), the meso-level on organisations (processes, capabilities), and the macro-level on a system basis, e.g. sector-wide network, (business models, culture, complementors, sector-wide structure). These levels have reciprocal relationships that form feedback loops that drive system dynamics and echo the theory developed by Jacobides and Winter (2012). The generalised similarities of failure are then compared to success mechanisms documented in the published literature on Uber, Toyota and Intel. These successful examples were frequently mentioned and suggested for comparison by the interviewees. To systematically compare examples of failure and success, I used the same multi-level design to collect and triangulate data at three levels.

A key contribution of this chapter is the extension of the overlooked theory of failed mechanisms of ecosystem orchestration in order to provide a deeper understanding of why and how business ecosystems fail to emerge in certain contexts. This work goes beyond the traditional focus of the literature on successful firm strategies that highlights critical conditions for ecosystem failure in relation to sector context. Indeed, there is sufficient knowledge on how individual organisations become leaders of successful business ecosystems, but there is little understanding about the failure of sector-wide inter-organisational innovation (Aldrich & Fiol, 1994; Jacobides et al., 2016). This chapter provides a detailed empirical consideration of a multi-level analysis of one failed sector and compares it to successful ecosystems in other sectors. The empirical findings contribute to the growing interest in cognition and frames at the sector level and business model innovation (Jacobides et al., 2016; Kaplan, 2011; Porac et al., 1989), and the dark side of ecosystem orchestration (Oliveira & Lumineau, 2019).

4.2 COMPONENTS AND CONSTRUCTS OF SUCCESS AND FAILURE IN ECOSYSTEM ORCHESTRATION

Interorganisational networks offer multiple benefits and opportunities to their participants in terms of access to resources, knowledge and learning (Ahuja, 2000; Dyer & Nobeoka, 2000; Powell et al., 1996). Thus, modern firms are increasingly moving to collective value creation and capture in ecosystems (Jacobides et al., 2018). The concept of ecosystems as a network of cooperating and competing firms emerges from the interactions between multiple heterogenous organisations that create new business structures to bring focal value propositions to existing markets or create a totally new market (Adner, 2006; Iansiti & Levien, 2004b; Moore, 1993). Ecosystems are ultimately a new form of network organisation that gives companies a strategic scale advantage to enable a digital economy (Jacobides et al., 2019). They are viewed as new ways to produce goods and values in the Twenty-First Century, also offering numerous benefits for participants (Teece, 2018b). Thus, a new wave of academic publications (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013; Valkokari, Seppänen, Mäntylä, & Jylhä-Ollila, 2017) and industry efforts (Jacobides et al., 2019; Kelly, 2015; Lang et al., 2019; Sengupta et al., 2019) have emerged to identify and articulate the orchestration mechanisms of successful leading firms. Governments have also invested great efforts in searching for effective mechanisms to enable ecosystem emergence and thus contribute to the digital economy (Rinkinen & Harmaakorpi, 2018; Rytter Sunesen, Henriksen, Kantanen, Dressler, & Buhrmann, 2019). This literature has an optimistic angle in presenting the success stories of singular firms that have created new digital markets by putting traditional industries at risk of extinction.

While the majority of publications are dedicated to successful examples based on limited empirical analysis, few scholars dedicated rigorous empirical work to failed cases (Aldrich & Fiol, 1994; Jacobides et al., 2016; Ozcan & Santos, 2015). This suggests that ecosystems can generate successes as well as failures, or a success in one context and a failure in another. For example, a successful mobile Internet service created by the Japanese mobile network operator, NTT Docomo, failed in the EU context (Tee & Gawer, 2009). Cusumano and Gawer (2002) attributed its success to platform leadership and ecosystem orchestration in the Japanese context, while Tee and Gawer (2009) explained its failure in the EU context suggesting that there are distinct differences in the industry architecture (Jacobides et al., 2006). Failure can also be attributed to ecosystems becoming "*ego-systems*" (Jacobides et al., 2019: p.17), or a double-edged sword exhibiting an inequitable distribution of value share by leading orchestrators (Jacobides & Tae, 2015). Indeed, scholars have fixated on success stories overlooking the failed cases of both ecosystems and industries that attempted to make a transition towards new digitally networked economies (Aldrich & Fiol, 1994).

The review of existing literature on the orchestration mechanisms of successful examples revealed its lack of clarity on the critical components of success and failure. However, despite the lack of an integrated view on ecosystem orchestration, some claim that ***modularity*** leads to ecosystem emergence (Jacobides et al., 2018), while others suggest the important role of ***leadership*** (Iansiti & Levien, 2004c; Müller-Seitz, 2012) and ***governance or orchestration mechanisms*** (rules, coordination, roles, leverage, and etc.) for ecosystem emergence (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011). ***Platform leadership and design*** interlinked with modularity is also attributed to the success of individual heroic cases, like Google and Intel (Gawer & Cusumano, 2002). Firms that are able to resolve and control technical and strategic ***bottlenecks*** can capture significant value by controlling the performance of an ecosystem. The concept of ***bottlenecks*** explains why some platform leaders are able to capture disproportional value (Baldwin, 2015; Hannah & Eisenhardt, 2019). Some studies highlighted the importance of the ***capabilitie*****s** of leading firms in orchestrating the ecosystem (Dagnino, Levanti, & Mocciaro Li Destri, 2016; Helfat & Raubitschek, 2018; Teece, 2018a), while others suggest that capabilities are developed through experience as the case of Intel showed (Gawer & Cusumano, 2002). Capability development, however, is largely affected by the feedback loops provided by the ***industry architecture*** that also guides ***agency and capability*** development (Jacobides & Winter, 2012; Tee & Gawer, 2009). The ***business models***, as structural innovations, guide firm-specific choices in the context that also determine the evolution of capability development (Jacobides & Winter, 2012). Some studies described the complexity of ***power relations*** between organisations (Gurses & Ozcan, 2015; Jacobides et al., 2016; Ozcan & Santos, 2015) explaining why ecosystems fail in certain industries. Few studies mentioned ***cognition, frames and mindset*** as critical components of ecosystem failure (Jacobides et al., 2018;

Jacobides et al., 2019; Porac et al., 1989; Smith, 2006). Despite its importance for agency development, evidence of serious studies examining cognition, frames and mindset in relation to failure is scarce across the ecosystem literature. Together, the findings of these studies are consistent with the importance of many different factors that contribute to failure and success in individual cases.

Thus, the presented constructs and components of the success and failure of ecosystem emergence (modularity, leadership, orchestration, bottlenecks, capabilities, industry architecture, agency, business models, power relations, platform and cognitive frames) are organised across three levels: individual, organisational and system. They constitute a basis for the systematic order of critical components presented in the literature on heroic examples of success and failure. Each published study considers the components that contributed to failure and success. **Table 10** presents the analysis of studies that documented the success studies and **Table 11** presents the analysis of failure studies.

The systematic order of components revealed that the success of ecosystems is largely attributed to leadership and orchestration mechanisms. The review of failure cases shows three critical constructs that contribute to failure: cognition and mindsets, industry architecture and power relations. It seems that different types of component hold certain functions for ecosystem emergence and orchestration. However, the surplus of studies exploring the cases of failure and success is increasing; a large proportion of studies lack empirical evidence offering ad hoc explanations of success with limited consideration of the sector's context of ecosystem embeddedness. These studies offer little insight into the order of underlying components of failure and success and leave questions open about the relevance of the sector context for ecosystem orchestration.

Table 10 Systematic Order of Components and Constructs of Successful Ecosystems, Derived from the Literature [11]

		Critical components of ecosystem success													
	Levels	**1**			**2**			**3**							
N	**Components of success derived from literature**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**Sector**	**Type of ecosystem**	**Summary**
1	(Parida, Burström, Visnjic, & Wincent, 2019)		1				1			1			Manufacturing	Business	6 manufacturers are transforming business models & orchestrate ecosystem for circular economy
2	(Roundy et al., 2018)	1			1		1						-	Entrepreneurs hip	Entrepr. Ecosys. Emerg.: intentionality, coherence of activities, and injections of resources
3	(Teece, 2018a)		1		1					1			Uber	Business	Business model innovation is not a guarantee of success; dynamic capabilities define success
4	(Giudici et al., 2018)		1				1						Business Incubator	Innovation	Open-system orchestrator builds a network's capabilities
5	(Helfat & Raubitschek, 2018)		1		1								-	Platform	Expanded Teece (2018), dynamic capabilities are critical to platform leaders
6	(Hurmelinna-Laukkanen & Nätti, 2018)		1		1								-	Innovation	Leaders need capabilities to be able to orchestrate
7	(Dattée et al., 2018)		1			1	1		1				Tech-based firms	Platform	Firms orchestrate the complementors while uncertainty
8	(Hannah & Eisenhardt, 2019)		1			1	1						Residential solar	Business	Presented strategies of several firms, capabilities are not given but built through experience
9	(Dagnino et al., 2016)	1	1		1		1			1			-	-	Multi-level analysis of intentional governance of network
10	(Van Alstyne, Parker, & Choudary, 2016)		1		1		1			1		1	Apple	Business	Two-sided market with value built on the network effects
11	(Jacobides & Tae, 2015)		1		1	1							Computer sector	Business	Firms with superior capabilities holding a higher share of the market can become a bottleneck capturing most value
12	(Gurses & Ozcan, 2015)						1				1		Pay TV	Business	Entrants can frame their product as complementary to the incumbents, and in alignment with the dominant frame of the regulators. Groups that create a ripple effect to influence institutional actors
13	(Levén et al., 2014)		1				1						Process IT govern. programme	Innovation	Emphasised the importance of hub and orchestration processes
14	(Libert et al., 2014)						1			1		1	Uber	Business	New business model and agency to change regulation, and become a tech-firm
15	(Thomas, 2013)		1		1							1	Telecommunications	Business	Process of ecosystem emergence involves resource, technological, institutional and contextual activities
16	(Gawer, 2000; Gawer & Cusumano, 2014)	1	1				1	1		1		1	Intel	Platform, innovation	Intel's leadership & capabilities in propagating a change across the whole sector towards modularity

[11] **Individual level:** A-Agency, B-Leadership C-Cognitive frames/Mindsets; **Organisational level:** D-Capabilities, E-Bottlenecks, F-Orchestration
System level: G-Modularity, H-Industry architecture I-Business models, J-Power, K-Platform
1- Success, 0- Failure

Table 8 Continued [12]

		Critical components of ecosystem success													
	Levels	**1**			**2**			**3**							
N	**Components of success derived from literature**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**Sector**	**Type of ecosystem**	**Summary**
17	(Paquin & Howard-Grenville, 2013)		1				1						Industrial Symbiosis	Business	Hub builds the capacity for orchestration
18	(Cennamo & Santalo, 2013)											1	Video game	Platform	Role of positioning & strategy is driving competitive advantage
19	(Gausdal & Nilsen, 2011)						1						Health Innovation	Innovation	Parker’s orchestration process is enhanced with eco-health
20	(Batterink et al., 2010)		1				1						Agri-food sector	Innovation	Innovation network
21	(Nambisan & Sawhney, 2011)		1				1						Salesforce, Boeing	Business	A hub firm is orchestrating the ecosystem
22	(Piepenbrock, 2009)		1				1						Auto, Airline, Airplane	Business	“Sources of superior firm performance lie […] in the network architecture of the firm's extended enterprise.” (p.59)[13]
23	(Santos & Eisenhardt, 2009)			1							1		Comput. & telecom.	Business	Agency and logic rest on the rationale of power
24	(Li, 2009)		1				1			1		1	Cisco	Business	Heavily relied on external partnerships for symbiosis
25	(Iansiti & Levien, 2004c)		1				1					1	-	Business	Keystones and dominators that take it all
26	(Cusumano & Gawer, 2002)		1				1					1	Mob. internet service	Business	Success is attributed to the platform strategy leadership
27	(Chesbrough & Rosenbloom, 2002)		1							1			Xerox	Business	Employed an effective business model for tech. commercialisation
28	(Dyer & Nobeoka, 2000)		1		1		1			1			Toyota	Business	Alliance network orchestrated the supply chain
29	(Moore, 1998)		1				1						-	Business	Firm and new way of organising business wins

[12] **Individual level:** A-Agency, B-Leadership C-Cognitive frames/Mindsets; **Organisational level:** D-Capabilities, E-Bottlenecks, F-Orchestration
System level: G-Modularity, H-Industry architecture I-Business models, J-Power, K-Platform **1- Success, 0- Failure**

[13] “Sources of superior firm performance lie neither exclusively within the firm, nor in its industrial environment, but in how the firm interacts with its environment - i.e. in the network architecture of the firm's extended enterprise.” Piepenbrock, T. F. 2009. ***Toward a theory of the evolution of business ecosystems: Enterprise architectures, competitive dynamics, firm performance & industrial co-evolution***. Cambridge, MA: MIT Press. , Cambridge, USA. (p.59)

Table 11 Systematic Order of Constructs and Components of Failed Ecosystems, as Defined in the Literature [14]

		Critical components of ecosystem failure														
	Levels	**1**			**2**			**3**								
N	**Components of failure derived from literature**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**Sector**	**Type of ecosystem**	**Summary**
1	(Heikkilä & Heikkilä, 2019)				1		1		**1**	1	1	1	0	Taxi	Business	Deregulation of taxi sector has led to increased tax evasion, traffic congestion, reduced use of public transport by 6-7%
2	(Almpanopoulou, Ritala, & Blomqvist, 2019)			0					0		0			Energy sector	Innovation	Set of regulative, normative, and cultural–cognitive barriers that restrict the emergence of ecosystems
	(Mele et al., 2018)	0												-	Service	Dark side of agency (opportunism, conflict, ambiguity)
3	(Jacobides et al., 2016)	0		**0**				0	**0**		0			Automotive sector	Business	Modularity was dropped to preserve the hierarchical control over the supply chain
4	(Ozcan & Santos, 2015)			0							**0**			Mobile payment service	Business	Participants in distinct global industries cannot agree on the market share with a history of sector dominance
5	(Gurses & Ozcan, 2015)								0		0			Pay TV	Business	Our comparison of one failed and one successful attempt to introduce pay TV in the U.S. Failed strategy to enter the field with powerful incumbents in a regulated market
6	(Helper & Henderson, 2014)			**0**										General Motors	Business	GC failed to copy Toyota's orchestration practices
7	(Clarysse et al., 2014)		0				0							Start-ups, govern. Programme	Knowledge	Business ecosystems need global large players; the knowledge ecosystem failed to attract business leaders to form business
8	(West & Wood, 2013)			0						0				Symbian	Platform	Had solutions much earlier than iPhone and Android but failed to agree within the firms. Issue was managerial and organisational
9	(Tiwana, 2013) (book)						**0**							Smartphone	Business	Failed to recognise that nature of competition changed to ecosystem orchestration
10	(Davis & Higgins, 2013)			0						0				Blockbuster	Business	Outdated Business Model while missing opportunity to purchase Netflix
11	(Libert et al., 2014)			0										Taxi	Business	Taxi drivers: "we are not a technology firm". Ownership model (traditional taxi) over intangible assets (Uber), control over orchestration
12	(Tee & Gawer, 2009)		0						**0**			0		Mobile internet service	Business	i-mode successful in Japan but failed in the EU due to the sector structure and the inability to persuade complementors

[14] **Individual level:** A-Agency, B-Leadership C-Cognitive frames/Mindsets. **Organisational level:** D-Capabilities, E-Bottlenecks, F-Orchestration **System level**: G-Modularity, H-Industry architecture I-Business models, J-Power, K-Platform. L-Side Effects **1- Success, 0- Failure**

Table 12 Continued[15]

		Critical components of ecosystem failure														
	Levels		**1**			**2**		**3**								
N	**Components of failure derived from literature**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**Sector**	**Type of ecosystem**	**Summary**
13	(Lucas & Goh, 2009)			0										Kodak	Business	Culture and rigid, bureaucratic structure hindered a fast response to new technology – Innovator's dilemma
14	(Benner & Tripsas, 2012)			0	0									Digital cameras	Business	Perception based on sector affiliation; mindset can be driven by capabilities
15	(Porac et al., 1989, 2011)			**0**	0						0			Knitwear	Business	The mental models of strategists form a critical link between group-level and firm-level dynamics.

[15] **Individual level:** A-Agency, B-Leadership C-Cognitive frames/Mindsets. **Organisational level:** D-Capabilities, E-Bottlenecks, F-Orchestration
System level: G-Modularity, H-Industry architecture I-Business models, J-Power, K-Platform. L-Side Effects **1- Success, 0- Failure**

This chapter aims to fill this gap by empirically examining the sector's context and the components that contributed to the failure of ecosystem emergence while comparing them to the success stories. The chapter answers the following questions: (1) *What is the role of the components and constructs in contributing to the success and failure of the ecosystem orchestration? Is there an order to these components and constructs?* (2) *How and why does the sector's context matter for ecosystem emergence and orchestration?*

4.3 METHODS AND DATA

Given that the failure mechanisms of ecosystem orchestration are underexplored empirically, this research pursued an inductive interpretivist methodology with an unbiased perspective (Gioia et al., 2013). The methodology adopted by Gioia et al. (2013) is used in this study to explore the similarities of failure mechanisms in two case studies at three levels - individual, organisational and system level, e.g. sector-wide network, - and to contrast these similarities with the successful mechanisms provided in existing literature. Gioia et al. (2013) offers a methodology that captures the meaning of people's experience of a given phenomenon and theorised this experience scientifically (Gehman et al., 2018). As per Strauss and Corbin (1990), interviewees' experiences are interpreted and structured to construct a theoretical perspective that is grounded in, and emerges from, the data. Considering that the well-established template of Gioia et al. (2013) often focuses on single cases to build a compelling story, Gehman et al. (2018) suggests that the method can be customized and modified for a particular research context to find the theory-method fit.

While Chapters 2 and 3 presented contrasting open and closed-system orchestration mechanisms and their effects on sector-wide innovation, this chapter ignores the systemic differences of two cases. This considers the orchestration mechanisms of TEKES and the software vendor, varieties of capitalism (Hall & Soskice, 2001), market size, geography and standardisation as irrelevant drivers of failure. Instead, the focus is on the similarities between the two failures because this research suggests that the potential explanation for the failures in two cases is grounded in similarities. Considering the richness of the data collected, the methodology developed by Gioia et al. (2013) was used to construct the grounded model that was based on similarities between two cases. From this basis, the emergent data structure was contrasted with existing success stories to make a contribution.

4.3.1 Empirical Context: Case Selection and Overview

The research setting is the implementation of Building Information Management (BIM) technologies in the northern Californian and Finnish digital built environment sectors. I refer to the digital built environment sector as a general term describing the supply chain and its wider network of co-evolving actors who adopted BIM technologies.

The setting is attractive to this research for several reasons. First, two cases were chosen because of their contrasting varieties of capitalism (Hall & Soskice, 2001), their early adoption of BIM, their extensive sector and research collaboration for BIM R&D, their openness to innovation, collaborative cultures and the presence of high-tech communities that exhibited a strong interdependence between various actors in the ecosystem of the sector. The significant difference is in the orchestration mechanisms within the two contexts: while Finland had 37 years of national development of BIM led by a governmental public funder, the northern Californian built environment sector is orchestrated by the software vendor which is co-located and intertwined with Silicon Valley actors and a network of top local universities. There is a distinct regional advantage in both cases. Both cases exhibit complex relationships between various actors making inter-firm and inter-organisational collaboration crucial for the development of relationships. Furthermore, actors from both contexts have a long-term international collaboration and exchange of knowledge for BIM R&D.

Second, despite the systemic differences, these cases have produced similar results, such as the lack of business ecosystem emergence, a preference for vertical integration, the preservation of status quo and the inability of the sector actors to capture the promised benefits from BIM implementation while adopting BIM under old business practices. Previous chapters presented the failed orchestration mechanisms set by a public funder to support BIM implementation in Finland and the software vendor that orchestrates the ecosystem for its sector platform in California.

4.3.2 Data Collection

Interviews. The collected qualitative data is comprised of interview data as a primary source and archival data as a secondary one. A total of 25 interviews were conducted in Finland in 2015 and 37 interviews were conducted in California in 2018. The interviews were conducted with the leading experts across six key stakeholders: i) academia (FIN:6; CA:3); ii) clients (FIN:2; CA:5); iii) supply chain: business & management (FIN:8; CA:13); iv) supply chain: technology operation (FIN:4; CA:9); v) other (FIN:5; CA:7)). The other actors comprised software vendors, start-ups, individual public organisations and institutional communities. The juxtaposition of different viewpoints on technological development brings into focus contrasting perspectives on socio-technical change. Such integration has provided contrasting pictures of the same processes without nullifying these differences (Van de Ven & Poole, 1995). The interviews varied in duration but ranged between 30-160 minutes. A total of 62 key leading experts shared their experiences with BIM across Finland and California. The interviewees were generous in sharing their insights as the data collection was rich and fruitful.

The original semi-structured interview protocol was based on the approach developed by McCracken (1988). The following questions were explored: (1) *How has the sector evolved in relation to the use of ICT and BIM?* (2) *What is the current state of the sector's adoption of BIM?* (3) *What are the critical challenges that the sector is currently experiencing with BIM?* As the interviews progressed, open questions were directed at emerging themes and cases.

However, the approach by McCracken (1988) was useful in the Finnish context and proved to be irritating to the Californian interviewees. As long as the interviews continued in California, I adjusted my methods to direct the discussions towards specific questions by allowing the interviewees to freely highlight the important issues, as experienced in their practice and based on the problem-driven theory developed by Corley and Gioia (2011) .

When the data collection was completed, each interview transcript was provided for approval by the interviewee while every transcript was labelled with a unique number identifiable only by the researcher to preserve the anonymity of the interviewees. Quotes that could potentially identify individuals were eliminated to preserve the anonymity of the interviewees.

Archival sources. In addition to the interview data, relevant literature on the Finnish and Californian built environment sectors in the form of reports, published articles, news articles and internal company documentations were collected to obtain historical evidence of strategic change in the industries in relation to technological implementation over the last 20 years. Furthermore, successful orchestration mechanism cases were also collected to build an understanding of how successful firms orchestrate their ecosystem and what mechanisms they implement at the designated three levels (individual, organisational and the sector-wide network). The cases were selected because the key interviewees frequently pointed out that I should compare the case of the DBE sector with those of Uber, Intel and Toyota.

The richness of the collected data allowed for triangulation in various ways (Jick, 1979), by circulating between the validated transcripts, archival sources and the discussions with key experts, and thereby eliminating potential biases and validating the results. During the process, I continued to communicate with key interviewees informally by providing preliminary evidence to clarify certain issues. This process allowed for the engagement in "*gestalt analysis*" to make sense of the data (Gioia & Thomas, 1996: p.377).

4.3.3 Data Analysis

The interviews provided the primary data for analysis while the archival sources were used to refine interpretations of the emerging categories. The analytical process allowed for the construct of a theoretical model through a disciplined examination of the emerging competing explanations by considering similarities between two empirical cases. As the research progressed, the emerging categories, as drivers of failure, were contrasted with the existing literature. Thus, the data were analysed in accordance with the methodology provided by Gioia et al. (2013) in which my empirical observations were connected to extant theoretical ideas (Langley et al., 2013). A simplified sequence of steps is presented through multiple, intertwined steps that were repeated a number of times.

Step 1: Event analysis and open coding. Although the cases were analysed in the previous chapters, this chapter required the coding of data to focus specifically on the sector context rather than the orchestration mechanisms. Therefore, the analysis started with the open coding by systematically reconstructing the myriad codes and themes, each containing a sentence or a sequence of sentences (Weber, 1990). I continuously engaged in an intensive reading of the data (Strauss & Corbin, 1990) building a large database of two in-vivo codes and following the guidance provided by Gioia et al. (2013). I frequently iterated between the emerging categories and the creation of the first-order categories (Strauss & Corbin, 1990). Then, I further refined the first-order categories by merging them and forming second-order categories that presented issues related to the sector context. In this step, more than 50 different second-order codes emerged for each case.

Step 2. Axial coding. In the next step, the analysis progressed to axial coding. First, I further continued to refine the emerging second-order categories by reducing and merging them into aggregated themes (Gioia et al., 2013) for each separate case. Then, I started to eliminate the categories dedicated to the software vendor, the public funder's orchestration mechanisms and the specific issues related to BIM implementation leaving all the remaining categories. As the research progressed, the continuous circulation and iteration allowed for further refinement of the categories and themes by reducing their number to a mutually exclusive and collectively exhaustive number of second-order categories and aggregated themes and dimensions (Gioia et al., 2013). This step has been performed iteratively by making extensive use of notes and discussions to interpret the data.

This generated two different data structures that were still messy; however, they were telling a very similar story. The remaining categories and themes in each case were clearly pointing to the issues related to the sector's desire to preserve the status quo and its inability to evolve beyond the established business practices. These issues were mentioned in the previous chapters, but this data points to the dark side of the sector suggesting that orchestration mechanisms were not definitive factors in the failed emergence of business ecosystems despite their significant influence on sector-wide innovation. The final refinement of the themes and dimensions pointed to sector issues as underlying components of the sector dynamics. These were related to individuals, sector structure and processes, and the inter-organisational relations between conflicting sector actors and actors from outside the sector, e.g. software vendors, government, academia, clients, insurance firms, etc. The data further suggested feedback loops between the sector structure, the agency of individuals, and the capabilities behind the inertial forces echoing the theory of Jacobides and Winter (2012). This highlighted the role of context and high-level casual forces driving the system dynamics at three levels: individual, organisational and system. At this stage, two data structures were generated and merged into one. This iterative process resulted in a data structure **Figure 18** **(**see **Appendix D** for the full version). The research gradually progressed to a theory-driven explanation (Strauss & Corbin, 1990).

Step 3. Contrasting the success examples and building a grounded model. The articulated themes and aggregated dimensions provided a basis for building the grounded model by identifying the linkages between the aggregated dimensions. This helped to explain the sector dynamics and why it preserved the status quo. I have not only induced the categories but also generated interpretations of the observed phenomenon to form a storyline between the second-order categories, aggregated themes and dimensions. These interpretations described the processes and phenomena under investigation, and the so called "*deep processes*" in their relationships (Gioia, Price, Hamilton, & Thomas, 2010).

Then, I collected all quotes related to the suggestions provided by the interviewees in order to compare the BIM implementation in Finland and California to successful examples in other industries. Uber, Toyota and semiconductor industries were frequently mentioned by interviewees. Moreover, through the analysis of the history of the semiconductor sector, I identified that Intel played an important role in orchestrating the sector. Thus, I selected Uber, Toyota and Intel as successful examples.

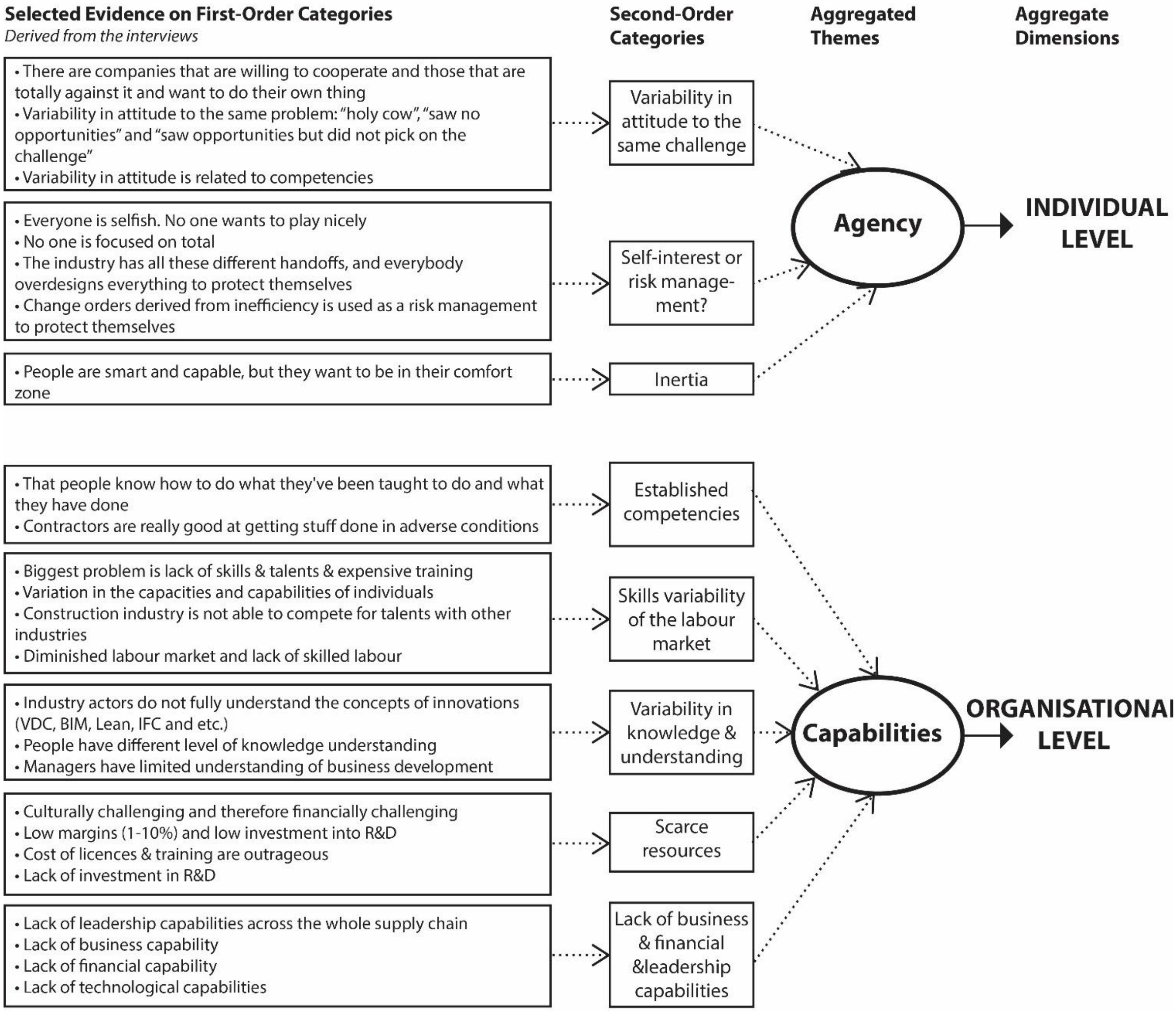

Figure 18 Data Structure

The published literature provides an overview of the orchestration mechanisms set by these firms. Finally, I contrasted the empirical insights generated in this study and the successful mechanisms derived from the Toyota, Uber and Intel. I continuously cycled between the empirical evidence of failure and the published literature, constructing a dynamic image of the phenomenon observed (Nag, Corley, & Gioia, 2007).

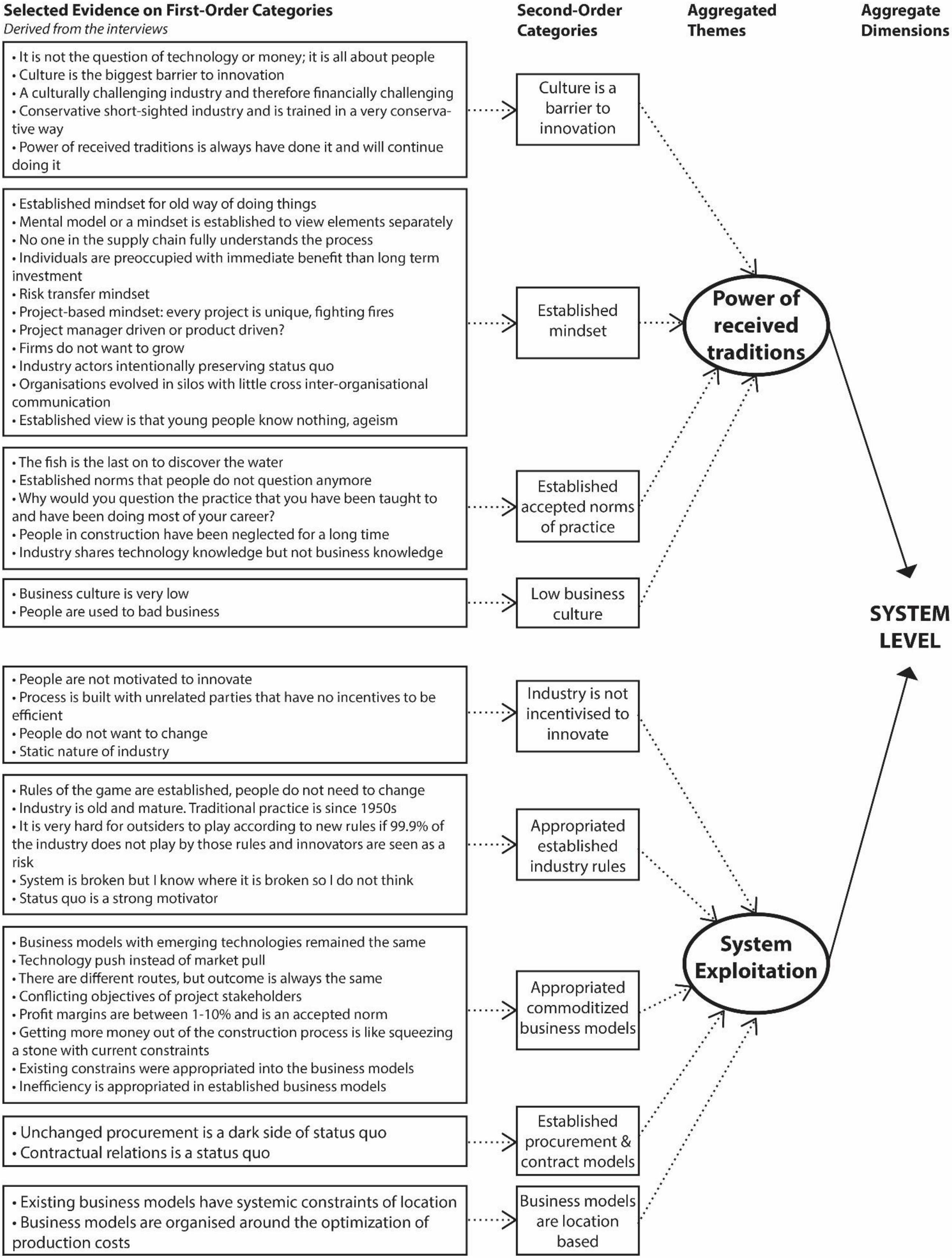

Figure 18 Data Structure Continued

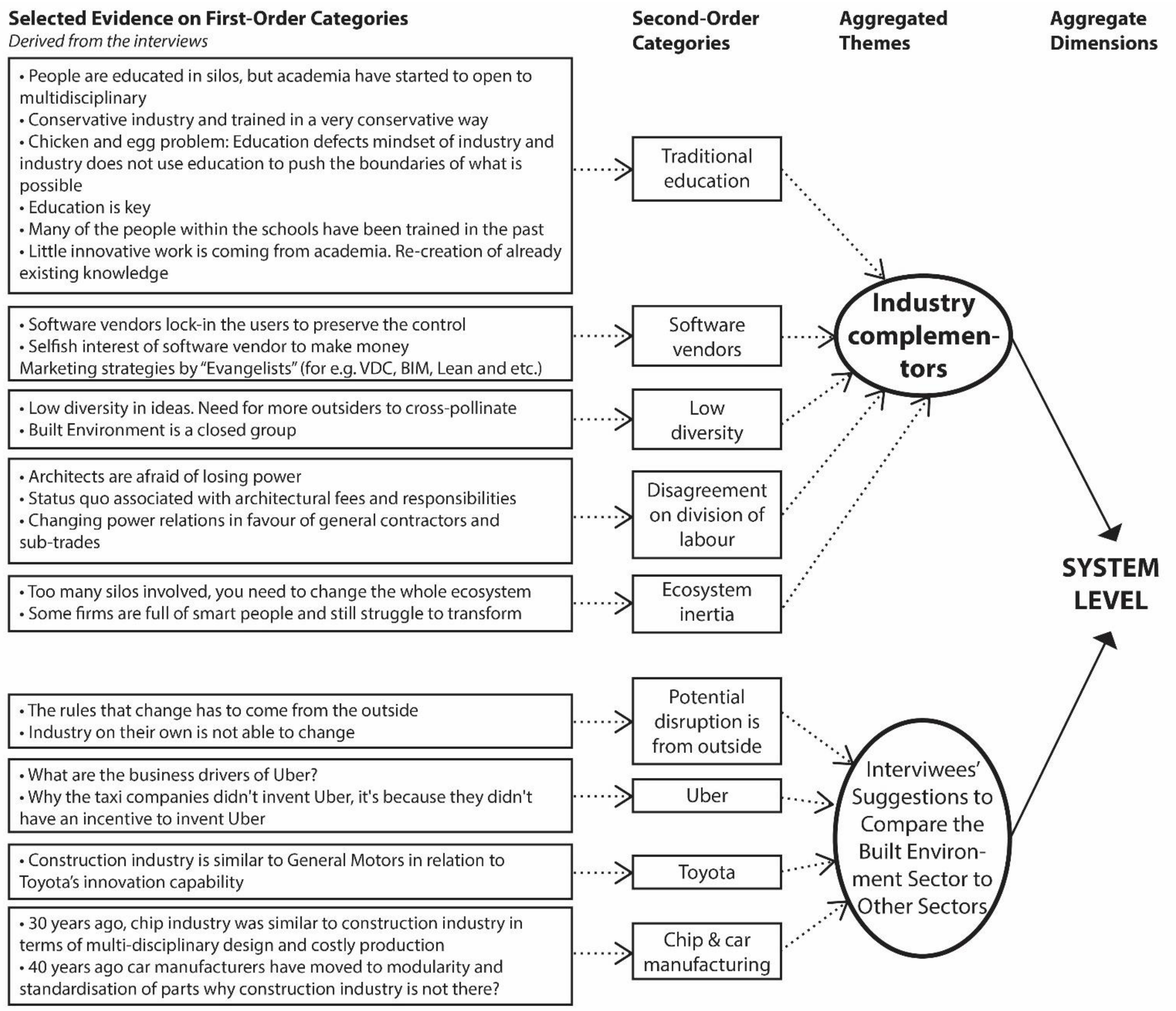

Figure 18 Data Structure Continued

I aimed to understand if there is an order to the components that contributed to the failure and success and whether the sector context mattered in this case. In doing so, I was able to build an understanding of the order of components and their importance for ecosystem emergence and orchestration. The emergent relationships between the components were organised in order of the function and importance they hold at the three levels. This order and the exploration of sector context for ecosystem orchestration constitutes the contributions of this study.

4.4 RESULTS

4.4.1 Exploration of The Sector Context for Ecosystem Orchestration

Following the evidence provided in the previous chapters, this study explores the sector context on ecosystem formation by identifying similarities and critical issues that emerged from the failed cases of ecosystem orchestration in Finland and California. Following the inductive analysis of the interviews in Finland and California, similarities manifested at three levels: *individual*, *organisational* and *system*. At an *individual level*, an aspect of agency varies from individual to individual which aligns choices with capabilities and incentives provided by the organisational and system levels. The *organisational level* is concerned with the constraining areas of capability and resource deployment across the whole sector, which are dependent on the system level. The *system level* was largely taken for granted (Jacobides & Winter, 2012); however, this study suggests that the system level is a critical issue that builds capabilities and influences the strategic choices and agency of individuals, which aligns with the findings of Jacobides and Winter (2012). The dynamics of the sector can be viewed as exploitative. The sector actors who hold power favour the status quo for power preservation as the sector's ecosystem disincentivises them from innovative practices. Evidence shows that individuals are blindfolded by their predisposed beliefs of success and failure because there are no effective measures to prove overwise. There is clear evidence that the sector is struggling to move beyond the established practices due to the absence of necessary elements in the sector's ecosystem, as explained by the CEO of a consultancy firm (CA17):

> Have you read the innovator's dilemma? So, it sounds as much as **it's a closed innovation**. So, you remember the three pillars, he says, it needs disruptive innovation, right? So, you need a simplifying technology; **there is not a single simplifying technology** that's out there. […] So, the Apple Music that was a simplifying technology. So, the second thing is, **you need a new business model, right? We do not have that**… And then most importantly, you need a **value network**… and **we don't have that** because no one wants to play nicely. Everyone wants to kind of say, this is mine and I'm not changing, but you can do whatever you want. (CEO, Ai Consultancy, CA17)

This quote suggests that the sector's organisational structure remains traditional. The next sections will present the interview results at three levels - *individual, organisational* and *system* - considering the details of the collected data in two cases presented in previous chapters.

Individual Level

The literature on inertial properties and the agency-related forces of change are under-represented (Jacobides & Winter, 2012). Considering the complexity of relationships along the value chain of the DBE sector, the analysis indicates that the agency of individuals and their attitudes to the same issues vary. **Variabilities in attitude** are found in individuals within and between firms, who react differently to the same challenges. Researcher (CA38) who promoted BIM to general contractors explains:

> Three companies but with different attitude[s] to BIM. First, [hidden] rejected [the] idea of BIM and did not see any opportunities to learn. Second, […] three top project managers saw BIM as [the] holy cow and saw the future, then they have become CEOs of the same company driving it. Third, [hidden] did not have a bad attitude to BIM but did not see any strategic opportunity. (Researcher, CA38)

The variability in attitude is related to the capacities and competencies of individuals. The individuals have been referred to as smart and capable but wanting to stay in their comfort zones, thus suggesting inertial forces. These inertial forces constitute power preservation, the security of jobs and existing business models.

While some interviewees referred to individuals as "*no one wants to play nicely*" (CEO, Ai start up, CA17) and that some are "*totally against anything*" (CEO, structural engineering firm, CA07) suggesting an ego-centric attitude amongst some actors who hold power, these behaviours are explained by others as a risk management strategy that protects their businesses from loss, e.g. survival strategy. This evidence suggests that structure plays an important role in driving individual choices (Jacobides & Winter, 2012). As a risk management strategy, some individuals intentionally seek change orders in the construction processes. Change orders offer the possibility to occasionally "*win money*" (FIN20) to cover the inherent losses from the lowest bid procurement strategies. The systemic issue is that, in order to win projects, during the procurement phase firms submit proposals based on a lowest bid strategy. Invariably the lowest bid always wins. The change of orders can potentially cover some losses from the lowest bid strategy. However, this strategy is more of a gamble. The risks are associated with unforeseen transactions costs as the manager of a health care client explains:

> What happens is your general contractors are on the job and they are really nice, everything's going well for them, they're checking how much money they can make but once they get to a point they start to lose money then they make the calculation and ask *do I want to stay in a good relationship in this or not*? And to the extent that they want to stay in a good relationship they will just lose margins to keep the owner happy. They even can make a small loss on the project because they really want the next job or there is a benefit to being in this relationship, but at some point, they will switch, right. It may be early, may be late but then they will start to bury the project in change orders, because they have been stockpiling paperwork through the project so they can use it when they need. So, **it is really a risk mitigation tool.** I understand how hard it has been for us to build systems to get people to really accurately project the final cost of the work. (Manager, Health Care Client, CA08)

The issues associated with this strategy arise from the fact that individuals lack system thinking, as no single person understands how the whole sector functions and has no definitive measures of value capture. Individuals also end up with a reductionist view of what constitutes sector dynamics and how the whole functions. This incentivises an individual to protect themselves from losses while dealing with the established norms (e.g. lowest bid culture) of construction practices by acting in a silo. This vicious cycle negatively reinforces the status quo.

While this behaviour is associated with construction professionals, designers were viewed by general contractors and clients as professionals who "*build hours […] by overdesigning*" (CEO, VIF, CA32). The interviewees suggest that this behaviour exists to protect individuals from associated risks. The interviewees stated that clients tended to cut hours from the contract in the design phase. Clients typically assume that the use of BIM technologies allow designers to be more efficient and are therefore not willing to pay for hours above the established industry norm. The status quo associated with the designer's fee structure is a norm that can be observed in the built environment sector in both contexts. However, designers use the given hours to produce safe designs and meet regulation needs. Therefore, within the given time, designers can utilise only workable solutions that are safe. The use of BIM also requires more time in the first design phases, which are typically misunderstood by clients. While clients cut the designer's hours, they also reduce their innovative capabilities, as they tend to stick to existing solutions thus producing conservative designs under time pressures. By working within a limited timeframe, designers overprotect themselves and are not typically willing to take liability for the design or to share their models. The disintegrated process reinforces protectionism, the status quo and traditional practices thereby disincentivising disciplines for innovation, as explained by a CEO of a VIF (CA32):

> The sector has all these different handoffs, and everybody overdesigns everything, you know, to protect themselves. The architect is a separate company from the engineers, the general contractor is a separate company, and subcontractors. And so, the whole process with a bunch of different companies, they're unrelated that work together. […] They have no incentive to innovate (CEO, VIF, CA32)

The protectionist attitude is explained by the tension that individuals experience in projects. The tension arises between the individual's need to protect themselves from the risks associated with the design and the opportunity to innovate. This arises from the unresolved contractual issues associated with liabilities and responsibilities. However, as the CEO of the structural engineering firm (CA07) pointed out, "*contracts represent only 5% of what is happening in the construction*". Therefore, individuals and organisations focus on their siloed survivability strategies while no-one focuses on the whole life cycle costs, e.g. "*no one is focused on total dollars*" (Manager, GC, CA11). The empirical evidence suggests that the ecosystem conditions disincentivise individuals to innovate and make different strategic choices at an individual level. The complexity of choices arises from the dependence on the organisational and system levels.

Organisational Level

The empirical evidence shows great variance in the capabilities and capacities of organisations in the sector, which is also limiting and slows BIM implementation processes in the sector. Indeed, the empirical evidence on competence and capability variability in any sector exhibits substantial performance differences amongst organisations (Gibbons & Henderson, 2012). Organisations lack the business and financial capabilities while holding technical but traditional competencies. Interviewees further reported that traditional competencies are also diminishing in the sector. For example, superintendent (GC, CA22) stated: "*the skills of the tradesmen have diminished. That's a big problem too*". Sector actors have different levels of knowledge and understanding, such as the understanding of their own business model and business model innovation. For example, research on the role of business models in Finnish design and construction firms by Pekuri, Pekuri, and Haapasalo (2013) confirms these findings. Sector actors also understand the concepts of innovation (e.g. BIM, VDC, Lean, etc.) in limited terms or interpret according to established frames of reference, as explained by a VDC manager (CA11_1):

> A lot of people when you start talking to them and you start asking questions about virtual design and construction, … can respond in the conversation with you but I'm not sure that they actually understand virtual design and construction in the way that CIFE would explain. You think that you are gathering information on this topic and you're talking about the same thing but you're not talking about the same thing. (VDC Manager, GC, CA11_1)

Following the evidence presented in the previous section, risk management strategy and financial projection in the sector are poorly understood. For example, some supply chain actors do not understand whether they are making money or not in projects, as explained by a client (CA36):

> I just assumed that companies were a lot more sophisticated in financial projection capability. And we found that some companies are very sophisticated, we found that some big companies have absolutely no idea if they're making money or not, believe it or not, 100 million company in annual revenue has no idea if they're making money or not. So, we've uncovered the things that, in a lonesome agreement or a GMP, you would just never be exposed to that. But once you run a job, basically you open the book with profit and risk and profit sharing, all of a sudden, you start to go like: "WOW, this sector is a lot more dysfunctional than I thought." (PM, Health Care Client, CA36)

Despite a limited understanding of novel concepts, interviewees frequently admired the existing capabilities of sector actors; for example some suggested that people are capable and hardworking, "*contractors are really good at getting stuff done in adverse conditions*" (PM, software vendor, CA30), and "*that people know how to do what they've been taught to do and what they have done*" (Innovation manager, GC, CA11). However, "*being busy, it doesn't mean that you're productive, or that you're efficient*" (Consultant, CA13). This poses serious challenges for changing the system as the hard conditions that actors are used to also constrain them. This will be discussed in more detail in the next section entitled '*System level'*.

A lack of skills, talent, diversity and the diminished labour market have been identified as problematic for the evolution of the sector. While organisations struggle to attract top talent, they are unable to compete with organisations in other industries that offer better opportunities and prospects. This is validated by the existing literature (Farmer, 2016). Moreover, a lack of diversity reinforces biased decisions and established views, thus producing an echo chamber effect.

The deployment of resources is also an issue as interviewees frequently refer to the low profit margins of supply chains, which range between 1 and 10%,; the sector is "*culturally challenging and therefore financially challenging*" (CEO, start up, CA35). The low margins coupled with high risks and the inability of organisations to manage the risks effectively were frequently linked to the established culture of the sector. These conditions have become an accepted norm and were published in sector-recognised reports as early as: *Constructing the team* published by Latham (1994); *Rethinking construction* report published by Egan (1998); the *UK Government construction strategy* published by the Cabinet Office (2011), and *Construction 2025* report published by HM Government (2013). According to Designing Buildings Wiki[16], Alfred's (1934) book, '*Building to the Skies: The Romance of the Skyscraper*', offered one of the first major criticisms of the UK construction sector's standard of performance. The structural conditions of modern construction remained similar to those observed in the 1960s (Wood, 1975).

Low margins further create limited investment within R&D and innovation. For example, "*the outrageous price of personnel training and the cost of software licences*" (Manager, sub-trade, CA21) could be seen an obstacle from the firms with low margins that try to invest in staff training. The cost of training in the sector is not well established. Overall, the sector is ill-equipped to deal with changes and systemic innovation (Katila et al., 2018); in particular,

[16] https://www.designingbuildings.co.uk/wiki/Building_to_the_skies (accessed on 18/03/2020)

the learning curve as a whole in the sector is noted as very slow. An important question arises: *if key decision makers in this sector recognised these issues as early as the 1960-70s, then why does the process remain unchanged and why has it evolved incrementally?* This question will be answered in the next section.

System Level

System exploitation. Empirical evidence supports the importance of system incentives to support innovation in the sector. It clearly indicates that the system disincentivises individuals and organisations to invest in innovation. The system generates feedback loops that incentivises the preservation of the status quo and the established norms of practice. Consequently, powerful sector actors exploit the system for self-preservation, and particularly exploit the inbuilt system inefficiencies.

As the sector structure and practices have remained unchanged since the 1960s (Wood, 1975), "*the rules of the game have been established* […**]** *people do not need to change*" (Innovation Manager, GC, CA11). The appropriated established rules create certain barriers for innovators as "*changing any rule is seen a risk*" (CEO, Ai Start Up, CA). The established sector rules dictate the governing cooperation, competition and outcome.

An acknowledged fact is that the existing "*business models [of the sector] are from the 80s*" (Consultant, FIN04). Interviewees further suggest that whilst actors can take different routes, the outcome remains the same as "*at the end of the day, we still deliver a building*" (PM, Sub-Trade, CA21) and it is their main business. The accepted profit margins (1-10%) have remained low since the economic crisis in 2009, "*getting more money out of the construction process is like squeezing a stone with current constraints*" (PM, Software Vendor, CA30). An interesting finding is that the ecosystem provides incentives to exploit the inefficiencies of existing business models. The existing constraints were appropriated into the established business models as PM (Software Vendor, CA30) shares a conversation with a group of general contractors:

> What are the constraints on the construction sector? What are the things that are keeping the construction sector from being efficient? What if we removed them? And, the contractors all hated it [removing the constraints] and it was not like a definitive sample of it. And, the contractor's feedback quite strongly was you should not be removing these constraints, you should be helping us with these constraints. And I thought that was really interesting because essentially, they have incorporated these rules into their business model. And so, **while these rules are holding them down**, and holding them down to that 4% profit, or that 1% profit, **they are also keeping these constraints in the sector** that are keeping them down, but **they're also keeping them relevant**. (PM, Software Vendor, CA30)

This statement suggests that some leading key sector actors (e.g. consultants[17], contractors and sub-trades) are intentionally preserving established business models. This constitutes "*the dark side of the status quo in that the sector creates money from the waste and some people do not want that changed*" (Researcher, FIN20_1).

The socio-cognitive factors, like mindsets and cognitive frames, guide the sector actors in preserving current constraints while justifying their relevance. As a result of the preservation of the status quo, innovative efforts in the sector are incremental and were mainly dedicated to technology development to improve intra-organisational productivity. Results derived from the Finnish and Californian studies exhibited a strong technology push instead of a market pull.

However, one PM (GC, CA11) suggested that an innovation of a business model could potentially lead to capability development and a mindset shift as it could offer incentives for new value creation and capture, and eventually prompt an evolution of practice:

[17] Consultants are referred to architects, engineers and any other types of design consultants

> When the business deal is different, then that's when you begin to see a deeper change and getting different answers to your questions. […] But it seems if you can make different offers in the market and creating [the] capacity to do that, you end up changing a lot, you change, you use technology differently, you may invent, create technology, your social organisation, the way you organise the work and the way people in that place, work and relate to each other, it can be very different than what you see on most construction sites. (VDC Manager, GC, CA11_1)

The important parts of business models, such as contractual relations and procurement models, also remain unchanged (Cabinet Office, 2011; Mosey et al., 2016). Although some actors, like Sutter Health in California, have implemented Integrated Project Delivery (IPD) that changes the business models of projects (Ashcraft, 2011), empirical evidence shows that the IPD model is not necessarily changing the rules and established practices of sector actors despite the observed benefits of improved collaboration. Client leadership in governing IPD projects becomes of utmost importance in correcting behaviours. However, client leadership typically fails because they do not have the capabilities to lead projects as noted by the interviewees.

Unchanged rules, business, contractual and procurements models constitute the dark side of the construction sector ecosystem. A risk-averse culture is propagated across the whole system including amongst owners. One of the explanations as to why the sector preserves the status quo and confirms its difference from other sectors is because construction business models are dependent on location. Two different buildings in the same location can be bought for a similar price, which leaves little incentive for sector actors to invest in innovation. The price of a building is largely dependent on the value of the land and not the quality of the building or the process of delivery. The location determines the willingness to pay for a building product as end users incentivise sector actors to aim at optimising internal production while the client pays the bills for delivery:

> It is a part of system exploitation and business models. It is good to remember that there are no products where the price of the product would have anything to do with the production costs. Every product, the price for the phone is the willingness to pay. **And the same with the houses; the price of the house has nothing to do with the production cost, it has everything to do with the market price.** What people are willing to pay. The mobile phones, there is no such thing as the location for a phone; you buy phone because of [the] reputation and quality of the product, so these companies have to invest in innovation. But in the building sector, the quality of [a] product, as long as it is good enough to be bought. […] **But as long as the clients are willing to pay [the] asking price, but you do not try to develop it better because it does not pay back. It is part of [an] ecosystem, because it cannot be changed**. No matter what we do. If you are able to reduce production costs you can save money […]. Then, **I do not think it is realistic to think that the construction sector will ever be like [a] car manufacturer or mobile phone**. The situation is so different. (Researcher, FIN20)

Power of received traditions. Both the cognitive and structural elements constitute the building blocks of new ecosystems (Santos & Eisenhardt, 2009). Interviewees have identified the sector culture as a barrier to innovation. Interviewees from both contexts agreed that the issue of innovation in the sector is not the issue of technology or money, but of culture, as an engineer (CA23) explained:

> In my experience, the biggest problem is not a technical one but more of a cultural one. There is sort of established norms on how people work, and people are so used to it and it is so ingrained that people do not question it anymore. (Optimisation Engineer, VIF, CA23)

The power of received traditions dominate the decision-making process suggesting a short-sighted culture amongst sector actors. The established mindset is an important part of culture, which guides sector actors and has a negative connotation, as explained by a consultant (CA13):

> I think that one of the worst mindsets that we have in construction … has been inherited from project to project, from generation to generation is **the mindset of fighting fires**. […] they're **very short in the mindsets**…**there's no leadership, there's no role modelling**, right? The mindset says […] you have to suffer and to sweat blood, because we don't learn from project to project […] each project is unique […]. And actually, I think that one of the worst mindsets that we have in construction is this has been inherited from project to project, from generation to generation is the mindset of fighting fires, right? We have to be busy all the time. And being busy, it does not mean that you're productive, or that you're efficient. […] We have to move from the fighting fires mindset to the look-ahead mindset. (Consultant, CA13)

The issue of the established mindset is derived from the history of the sector's evolution when organisations and disciplinary communities evolved in silos with little cross-organisational communication. Culture provides the established norms that sector actors do not question, as "*Why would you question the practice that you have been taught to and have been doing most of your career*?" (Innovation Manager, GC, CA11), and "*I have always done it and will continue doing it*" (PM, Software Vendor, CA30). A few interviewees further suggested that the sector actors "*are used to bad business*" (Researcher, CA37) and referred to them as "*the fish is the last one to discover the water*" (Innovation Manager, GC, CA11).

Sector complementors. Finnish and Californian sector actors have pointed to the important role of universities in building mindsets and the sector culture. However, according to interviewees, the conservatism, low R&D standards and the traditional siloed methods of teaching are also relevant to the top world universities. Thus, disciplinary education contributes to the development of the mindset of individuals by educating them via traditional methods in silos. The CEO of an Ai start-up (CA35) observed:

> It is [a] chicken and egg problem: education defects [the] mindset of [the] sector and [the] sector does not use education to push the boundaries of what is possible. […] Conservative sector and is trained in a very conservative way. (CEO, Ai Start Up, CA35)

The interviewees pointed out that some educators trained in the past and have limited sector experience; they often do not know how the sector functions and may intentionally preserve the status quo. The data also indicates that some lecturers and professors are afraid of digitalisation, which could potentially lead to the loss of established position and power in traditional methods. Academic success is measured by the number of academic publications; therefore, research does not need to be implemented in the sector, which contributes to a disconnect between academia and practice. The interviewees in both contexts noted that the disconnect between academia and practice are critical. Educational institutions are key complementors that influence the evolution of the sector's mindset, but they are ill-equipped to self-transform or support a sector-wide transformation. These conditions negatively reinforce the sector's status quo.

The surprising fact is that, despite the co-location of the Californian construction sector with the network of top universities and Silicon Valley, the sector is "*still on the conservative side*" and similar to other countries, as explained by the CEO of a start-up (CA35) and a consultant (CA13):

> Silicon Valley is not a construction sector, I am talking about the construction sector; SV is like [a] little microcosm. We have [a] few start-ups here, but they are not there yet, and it takes time. (CEO, Ai Start Up, CA35)
>
> I can say that I've been in projects all over the world. And **there's no difference between a project in South America to a project in the Middle East, or in Africa or in Europe**. **The mindset** is... and sometimes I tell people, **it looks like they were cut out by sisters**, right? That they're out of that cookie cutter thing. They're equal…their mindsets are equal. Well, the way they behaved [is] equal, the way they treat people [is] equal. […] California is slightly more on a progressive side. (Consultant, CA13)

The role of software vendors as strategic partners has also been emphasised in both contexts. However, evidence shows that, although software vendors and technology providers can become strategic sector partners and complementors, they pursue selfish interests for self-benefit. Thus, they have a disproportional influence on the sector dynamics by preserving the power and control, and reinforcing the status quo feedback loop. An example of the software vendor's influence was discussed in detail in Chapter 3.

Inertia is observed across all sector actors while the diversity of the sector remains low. Essentially it falls under the category of "*a closed group*" (CEO, Ai Start Up, CA17; Innovation Manager, FIN21). The sector consists of siloed groups with protectionist attitudes (Morrell, 2015). For example, architects have been resistant to any technological change because supply chains were unable to agree on the division of labour, profit and liabilities. The established designer's fee structure is a status quo while architects are unwilling to lose power in projects. With the implementation of BIM, the power of construction project leadership has shifted from architects to general contractors. The closed-systems in conjunction with conflicting power relations related to the industry architecture hinder the sector's digital evolution. Consequently, sector actors are not able to renew themselves as they are dependent on other competing actors in the ecosystem, e.g. academia, software vendors, insurance firms, regulations, clients, etc. Indeed, "*the nature of innovation challenges [are] confronted by external partners*" (Adner & Kapoor, 2010: p.307).

Selection of sectors for comparison. On the recommendation of key interviewees and scholars who were familiar with this work, a number of sectors were selected for comparison as part of the research design. Finnish key scholars suggested that I should conduct substantial comparisons between the failures and successes in the built environment sector with examples in other sectors. While interviewing experts in California and Finland, some experts compared the BE sector with other successful firms and their business ecosystems. There is a discrepancy in the literature as to which constructs and components do in fact lead to success; thus, there is currently no appropriate theory to explain this (Lussier & Halabi, 2010). An understanding as to why ecosystems fail and succeed is crucial for the development of theory, namely *Why do some ecosystems succeed, and others fail?*

The general observation and agreement amongst key sector actors were that the sector is not able to evolve on its own and disruption has to come from the outside, whether by challengers like Uber or by government initiatives. Three sectors have been mentioned by experts and scholars: 1) the traditional taxi sector and the disruptor Uber; 2) Toyota and the case of General Motors; 3) the evolution of the semiconductor sector.

Uber is disrupting the traditional taxi sector by threatening its existence, as explained by a manager (CA30):

> Look at Uber, they just kind of moved into cities with their lawyers and they said, we do not do medallions, we do not need to follow the rules because of XYZ. So, it is not like, you know, the taxi companies not under threat from another taxi company, it's under threat from something completely different. (Manager, Software Vendor, CA30)

Overall, I was advised by the manager at TEKES (FIN12) to look at the business drivers of Uber to understand the sector dynamics:

> What is the key driver for Uber? You should study that. […] **Customer value – they will pay for everything + Scalability. When you are doing a doctoral thesis, I would strongly recommend you compare other business areas. And Uber is an excellent example.** Very traditional business, all over the world, very regulated and when you look at other areas, you can find thousands of those. Then, when you have a little bit of imagination, you can think about similar cases in construction as drivers. (Manager, TEKES, FIN12)

The traditional taxi sector was compared to the traditional construction sector. The CEO of a VIF (CA32) questioned the traditional taxi sector pointing to the issue of incentives:

> Why didn't the taxi companies invent Uber? It's because they didn't have an incentive to invent Uber. (CEO, VIF, CA32)

Toyota was referred to as the example of an actor with an orchestrator's capabilities while the issues that actors in the sector experience are similar to those of General Motors:

> **This sector has a long way to go to reach Toyota's level of collaboration. […]** But the interesting thing about Toyota was that they were open to receive visitors from Ford, Chrysler, all their competitors got to see what Toyota was doing, but their competitors had the fish problem. […] They literally didn't believe what they saw. Because they knew it could not be true. They were like the fish. **They just, they could not understand anything other than the environment they were in. There was no other way to build cars than to have a giant factory.** (Innovation Manager, GC, CA11)

Numerous attempts to change the project delivery following Toyota's example have been made by clients in California who own large building assets. Clients compared themselves to General Motors who have been failing because of misaligned incentives in the contractual models that constituted the basis of a business model for project delivery, and a lack of leadership:

> You have to have a **financial business deal that supports teams working in the interests of the project**; **the team needs to know that they are collectively at risk**. […] Everyone has the same story. I tried to do it without that [business deal]. And then I had projects that kept failing. **I think General Motors has been through the same thing**, I think [client] as well. […] they need to be incentivized to work together to make the project well […] **but the business deal still doesn't make it all work and just creates an environment which everything else seems to make sense to everybody** because in order to win, you need these other things. **But if you don't have that it's all about goodwill and intention,** which when a project hits, and hits really hard, there is a very high risk of just falling apart and everybody will default to "I got to save my own company". (PM, Health Care Client, CA08)

Intel was cited as an example of industry transformation that did not happen in the built environment sector. Interviewees who worked previously in the silicon chip sector noticed that the built environment sector architecture today is similar to the silicon chip sector's architecture 30 years ago in terms of the fragmented and complex multidisciplinary design and product development, which functions by "*throwing drawings over the wall*" (Engineer, VIF, CA23). An engineer explains that the semiconductor sector was forced to rethink its production:

> … 30 years ago, chip design was similar to the building sector in the sense that many teams were involved in designing all kinds of chips. […] and they all had their own tools, and they did their own thing. Again, in the end, the chip was put together. The particular thing about chip design is that once it is designed, think of it as it goes to the oven, the outcomes are either it is working or [an] inexpensive piece of glass. It was very hard to design a chip that worked first time. And that, also coupled with how costly it was to design something new, you had to stop the whole factory to try [the] new thing. The chip fabrication these days costs like 2 billion. So, if you don't use it for a week, that's a tremendous amount of your resources. They were forced to rethink, and they were forced to go out of their silo environment where everyone used to their own thing and throwing things over at each other. Construction these days, it is about throwing it all over the wall. (Engineer, VIF, CA23)

Thirty years ago, the manufacturing sector also had to rethink its production "*that whole thing has been standardised, that all the standardised pieces come together in a unique way*." (Engineer, VIF, CA23). While one interviewee (PM, GC, CA17) suggested thinking about potential disruption from manufacturers and to answer the following questions: "*What if manufacturers entered the building sector? What if they made the entire building? How would they change the entire ecosystem?"* There are vertically integrated firms whose top management are from the manufacturing sector. For example, Katerra entered the built environment sector to deliver the whole building to the client. However, there is no evidence that vertically integrated firms are changing the ecosystem yet, as they co-exist with traditional firms. A question is, *what can affect a digital transformation in the ecosystem? Why do some ecosystems succeed, and others fail?*

The cases of Uber, Toyota and semiconductor manufacturing were selected for comparison because they were mentioned by interviewees and offer excellent examples of ecosystem orchestration that changed their sectors.

4.4.2 Comparison of Successful Ecosystems to the Failures in the BE Sector

Following the recommendation of interviewees, the success cases -Toyota, Uber and Intel - have been compared to the empirical findings. **Table 13** summarises the critical constructs and components in the success of Toyota, Uber and Intel and the failure of the built environment sector. These constructs and components were discussed in the *Section 4.2 Components and Constructs of Success and Failure in Ecosystem Orchestration*. The analysis showed that leadership and orchestration are important for the success cases and for change in the industry architecture while the built environment sector failed at multiple levels. An in-depth analysis of each success case is depicted in

Table 14**.** The analysis of the critical components in relation to the success cases of Toyota, Uber and Intel are presented below.

Success of Toyota's Orchestration

Several scholars mentioned Toyota as a successful ecosystem orchestrator (Gobble, 2014; Schrage, 2013). While its orchestration mechanisms align with the ecosystem literature, Toyota remains an alliance type of network orchestrator (Dyer & Nobeoka, 2000;

Jacobides et al., 2019). Toyota is regarded a successful example of network management (Womack, Womack, Jones, & Roos, 1990) that proved useful for this research.

Table 13 Systematic Order of Successful Orchestration Mechanisms Contrasted with Failures in the DBE Sector[18]

N	Case studies	Critical components of ecosystem success											Sector	Type of ecosystem	Summary
	Levels	1			2			3							
	Compon.	A	B	C	D	E	F	G	H	I	J	K			
1	Toyota		1		1		1			1			Car Manuf.	Alliance	Run the worst plant in the USA successfully in 3 months
2	Uber		1		1		1			1		1	Taxi	Business	Uber offered disruptive business model
3	Intel	1	1				1			1		1	Computer	Innovation	Intel changed PC's industry architecture through leadership and modularity
4	DBE cases		0	0	0		0	0	0	0	0	0	Built Environ-ment	Failed Business	Failed ecosystems and platforms

The analysis of Toyota's orchestration mechanism shows the importance of managerial practice as well as its supporting business structures. Toyota's leadership and orchestration mechanisms were supported by the relational contracts that defined the business model. In this way, Toyota effectively managed its value creation and capture by the suppliers.

The success of Toyota is confirmed by the findings provided by the VDC manager (CA11_1) who stated, "*when the business deal is different then that's when you begin to see a deeper change". Meanwhile, the PM at the health care client (CA08) suggested "*the business deal*

[18] **1- Success, 0- Failure**

Individual level: A-Agency, B-Leadership C-Cognitive frames/Mindsets

Organisational level: D-Capabilities, E-Bottlenecks, F-Orchestration

Sector-ecosystem level: G-Modularity, H-Industry architecture I-Business models, J-Power, K-Platform *still doesn't make it all work and just creates an environment which everything else seems to make sense to everybody".* This advocates the corresponding proposition:

Table 14 Comparison of Uber, Toyota and Intel Across Components

	UBER & TRADITIONAL TAXI	**INTEL & COMPUTER**	**TOYOTA & GENERAL MOTORS (GM)**	**DIGITAL BUILT ENVIRONMENT SECTOR**
Source	(Cramer & Krueger, 2016; Libert et al., 2014)	(Gawer, 2000; Gawer & Cusumano, 2002)	(Dyer & Nobeoka, 2000; Helper & Henderson, 2014)	Empirical evidence presented in this thesis
Sector	Taxi	Computer	Car manufacturing	DBE Sector
Type of ecosystem	Business	Innovation, Business	Alliance	Non-existent or failing
Ecosystem Strategy	Cheated the competition by creating a new business model	Led the fragmented sector towards modularity intentionally	Management practice supported by relational contracts	Failing or currently emerging
Location factor in nature of the business	Not owning assets, location is irrelevant, open ecosystem	Location is irrelevant, open ecosystem	Location is irrelevant, closed alliance	**Physical, immobile. value is defined by the location**
Business type	B2C	B2C	B2C	**B2B**
Open/closed	open	open	closed	closed
INDIVIDUAL LEVEL				
Agency	Agency activated from the need	Intentionally initiated sector evolution from the need to evolve	-	Cannot evolve without an orchestrator or a need
Leadership	Not documented	Yes	Yes	Failed
Cognitive frames/Mindset	Taxi sector was not able to evolve	Computer sector was not able to evolve	GM failed to adopt Toyota's practices	Definitive factor
ORGANISATIONAL LEVEL				
Capabilities	Yes, capabilities are a factor	Did not have capabilities but built them during the process	Yes, capabilities are a factor	Low, business and financial capabilities are inadequate
Resources	Had resources	Had resources	-	Low, 1-10% Prof.Mar.
Competencies	Was a top entrepreneur	Was a top supplier	Was a top manufacturer	Low, traditional
Bottleneck	-	-	-	Non-existent or not articulated
Orchestration	Does not follow any rules, changed regulation and interacted with the environment	Learnt how to orchestrate during the process	Successfully managed the recalcitrant nature of GM's union and workforce	Failed orchestrations in Finland and California

SECTOR-ECOSYSTEM LEVEL				
Modularity	-	Fragmented sector evolved into modular	Supply chain modularity	Emerging in a vertically integrated supply chain
Industry architecture	Ignored sector structure	Changed structure	-	Failed to change
Platform	Yes	Open standards	-	Failed
Business Model	Business model is a competitive edge	-	Relational contracts to provide the basis of a business fee structure	Failed, unchanged
Power	Changed regulation for self-benefit	Persuaded incumbents (IBM, Microsoft) to change	-	Incumbents preserve power, siloed opportunistic orientation
Culture	Avoided dealing with existing culture of the taxi sector	Changed culture of the sector	Culture is not a factor as Japanese managers managed the worst factory in the US	Strong factor in guiding the sector

Proposition 1*. The business model defines the environment providing a structure and necessary incentives for the development of the agency and capabilities of the ecosystem participants. The business model is a building construct.*

While analysing Toyota's orchestration mechanisms, the case of General Motors' failure became apparent. Toyota's success is best understood in relation to the history of General Motor's inability to imitate Toyota's practices (Helper & Henderson, 2014). General Motors (GM) was regarded as the best-managed and most successful firm in the world (Helper & Henderson, 2014) and yet it failed to adopt the managerial practices of Toyota. When GM established a joint venture, NUMMI (New United Motor Manufacturing, Inc.), with Toyota, to enable an insight into its capabilities, GM allowed Toyota to manage its worst plant that had been already closed for two years (Brown & Reich, 1989). Despite the worst possible conditions for management, Toyota was able to effectively match the efficiency and effectiveness of this US-based plant to Toyota's Japanese plants in just three months (Womack et al., 1990). Helper and Henderson (2014) argued that the mental models and perception of success guided GM's managers towards failure in adopting Toyota's practices.

This case suggests that the mindset and cognition of managers are critical to innovation while "*Japanese culture or governance, or the uniquely recalcitrant nature of GM's union and workforce [...] are implausible*" (Helper & Henderson, 2014: p.53).

> ***Proposition 2****. The culture of the sector is an implausible factor in failure as it can be changed with self-reinforcing business model innovation and leadership. The mindset is critical to innovation and is a failing component.*

Success of Uber's Orchestration

The analysis of **Uber's success** has illuminated a new type of digital orchestrator that, with the use of a disruptive self-reinforcing business model, innovated the supply-demand mechanisms threatening to displace the traditional taxi sector (Teece, 2018a). The business model of Uber is built on facilitating a business ecosystem orchestration by relying on intangible assets by not-managing and not-owning assets; this contrasts with the traditional taxi sector. The founders of Uber had the capabilities and resources to spot a new business opportunity that matched the demand of passengers with the supply of drivers. Uber did not only provide value to the driver-passenger but drove deregulation in the taxi sector (Libert et al., 2014).

An interesting fact is that traditional taxi drivers were not moving into the technology market because they considered themselves non-technology firms (Libert et al., 2014). In line with the traditional taxi sector, design and construction actors are clearly distinguishing themselves as non-technology firms "*as they are not built to become a technology firm*" (innovation manager GC, CA11). Furthermore, Uber does not seem to be concerned with the health of the ecosystem exerting control over the community (Sundararajan, 2014). This suggests that the culture of the organisation and sector are not determinations of failure.

Heikkilä and Heikkilä (2019) present the negative side effects from the Finnish government's deregulation of the taxi sector to support emerging digital businesses in the taxi sector, as in the case of Uber in Helsinki. They further report the negative effects of these processes, such as tax evasion, domination by powerful global firms and the reduced use of public transport. It seems that the case of Uber is an individual success as well as, some may argue, a public failure.

> ***Proposition 3.*** *The culture of the leading hub and sector is not a determining factor for success. An outsider's innovative business model can challenge the established industry architecture and status quo. Successful firms actively change the environment to their needs. The industry architecture is a failing construct if the sector is old and mature.*

Teece (2018a) further argues that Uber's business model innovation is not a guarantee of success as there is no best way to organise a business (Hofer, 1975), while dynamic capabilities are necessary for ecosystem orchestration. Therefore, dynamic capabilities seem to be important for ecosystem orchestration, while Intel's case shows otherwise.

Success of Intel's Orchestration

Contrasting evidence of the need for capabilities is provided by the example of **Intel** who had no experience in orchestration and had to develop capabilities to orchestrate conflicting actors in one of the most complex and fragmented industries - the PC sector - through trial and error (Gawer & Henderson, 2007). The case of Intel shows how a highly competent component maker can become a strategic leader by facilitating sector-wide platform innovation (Gawer, 2000). This suggests the following proposition:

> ***Proposition 4.*** *Capabilities can be built during the process of ecosystem orchestration. Capabilities are a building component.*

The computer sector and Intel were not able to evolve on their own; a symbiotic co-evolution was needed. Intel's initiative started with a few top managers who saw an opportunity. They identified the sector's limitations in delivering value to the end-users. The limitations were the system architecture and the absence of strategic leadership. New uses of a computer platform were needed to increase demand, but different technical bottlenecks in the system architecture slowed the evolution. The failure of established computer manufacturers to address this issue created an opportunity for Intel to become involved in the design of industry architecture (Gawer & Cusumano, 2002). Intel took the lead in governing the ecosystem for a technology evolution and in managing business relations within the ecosystem by becoming *"a catalyst for innovation in the sector"* (Gawer & Cusumano, 2002: p.424). Intel had the "*need*" to evolve and, therefore, became an example of an ecosystem orchestrator who intentionally transformed itself and the surrounding environment. It led the sector transformation from a vertically owned mindset towards a heterogeneous network of actors without a hierarchical chain of command and from a disintegrated industry architecture towards a modular structure. It provided incentives by articulating a value proposition at a system level to conflicting sector actors while offering an opportunity to define value propositions at the individual level (Gawer & Cusumano, 2002). By articulating the value propositions, Intel secured a shared agreement from these actors to restructure the industry architecture. This sustained innovation across the network (Gawer & Cusumano, 2014). The lesson learnt from Intel's success is that the existing culture and the fragmentation and complexity of the sector are not prerequisites for failure while capabilities can be built during the process.

> ***Proposition 5.*** *The existing culture, and the complexity and fragmentation of the sector favour ecosystem failure when leadership is absent. Ecosystem leadership*

can re-organise the industry architecture by articulating new value propositions to direct collective efforts. Value articulation is critical to value capture. Value articulation and leadership are enabling components.

The case of Intel shows that the PC sector went through a structural transformation of the traditional sector in order to become the high performing sector of today. According to interviewees and the literature, the transformation the semiconductor sector was previously similar to the traditional built environment sector. The differences between the PC and BE sector are presented in **Table 15**. The presented characteristics of the BE sector are similar to those of the PC sector thirty years ago. Such differences as value proposition, co-evolution, transparency, feedback loop, interdependence and modularity have been propagated by Intel across the ecosystem. The structural transformation that Intel achieved in the PC sector clearly indicates that the system architecture and leadership are critical to the emergence of a new ecosystem. Under certain conditions, leading firms can propagate sector-wide transformations. These findings indicate that the slow evolution of the built environment sector is linked to a lack of leadership, the system architecture and value articulation at the sector level.

Table 15 Distinctions Between the Computer and Built Environment Sectors

PC sector	Built Environment Sector
• Value is defined by the end-user's demand	• Value is defined by the location
• Scalability	• Unique project, prototype
• Co-evolution	• Temporary structure
• Feedback loop	• Lack of feedback loop beyond projects
• Learning	• Lack of learning beyond projects
• Interdependence	• Lack of interdependence beyond projects
• Science-based decisions	• Ad-hoc decisions, creativity
• Transparency	• Assumptions
• Predictability	• Unpredictability
• Global market	• Local market
• Modularity	• Customized, unique design
• Value for the end users (B2C)	• Value for clients (B2B)

• Mobile object • Explosion (user centric)	• Immobile object dependent on location • Implosion (efficiency, firm centric)

4.4.3 Contrasting the Success of Toyota, Uber and Intel with Failures in the DBE Sector

It is important to establish *why some sectors succeed in digital transformation while others fail*, and *what can be learned from a comparison of failed with successful sectors?*

Best practice management is one of the main streams of management research and was inspired by the work of Peters, Waterman, and Jones (1982) on excellence in private sectors. The scholars extensively looked at the characteristics of successful and innovative organisations and used them as a basis for case studies. The sole focus on successful cases is prone to biases and has some critiques. First, even successful cases today can become a failure tomorrow, like the case of General Motors; for example, some predict that Uber could fail in the near future (Cusumano et al., 2019). Second, scholars tend to test either cases of success or failure but rarely construct frameworks around the two streams (Borins, 2001). Third, the knowledge of variables that separate success from failure would provide ecosystem leaders with corrective mechanisms; "*only through a direct comparison of successes with failures will the variables that differentiate the two be identified*" (Cooper, 1979: p.94). Studying the digital transformation of the sector by comparing successful and failed cases can offer an opportunity to construct meaningful, grounded conclusions.

Scholars in the same sector have extensively studied the systemic issues of the built environment sector in relation to the adoption of information and communication technologies. Thus, one sector was studied as a failure, as theories were presented on why it failed, which means the formation of biases in relation to the identified systemic causes. By conducting a study on the digital transformation of one sector in two contexts and then comparing the results of this failure to the successful cases in other sectors, it was possible to eliminate and refine the critical issues of failure in the built environment sector. The process of comparison is particularly useful for this study because it helped to identify the multi-level and multi-dimensional factors of failure, thus offering an integrated unbiased view with generalisable propositions.

Following the comparison, it became apparent that successful orchestrators actively interact with the environment in order to alter it for self-benefit. For example, Intel led the traditional sector towards its structural transformation to open the path for self-evolution while Uber ignored the traditional taxi industry and influenced policy by deregulating the taxi industry and enabling a platform and start up economy following its success (Heikkilä & Heikkilä, 2019). The successful examples show that the leadership and orchestration mechanisms are critical to the success as well as the context of ecosystem orchestration, while the failed cases of ecosystem orchestration from the Finnish and Californian BE sectors illuminated that orchestration and leadership cannot be potential drivers of failure. This conflicting finding further illuminated that the presented empirical cases were failing leadership and orchestration mechanisms suggesting the legitimacy of leading organisations in leading sector-wide innovation. This chapter further argues that leadership and orchestration are important but other components must be also taken into consideration when looking at the failure or success of ecosystems.

The critical drivers of failure in the built environment sector seem to stem from the sector leader's inability to articulate values, mindsets and sector context (architecture, nature, sector-wide business model and maturity). Value is an important concept of business models. Value definition, proposition and articulation are rarely discussed in the literature on ecosystem orchestration. In fact, value articulation or demand articulation were not included as an orchestration mechanism by Dhanaraj and Parkhe (2006) nor by (Nambisan & Sawhney, 2011), although this is of critical importance to the success of orchestration processes (Batterink et al., 2010; Howells, 2006; Klerkx & Leeuwis, 2008). The value proposition, according to empirical evidence derived in this research, is a foundation for ecosystem emergence and orchestration. The empirical evidence shows that the software vendor is defining the value propositions for the sector while the sector actors fail to articulate the value propositions with emerging technologies, as explained by the PM of a sub-trade (CA21) and an innovation manager at GC (CA11):

> **Is there a value proposition**? So, my question to the owners: where's the value? If I give an owner right now a full 3d model that has all the stuff in it, most of them don't know what to do with it anyway. (PM, Sub-Trade, CA21)

> **If you want value, you have to define value and you have to make value flow. It's simple as I told the owners, they have first to define what value is.** Many customers in [the] building sector don't actually do that very well. And, they're not helped by the professionals they hire, by the architects. […] And it's [success] mostly because you have experienced people who are willing to trust each other. And you hear stories about this all the time. And we have plenty of examples in [the firm], **we've taken the same people and put them on the different projects, and they failed because the owner didn't know what she wanted or something happened or their partners were not there**. […] **Then we have many owners that ask to build the cheapest building possible. They don't even think about value, they can't describe what value means to them. So, we are responsible for ourselves including the customers we work for in every business.** (Innovation Manager, GC, CA11)

If the value proposition is not clearly articulated, then value capture in the ecosystem is failing as no definitive measures of success can be deployed, as explained by a PM at a health care client (CA08) and an innovation manager at GC (CA11):

> If you include project delivery owners and stakeholders, clearly defining the value of the building, the value definition phase, I think that that's really not a well understood phase. The phase before the start of design is **a phase of value definition, which is "why",** what problem we are trying to solve, what do we want out of the building on a long term. There's this thing called value capture at the end, which is also not in a traditional thinking process, which is like you're looking backwards to the beginning of the project and asking: are we capturing the value? […] all these phases, value definition and value capture, might help to identify the gap. Because **the biggest rework cycles are driven by imperfections and failures to really identify the WHY of the project**. (PM, Health Care Client, CA08)

> If you don't understand what value is, you have no good measurement system for the chances of giving them value are quite low. A lot of what is delivered today, its value is accidental. (Innovation Manager, GC, CA11)

This evidence suggests the following proposition:

> ***Proposition 6****. A well-articulated value proposition provides an incentive for the emergence of an ecosystem and enables effective value capture while driving value creation. Value articulation is an enabling component.*

A value definition or proposition can emerge from the need to evolve or start a business. Uber and Intel's initiatives commenced with "*the need*" to initiate a change and by doing so they provided a well-articulated value proposition to define why complementors should tap into their business ecosystems. A number of interviewees emphasised "*the need*" (CA11_1, 08, 13, 17, 32) as an important component in changing the mindset and inertia. The interviewees also referred to "*the need*" as "*a business deal*" (CA11_1) that provides business incentives or "*the need*"(CA13) to engage in a change process activating the agency of individuals and driving the development of capabilities:

> ***Proposition 7****. A business need with a well-articulated value propositions at the firm and sector level provides an incentive to build the necessary capabilities to engage with the environment and tap into the formation of an ecosystem. A business need and an incentive are enabling components while agency is a building component.*

Business models provide an important financial structure and incentives that align conflicting stakeholders and constitute the financial environment necessary for agency development. A review of the orchestration mechanisms set by Toyota, Uber and Intel illuminated critical distinctions of the nature of these industries and the built environment sector. Uber, Toyota and Intel operate in B2C contexts while the built environment sector, particularly the design and construction industry, is a B2B context. The market value of the building product in the design and construction sector is defined by the location, which is a critical distinction to the other industries. Uber, Toyota and Intel are not bounded by the location of their products although the traditional taxi industry is bounded by location. As Jacobsson et al. (2017) discuss, the building product is immobile while construction sector "*factories*" are mobile, which is the reverse of both the automotive and computer industries. The location factor appears to be a critical driver in the failure of innovation initiatives in the built environment sector, as explained by the researcher (FIN20_1):

> People are not investing in innovation, part of that is coming from the fact that **the price of your product is dependent on the location and not on the quality of the product**. Investment into innovation will not necessarily pay back; it might be that land is becoming more valuable because then you can make money, and this is something we cannot change. […] It is good to remember that there are no products where the price of the product would have anything to do with the production costs. Every product the price for a phone is the willingness to pay. And the same with houses, the price of a house has nothing to do with the production cost; it has everything to do with the market price. What people are willing to pay. The mobile phones, there is no such thing as the location for a phone; you buy a phone because of reputation and the quality of the product, so these companies have to invest into innovation. […] **But as long as clients are willing to pay the asking price, but you do not try to develop it better because it does not pay back. It is part of an ecosystem, because it cannot be changed.** No matter what we do. If you are able to reduce production costs you can save money, and of course from the client's side so that there are no big construction mistakes made when you own the house, that of course the client wants to match the price with the product. Then I do not think it is realistic to think that the construction sector will ever be like a car manufacturer or mobile phone. The situation is so different. (Researcher, FIN20_1)

The built environment sector has systemic limitations affecting the menu of business model innovation, which suggests the following statement:

> ***Proposition 8.*** *Business model innovation can be hindered by the systemic limitation of the sector's nature, the context, if the value proposition is not articulated. The sector context matters for ecosystem orchestration. The sector context, industry architecture and power relations are failing components.*

4.4.4 Critical Constructs and Components of Ecosystem Orchestration Success and Failure

In prior sections, I presented the components that emerged from the data through which the built environment sector failed to qualitatively change. I further contrasted these findings with the examples of successful ecosystems. The contrasting cases offered corresponding propositions in relation to the importance of the constructs and related components for ecosystem orchestration, as presented in the previous section. I summarise these in **Table 16.**

Table 16 Examination of the Critical Constructs and Components in Relation to Their Functions [19]

Components	T	U	I	D	Y/N	Findings	Functions
INDIVIDUAL LEVEL							
Agency	-	1	1	0	**N**	Is activated by the business need	Building
Leadership	1	1	1	0	**Y**	Can propagate change across the sector	Enabling
Cognitive frames/Mindset	-	-	-	0	**Y**	Is a significant factor in failure	Failing
ORGANISATIONAL LEVEL							
Capabilities	1	1	-	0	**N**	Are important but can be built during the process	Building
Bottlenecks	-	-	-	-	**N**	Can provide a strategic advantage to owners	Building
Orchestration	1	1	1	0	**Y**	Is critical for success	Enabling
SYSTEM LEVEL							
Modularity	-	-	1	0	**N**	Modularity enables ecosystem emergence but is not a driver	Building
Industry architecture	-	-	1	0	**Y**	Defines power relationships, capabilities and agency	Enabling
Business Models	1	1	1	0	**Y**	A business model is a definitive factor in the success of ecosystems as it provides a financial incentive structure for value distribution and defines value propositions	Enabling
Value Proposition	1	1	1	0	**Y**	Value propositions enable ecosystem emergence	Enabling
Power	-	-	1	0	**Y**	Power contributes to failure, but the case of Intel showed that incentives in the ecosystem can align conflicting stakeholders	Failing
Platform	-	1	1	0	**N**	Platforms are typically present in successful ecosystems	Building

[19] T- Toyota; U- Uber; I- Intel; D- DBE Sector

1-Success, 0-Failure

Y- Yes, a critical component; N- No, not a critical component

Culture	1	-	1	0	**N**	Culture is dominant if leadership and orchestration are inadequate. Cases of GM, Intel and Uber proved that culture is not a definitive factor in failure	Failing
Education	-	-	-	0	**Y**	Education contributes to the development of a mindset. It can accelerate innovation but is not a critical factor	Failing
Diversity	-	-	-	0	**Y**	The construction sector is a closed-system with low diversity amongst actors. It contributes to failure, but it is not a definitive factor	Failing

More specifically, I order them according to the three levels - *individual, organisational* and *system* - following the data analysis. The components are further marked across the cases demonstrating success (Uber, Toyota and Intel) and failure (DBE sector). Occurring across multiple levels, these constructs and components hold different functions and importance for ecosystem orchestration. I further distinguished them as *enabling, building* and *failing* constructs and components of ecosystem orchestration. *Enabling* components are components that drive the ecosystem emergence and orchestration and, according to the results derived in this research, appear to be critical to ecosystem orchestration. *Building* components are important but not critical and can be developed during the orchestration process. *Failing* components are those that are critical to failed cases.

In the next section, I discuss potential contributions of the findings derived in this research.

4.5 DISCUSSION

In this chapter, I explore the roles and order of constructs and components for ecosystem orchestration and emergence. The core theoretical contribution is empirically grounded in a relatively integrated framework of the order of components and constructs for orchestration processes. This framework is summarised in **Table 17.** The components and constructs were ordered according to function: *enabling* components (components that enable ecosystem emergence), *building* components (components that are dependent on the context and process of orchestration and that can be built during the process) and *failing* components

(components that contribute to the failure of ecosystem emergence). Collectively, they explicate important relationships between different components that contribute to the failure and success of ecosystem emergence and orchestration.

Table 17 Framework for the Order of Constructs and Components for Ecosystem Orchestration[20]

Levels	ENABLING ecosystem emergence	BUILDING during the process of ecosystem orchestration	FAILING ecosystem emergence and orchestration
Individual	**Leadership** directs collective efforts and provides corrective mechanisms. It can also change the industry architecture (Proposition 3,5) Quote: *"If something's not working, you have to address it, you don't just get a crappy job and then blame it on the person who wasn't performing. […] That's another thing owner doesn't do well."*	**Agency** is influenced by the embeddedness in the structure (Proposition 7) Quote: *"Three companies but with different attitudes to BIM. First, [GC firm 1] rejected BIM […]. Second, [GC firm 2] saw BIM as the holy cow and saw the future, […] Third, [GC firm 3] did not have a bad attitude to BIM but did not see any strategic opportunity."*	**Leadership** can fail by setting inadequate mechanisms or by aiming at selfish value capture (Failure case of BE sector) Quote: *"We cannot evolve unless government helps us."* *"In construction, leadership does not exist…"* **Cognition, Frames, Mindset** are critical contributors to failure (Proposition 2) Quote: *"this is more about a mindset rather than specific tool or a contract."*
Organisational	**Orchestration mechanisms** with leadership are critical for success (Proposition 5) Quote: "*But the business deal still doesn't make it all work and just creates an environment which everything else seems to make sense to everybody."* **Business need** provides incentives, shifts mindset and builds capabilities (Proposition 7) Quote: *"Why does this matter to us? […] now we need to*	**Capabilities** can be built during the process (Proposition 4) Quotes: "*Owners don't have the capabilities to drive the change? […] You need to work on changing those things. Like if the laws don't let you do it, change the law. […] There are excuses and there are results. Get results."*	**Lack of necessary capabilities** reinforces the status quo feedback loop (Proposition 4) Quotes: *"Can we say that the construction industry lacks skills of business development and has low levels of education? - I would say that. I would say that they are not using education to push the limits of what's possible. Unfortunately, the education defects the mindset of all people in the industry."* *"People were neglected for many, many years and for many*

[20] Key quotes from the interviews with Finnish and Californian key experts are included to support the propositions

	do something, now we need to be more efficient. There's a need, there's a reason why I want to do it. Before I didn't care!"		*different reasons. […] we don't invest in people."*
System	**Business model** as a structural innovation (Proposition 1) Quote: *"when the business deal is different then that's when you begin to see a deeper change"* **Value propositions** provides incentives (Proposition 6) Quote: "A *phase of value definition, which is "why" […] that's really not a well understood phase."* **Incentives** are necessary for innovation (Proposition 1) Quote: *"Why didn't the taxi companies invent Uber? It's because they didn't have an incentive to invent Uber."*	**Culture** can be changed with business models (Proposition 2) Quote: "*Japanese culture or governance, or the uniquely recalcitrant nature of GM's union and workforce are implausible factors of failure."* **Platform for innovation** can be built during the process, the case of Intel and Uber (Proposition 4) **Industry architecture** can be changed with leadership and orchestration - the case of Intel and Uber (Proposition 3, 4) **Modularity** can be built during the process, the case of Intel (Proposition 4)	**Power relations at the global level** can hinder the process at the sector level (Turf wars in a failed case of the BE sector) (Proposition 8) Quote: "*There are some drivers against it, […] This is natural; they [software vendors] are the market leader. Why would they support standard when their system cannot be a standard?*" **Industry architecture** as an existing structure can provide incentives to preserve power within the status quo (Proposition 3, 8) Quote: *"The rules of the game have been established […] people do not need to change."* **Sector's nature** can hinder the process (Proposition 8) Quote: "*The price of your product is dependent on the location and not on the quality of the product"* **Existing business model**, as an existing structure can provide economic incentives to preserve the status quo (Proposition 3, 8) Quote: *"They have incorporated these rules into their business model. While these rules are holding them down to 1-4% profit, they are all so keeping these constraints in the sector that are keeping them down but they're also keeping them relevant."*

A fundamental contribution of this chapter is the reinvigoration of the importance of context for ecosystem orchestration, providing new empirical evidence to current debates around business model innovation. This chapter highlighted that the emergence of the ecosystem can be seriously affected by the systemic limitation of the sector's nature. In the case of the built environment sector, this limitation appears to be the location factor that defines the value of the building product. As Jacobides and Winter (2012) argued, the industry architecture defines the structure of the division of labour, rules and roles within the sector that can affect the ecosystem emergence. Indeed, the industry architecture defines the power relations and fee structure that also can hinder the ecosystem emergence, as evidenced in this study. This chapter further adds new knowledge by providing empirical evidence of the importance of the nature of the sector, which has been taken for granted. The location factor is specific to the built environment sector but is often an irrelevant factor for other sectors. Indeed, the definition of a product's value by location is irrelevant in the examples of successful ecosystems. In fact, successful ecosystems are global entities and are not bounded by any single sector, country or location (Jacobides et al., 2018). The location factor combined with the B2B practices complicate the process of business model innovation. B2B ecosystems appear to have a higher chance of failure and a shorter life span than B2C ecosystems (Cusumano et al., 2019).

As such, the contribution of this chapter is to highlight that the sector's nature can hinder business model innovation and contribute some answers to the question posed by Jacobides and Winter (2012: p.1376) "*what exactly constrains the existing menu of business models?*". This study highlighted that, although building systems differ from country to country (Winch, 2000), the issues faced by the Finnish and Californian sectors are very similar, as evidenced in Chapters 2 – 3. This evidence suggests serious implications for the strategic choices that are shaped not only by individuals, organisations or sectors, but by a wider system-level network of actors and most importantly by the context of implementation. It explains why two contexts with different building systems and varieties of capitalism are surprisingly similar in how the sector evolves and makes strategic choices. Specifically, I find that, while the location factor constrains the menu of business model innovation, the existing business model constrains actors' strategic choices whilst simultaneously providing incentives to powerful actors to preserve the existing status quo. Vicious cycles (Masuch, 1985) were created and matured in the building sector, which constitute an intriguing result that deserves further study and theorizing. Therefore, this study addresses the call by Navis and Glynn (2010) for the study of failed ecosystems in order to offer novel explanations of why prominent firms in mature sectors struggle to create new ecosystems at the convergence of conflicting disciplinary co-specialised firms and complementary inter-sectors.

The empirical evidence further suggests that the limitation of the sector's nature for business model innovation can provide additional challenges to the sector in terms of value articulation at the system level. The component of value articulation and its importance for value capture was also largely taken for granted in the ecosystem literature. The inability of leadership and sector actors to articulate value contributes to the failure in value capture while value creation can occur with or without a clearly articulated value. Empirical evidence shows that the built environment sector is failing to capture value from emerging technologies, e.g. BIM, because "*the WHY*" (engineer, VIF, CA31) is not clearly defined by the mainstream sector actors. As Chapter 3 showed, due to its inability to articulate value, the powerful incumbents as complementors to the sector take a role in defining the value for the use of BIM technologies on behalf of the sector. The phase of value articulation, e.g. *the why of innovation,* is a promising line of inquiry for future research.

In this study, I find that difficulty of business model innovation also relates to the desire of actors with power and resources to preserve the status quo. As such, while actors with power and resources influence the environment to fit their capabilities (Penrose, 1959) they also intentionally preserve the status quo and hinder the development of capabilities for business model innovation. I further find that such components as leadership and its capability to intentionally shape the environment largely depends on the scale of the leading firm. Empirical evidence highlighted that innovative SMEs in the built environment sector are struggling to be heard or have little influential power to direct open innovation in the sector, while large firms steer innovation with a closed-system approach in siloes for self-benefit. As open innovation practices by SMEs have been neglected (van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009), future research could investigate the interactions between SMEs and large firms in terms of the components of business models that influence innovation dynamics in the sector.

By exploring multi-level interactions, the results of the study show that firms are favouring vertically integrated structures to maintain control over the supply chain instead of profiting from disintegrated co-specialised ecosystem strategies. In fact, while other sectors profit from ecosystem strategies, the built environment sector reintegrates by closing its organisational boundaries with BIM technologies. If successful firms depend on how they interact with the environment (Piepenbrock, 2009), then such firms are those that integrate the whole supply chain in siloes. The critical question that deserves further research is, if ecosystem strategies offer superior benefits to firms, then *why is the built environment sector moving in the opposite direction to other sectors?*

The multi-level qualitative approach also contributes to debates on cognition and power and their influence on the emergence of ecosystems in the sector (Porac et al., 2011). In this study, I find that the sector operates in a practice of cognitive biases, established mindsets and competitive logics. A failure to articulate new value by leading firms and a failure to envision value beyond established business models is largely linked to the existent cognitive biases in the built environment sector. While these biases guide the sector's strategic choices, they have also matured because of the long history of the sector's evolution and its established way of doing things. Cognition, frames and mindsets are critical contributors to the failure of the emergence of ecosystem in the built environment sector. Although cognition, frames and mindsets are significant in this particular sector, I further find that the sector's architecture is dependent on a wide range of stakeholders that shape collective feedback and, more importantly, on the economic incentives that dominate this sector. The established business models disincentivise firms with the power and resources to innovate suggesting that business model innovation is a complex context-dependent issue. A critical contribution of this chapter is the understanding that, while the industry's architecture drives the sector's capabilities (Jacobides et al., 2006), the business model drives the incentives that stimulate the sector's innovation dynamics and outcomes that can also be dependent on the actors beyond single industry architecture.

Overall, I extend the study by Jacobides and Winter (2012) by offering specific observations of the built environment sector. If the existing industry architecture drives sector capabilities (Jacobides et al., 2006), then empirical evidence shows that the industry architecture fails to drive the necessary capabilities for business model innovation, thus contributing to the failure to articulate the value propositions and value capture. The shortcoming of creative insights to envision and articulate new value propositions limits the menu of business model innovation.

Therefore, this study offers another critical insight that ecosystem literature assumes value proposition as a given component while extensively focusing on the processes of value creation. I argue that ecosystems can have effective value creation mechanisms but still fail at value capture if the value propositions is not articulated at the firm and system levels. This insight constitutes the key contribution of this chapter.

The final substantive contribution is the multi-level analysis of sector-level systemic issues. I argue that, to understand the process of change, I have to ground the analysis of one failed sector within the success of other sectors. This analysis is consistent with the call by Aldrich and Fiol (1994) and Navis and Glynn (2010) to study ecosystems that did not emerge and failed. Only by contrasting examples of failure and success, the relevance and importance of examined ecosystem components can be comprehended. By deriving them inductively from the failed cases and validating them in the successful cases, the findings were generalised to provide the order of the constructs and components. The presented framework is based on the specific constructs and components that rest on the nuances of the ecosystem literature. It is thus uniquely suited to the understanding of orchestration mechanisms and explains why and how some ecosystems fail to emerge and fail during the orchestration processes, while contributing to the emerging stream of literature on the dark side of ecosystem orchestration (Oliveira & Lumineau, 2019). I complemented the research by offering new insights which not only confirm that the power distribution in the sector matters (Jacobides & Tae, 2015) but that such components of business model innovation as value articulation for value capture and the sector's nature and context are critical components that should be taken into consideration for ecosystem emergence and orchestration. In comparison, there is little empirical knowledge on the drivers of sector dynamics; I found that the specific components of business models contribute to these dynamics. Future research can draw important multi-level relationships between the components for ecosystem emergence and orchestration. This chapter, in fact, may constitute a foundation for the future research on multi-level framework of ecosystem orchestration mechanisms.

4.5.1 Limitations and Suggestions for Future Research

The limitations of this study suggest future research opportunities. First, the study provides an inductive framework based on a broad overview of one sector and specific success case studies. While I have been able to provide a detailed account of the conditions of failure in the building sector and documented successful examples of ecosystem orchestration processes by careful triangulation, further research is needed to establish the generalisability of the results and to expand the list of constructs and components. Future research could take specific components of failure and success to systematically test them within a wider selection of cases. For example, Yoffie, Gawer, and Cusumano (2019) contrasted 209 failed platforms with 43 successful platforms in the US context and identified reasons for failure. However, they did not explore the components of ecosystem orchestration nor concrete results were published yet. Second, individual components of the framework can involve narrower and deeper qualitative, and possibly quantitative research to provide a comprehensive, relatively integrated framework of the relationships amongst the components. Third, while I allude to the importance of components and present a relatively integrated order of constructs and components, the relationships between the components were not visualised. Finally, I presented how and why the ecosystem actors intentionally preserve the status quo while blindfolded by the established cognition, mindsets and frames. Although these sector actors are traditional professions, there is an emerging stream of outsiders that offer Ai-based start-ups, which act as emerging digital ecosystems. A limitation of this study is the understudied context of emerging digital ecosystems. The process of evolution of these actors can be documented to provide novel insights into the process of emergence in a mature sector.

Despite these limitations, I believe this chapter offers important contributions to the literature. By shifting the focus towards a multi-level framework and looking at technological change in a failed sector, I can identify the critical constructs and components of ecosystem orchestration. This contributes a more fine-grained analysis of the constructs and components that can fail, be built, and enable ecosystems. The analysis shows that the sector, or sector context, is an important factor in the process of ecosystem orchestration as it affects the strategic choices of decision makers. The framework constitutes one of the few systematic efforts to explore failed ecosystems (Aldrich & Fiol, 1994) – an underexplored phenomenon and the dark side of ecosystem orchestration (Oliveira & Lumineau, 2019); it is of critical significance to progress the ecosystem field. It thus illuminates an interesting and understudied aspect of ecosystem emergence and orchestration.

4.6 CONCLUSION

This study has offered a relatively integrated theoretical framework based on a comparison of success and failure cases across different sectors to determine the critical constructs and components of ecosystem emergence and orchestration while indicating the critical role of sector context. In the process, I identified that constructs and components hold different roles in the process of ecosystem orchestration. I showed that the components can be used to enable ecosystem emergence, sustain ecosystems by building the necessary components during the process, and determine the critical components of ecosystem failure. By explaining this process, I uncover the critical roles of components that make up ecosystems and order them according to the functions they offer. I illuminated the critical role of the nature of the sector by presenting examples of the elements in a sector's nature that can constrain business model innovation menu. Overall, this study offers an important step in showing how and why ecosystems fail while contributing to the emerging field of the dark side of ecosystem orchestration.

4.7 ACKNOWLEDGEMENTS

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CHAPTER 5

Chapter 5. DISCUSSION AND CONCLUSION

This thesis contributes to the understanding of ecosystem orchestration and emergence. The review of prior studies in Chapter 1 highlighted important theoretical and practical limitations that have been discussed in the empirical chapters of this thesis. This concluding chapter discusses the main findings of the three empirical chapters; it starts by presenting the main questions and then summarizes the contributions of each chapter. The theoretical implications of the whole thesis are then discussed in an integrated way, and these are followed by the managerial implications, which summarize several recommendations for practitioners and policy makers. The chapter concludes with the main limitations and suggestions for future research.

5.1 MAIN RESEARCH FINDINGS

In the previous chapters of this thesis, I discussed the findings of the individual empirical studies while developing insights on the dark side of ecosystem orchestration from open-system and public (Chapter 2), and then closed-system and private (Chapter 3) approaches. The critical constructs and components of ecosystem orchestration were then theorised and grounded in the empirical data by focusing on the sector's context of ecosystem orchestration (Chapter 4). **Table 18** presents the research questions and the main findings and contributions of the individual chapters.

Table 18 Research Questions and the Main Findings per Chapter

Chap.	Research Questions	Brief answers
2	(1) How did the design and construction industry co-evolve with the national efforts for BIM R&D in Finland?	(1) The design and construction industry in Finland co-evolved with the national programmes set by the public funder, TEKES, to support knowledge creation for BIM technology development and interoperability in the sector. The national BIM technology programmes represented a technology push instead of a market pull. The process of the industry's BIM evolution between 1982 and 2019 resulted in distinct phases that contributed to industry-wide digital innovation.
	(2) How did the dark side manifest in open-system orchestration led by TEKES?	(2) Open-system orchestration processes can manifest the dark side. Open-system orchestration relies on the good will and entrepreneurship of participants in creating their own business opportunities, which can also incentivise participants to exploit the system instead of seek business opportunities on a global scale. While open-system orchestrators aim at open innovation, ecosystem dynamics can adhere to siloes even if actors aim for the public good. Public organisations can have a challenging role in succeeding in the exploration and value creation, but the industry can fail in value capture and exploitation of created value. The context of ecosystem orchestration matters as system dynamics determine the behaviours and decisions of industry actors.
	(3) What is the role of public organisations in orchestrating ecosystems?	(3) Public organisations play an important role in the creation of public good and leading knowledge ecosystems. The function of a public organisation impacts on dynamics in the ecosystem; for example, open-system orchestrators can be ineffective in enabling the scalability of newly created digital businesses if global players are not incentivised to participate and support the initiatives. Thus, actors with power at both industry and global levels can hinder the evolution of a knowledge ecosystem towards a business ecosystem and thereby contribute to the

	(4)	failure of value creation by public organisations and value capture by the industry actors.
3	(1) How and why did the software vendor fail the ecosystem orchestration?	(1) Although a software vendor is successful in private value capture, it sets exaggerated expectations in the sector from the use of a platform thus inhibiting value creation and capture in the sector. Network membership strategies utilising marketing power drive successful direct network effects but damage innovative capabilities and trust in the sector. The software vendor does not take responsibility or accountability for the data produced on its platform as there are no corrective mechanisms in the sector to address this issue which further impacts on value creation by B2B customers. Powerful actors within ecosystems can stifle value creation and capture by B2B customers in order to maximize their individual control and value capture. The context of ecosystem orchestration matters as the software vendor orchestrates the environment for the sector's platform thus artificially creating direct network effects while intentionally preserving the status quo by favouring large vertically integrated firms. Vicious cycles of the status quo are created between the siloed firms in power and the orchestrator.
	(2) To what extent can the theories derived from successful orchestration mechanisms in B2C contexts be applied to B2B contexts?	(2) The articulation of value propositions by the business ecosystem orchestrator on behalf of B2B customers in B2B contexts is taken for granted. Orchestrators should allow B2B customers to articulate value for their businesses while providing the basic infrastructure for value creation. By doing so, orchestrators might risk lost value capture. Therefore, they are further incentivised to act in siloes for selfish value capture. In doing so, the legitimacy of the orchestrator and the customers in B2B contexts to articulate and orchestrate value should be taken into consideration.
4	(1) What components and constructs contribute to the success and failure of ecosystem orchestration? Is there an order to these components?	(1) The critical components and constructs of ecosystem orchestration were identified, such as the sector's context and nature, business models, industry architecture, cognition and mindsets. Ecosystem orchestration is a multi-level complex issue that incorporates a number of different factors that contribute to success and failure. Thus, the proposed components and constructs were ordered according to their functions: *enabling, building* and *failing*. This order is organised across three levels: *individual, organisational* and *system*. Some components and constructs can hold several functions. For example, capabilities can *enable* ecosystem orchestration whilst a lack of them can contribute to failures in value articulation that further contributes to the lack of business model innovation or ecosystem emergence.
	(2) How and does why the sector's context matter for ecosystem emergence and orchestration?	(2) The sector's context and nature in ecosystem literature was largely taken for granted. Factors such as location-based business models are specific to only a few sectors, which were not specifically studied by management scholars. The location factor constrains the menu of business models. The maturity of long-established practices that generate established mindsets coupled with the industry architecture and location factor can seriously limit the menu of business models and possibility of ecosystem emergence.

5.2 THEORETICAL IMPLICATIONS

In this section, key findings of the empirical chapters are discussed in light of the contributions of this thesis and how they relate to each other. Some broader theoretical implications of the empirical studies are also explored, which are linked to the main contributions presented in Section 1.2. Overall, this thesis contributes to the literature on the strategy, organisation of ecosystems, and the dark side of inter-organisational relationships (Oliveira & Lumineau, 2019). Theoretical implications and contributions are discussed around literature on Ecosystem Orchestration, The Dark Side of Ecosystem Orchestration, The Importance of Industry Context for Ecosystem Orchestration, and The Critical Constructs and Components of Ecosystem Orchestration. These implications and contributions are discussed below.

5.2.1 Ecosystem Orchestration

Thus far, research has focused on various aspects of ecosystems, while only limited empirical research has been performed on ecosystem orchestration. However, the processes of ecosystem orchestration are vaguely understood (Dattée et al., 2018; Jones et al., 1997; Nambisan & Sawhney, 2011).

Existing research on ecosystem orchestration has largely explored the successful, long-lived ecosystems that are enabled by powerful leading firms or/and technological platforms. Ecosystem literature emphasised the importance of a single powerful firm or a hub in leading ecosystems. For example, Lorenzoni and Baden-Fuller (1995: p.146) emphasised that *"it is becoming increasingly apparent that those networks that are not guided strategically by the "center" [leading firm or hub] are unable to meet the demanding challenges of today's market*." Research on the orchestration of ecosystems assumes that leading firms intentionally and purposefully influence and manage networks (Nambisan & Sawhney, 2011). Indeed, there is an observation of the dominance of central hubs at the core of inter-organisational networks that intentionally direct its networks and construct the environment to ensure the competitive environment favours those firms and their networks (Astley & Van de Ven, 1983). This thesis proves the emphasis on leading firms is disproportional to the other components of ecosystem orchestration.

Building on multiple bodies of literature, which published successful examples, scholars have offered frameworks that describe the innovation processes deployed by powerful leading hubs and from the perspective of singular firms. To date, the only substantive frameworks of ecosystem orchestration are that of Dhanaraj and Parkhe (2006) and by Nambisan and Sawhney (2011), while some consider specific contributions to these frameworks (Batterink et al., 2010; Gausdal & Nilsen, 2011) and others offer new frameworks of ecosystem orchestration (Aarikka-Stenroos et al., 2017; Planko, Chappin, Cramer, & Hekkert, 2017; Reypens, Lievens, & Blazevic, 2016; Santos & Eisenhardt, 2009; Valkokari et al., 2017). However, scholars rarely define the concept of "*ecosystem orchestration*" and focus on the processes of orchestration, while the relationship between the ecosystem structure and the orchestration processes remains unclear. As such, ecosystem orchestration theory is often incomplete and disintegrated. By considering the increased scholarly interest in long-lived ecosystems and how they are orchestrated, this thesis offers contributions to the literature on ecosystem orchestration and the work of Nambisan and Sawhney (2011).

Dhanaraj and Parkhe (2006) and Nambisan and Sawhney (2011) clearly distinguish network design from network orchestration while emphasising the orchestration processes and the relationship between these processes. Less attention is given to the relationship between ecosystem design and orchestration processes. However, from the empirical evidence derived in this thesis, it became apparent that both design and orchestration are equally important. Through this empirical observation, the thesis illuminated that the design of business model innovation is equally important to the leadership and orchestration mechanisms and the success of ecosystems. There is a reciprocal relationship between what is designed and how it is orchestrated. As evidenced in this thesis and published literature, '*good*' design with a '*bad*' orchestration approach can still succeed as the context determines which organisational forms survive and dominate in an environment. Thus, badly orchestrated ecosystems can also be long-lived (Piepenbrock, 2009).

Design can be characterised as '*an intent for a result'*; it is composed of various components and constructs that are intentionally integrated in a creative way to achieve a result.[21] The design intent utilises '*instrumentation*'[22] to arrive at a certain structure that should produce a desired result. Instrumentation is not explicitly discussed in the network orchestration literature and constitutes a contribution by this thesis. Instrumentation determines the choice of components and constructs that are measured collectively. The concept of instrumentation can be a useful addition to the frameworks of Dhanaraj and Parkhe (2006) and Nambisan and Sawhney (2011). This thesis offers a first step in comprehending the components and constructs of instrumentation as they are critical to orchestration processes (see Chapter 4). Instrumentation determines *what is orchestrated*, design determines *how 'what' is composed or designed for a result*, and orchestration determines *the actual processes of realisation of how and what.* The critical components and constructs and their order (presented in Chapter

[21] As Piepenbrock (2009: p. 48) referred to the morphology and physiology of organisational forms, morphology can refer to network design and physiology to the orchestration processes: "*The form or species provides a first-order explanation of performance. In biology and business, whether in organisms or organizations, morphology trumps physiology - i.e. species type trumps the health of the beast. A weak cactus will typically outlive a strong oak... in a desert.*".

[22] The concept of '*instrumentation'* is used for the first time in this thesis and is widely used term in the orchestra. However, this term is usefully added to the design and orchestration in this research and can potentially be added to the frameworks of ecosystem orchestration.

4) represent the first step in the development of an integrated theory of ecosystem orchestration. Specific contributions and implications to the critical constructs and components of ecosystem orchestration are discussed in Section 5.2.4. However, these findings offer a view of components and constructs that contribute to the success and failure of ecosystems which offer a new theory to ecosystem orchestration illuminating the limitations of the existing frameworks.

One of the key contributions of this thesis is a presentation of empirical evidence that the role of orchestrators is closely related to other components of ecosystem orchestration. For example, while some scholars emphasise the role of capabilities as critical to ecosystem orchestration (Helfat & Raubitschek, 2018; Teece, 2009), it is empirically evident in this thesis that capabilities can be built during the process and are context-dependent (see Chapter 4).

Empirical evidence shows that one of the principal factors in *'good'* ecosystem orchestration is an equal balance of *'tone'* in the orchestrating instrumentation and design. As such, ecosystem orchestration is a creative process that supports the methods of design, direction and coordination of value articulation, creation and capture by heterogenous complementors and customers. Thus, instrumentation, design and orchestration are inseparable. Good instrumentation and design are prerequisites to good orchestration. It is not simply an art to select the mechanisms of orchestration but the choice of instrumentation, design and approach to orchestration '*colourises*' the ecosystems; undoubtedly, 'the *devil* lies in the detail'. Perhaps this is why the evolutionary processes of ecosystem emergence exist in a variety of forms (Thomas, 2013). Indeed, ecosystem dynamics are distinctive across the cases as logic, structure and approach differ across ecosystems. The processes of ecosystem orchestration are dynamic in nature (Jones et al., 1997; Powell, White, Koput, & Owen-

Smith, 2005). Besides the natural dynamic processes of ecosystem orchestration, which depends upon the orchestrator, such processes are only partially designed and intentionally organised (Jacobides et al., 2018). More importantly, however, is the empirical finding that the process of successful orchestration is contextualised and partially self-organised. Through structural, spatial and temporal bounded rationality, orchestrators are enabled and constrained through adaptation to the context and as a political coalition, ecosystem actors continuously negotiate and bargain about value (Piepenbrock, 2009). As such, ecosystems are not only orchestrated (directed, coordinated and managed) by orchestrators, but also partially designed. Design of ecosystems is an evolutionary process, same as orchestration processes. Ecosystem design and orchestration should leave room for creativity, serendipitous discoveries and, ultimately, emergence.

Value co-creation is non-linear (Moore, 1993) indicating that linear prescriptive models for ecosystem orchestration are ill-suited to address ecosystem dynamics and its complexity in orchestration (Dattée et al., 2018; Thomas, 2013). For instance, the software vendor adapted its ecosystem strategy to the BE sector as its evolution is constrained by the structure and culture of the sector (Chapter 3). However, it is simultaneously enabled by large vertically integrated firms and the processes it deploys in organising the environment to fit its capabilities. As such, the marketing power and complementors are components of instrumentation; while a *'vision'* of how a platform will function and what value it will provide are part of the design, the actual use of the marketing power to direct clients in construction projects is an orchestration process. The efforts by a national public agency with an open-system orchestration approach are also constrained by powerful international firms and the context of orchestration (Chapter 2 and see Clarysse et al. (2014)). While the national programmes in Finland were driven by a group of technology enthusiasts, the national efforts were also constrained by the structure and culture of the sector and the networks in which they were embedded. Thus, existing frameworks missed a process of adaptation to the context by ecosystem orchestration and the relationship between instrumentation, design and orchestration. This implies that ecosystem orchestration should be distinguished from linear firm-level top-down views of it as ecosystems are "*fundamentally new organisational species*" (Piepenbrock, 2009: p.47) that are non-linear, horizontal and dynamic.

The other potential area of advancement for ecosystem orchestration is based on the understanding that the process of value proposition articulation is potentially one of the critical components of ecosystem orchestration and business model innovation. Value propositions remain critical to the design and orchestration of ecosystems across heterogenous networks of complementors with conflicting goals. The composition of value propositions is negotiated in ecosystems. Orchestrators hold strategically challenging roles in bargaining and negotiating value propositions at the individual level of those complementors while directing the ecosystem towards the collective value proposition. Empirical evidence of this thesis and practice-based research indicates (Pidun, Reeves, & Schüssler, 2020) that value propositions are also context-dependent. It also explains why eBay's business model failed in China, while Taobao has succeeded (Cusumano, Gawer, & Yoffie, 2019) and why business ecosystem emergence in the built environment sector is a difficult process. However, it is not always possible to articulate clearly value propositions to compel the others to commit to a *de novo* ecosystem due to lack of visibility and high uncertainty. Therefore, articulation of emerging value propositions is a collective discovery and an evolving matter (Dattée et al., 2018). Dattée et al. (2018) explored such orchestration processes by multinational technology firms that were navigating through uncertainty towards an ecosystem strategy. Their contribution is exploration of the early-stages ecosystems where a leading firm is familiar with the ecosystem strategy, has resources and capabilities to operate in dynamic digital environments and clearly made a decision to build an ecosystem around emerging technologies with unclear value propositions. To extend their work further, this thesis presents the context where the firms operate in mature sector with limited resources, lack of capabilities, B2B service business models and strong cultural resistance to newness. The findings indicated that in such contexts the ecosystem emergence is a difficult process. The process of value articulation requires a firm to recognise the business need in order to proceed with such a difficult task. Some sectors might be unfamiliar with the ecosystem games, as a class of distributed strategies, and may be incentivised to preserve the established practice due to the existing incentives in the sector's business models. This constitutes a valuable contribution of this study.

Building upon the empirical findings derived in this thesis, the existing frameworks of ecosystem orchestration are limited in nature in depicting the complexity of their processes. Existing frameworks also consider that orchestrators are typically legitimate actors with good intentions to ensure equal value distribution, which is an optimistic and positive view of their role. To conclude, the theoretical articulation of the importance of instrumentation, design and orchestration hold the promise of a novel analytic lens. In particular, new theories of ecosystem orchestration should address the relationships between these three mechanisms that are more context-dependent and grounded in empirical evidence.

The following sub-sections present implications and contributions to the dark side of ecosystems, including industry context and the importance of constructs and components of ecosystem orchestration to the literature on organisation and strategy.

5.2.2 The Dark Side of Ecosystem Orchestration

Thus far, research has focused on long-lived, successful ecosystems (Santos & Eisenhardt, 2009) with only limited exploration of the sectors that have failed to generate ecosystems. For instance, previous research largely focused on individual firms that failed the transition to ecosystems and, therefore, lost the market to competition, such as BlackBerry, Blockbuster, Nokia, Kodak, Symbian, etc. The other stream explored ecosystem strategies that failed during the orchestration, thereby illuminating the dark side of inter-organisational dynamics (Gurses & Ozcan, 2015; Ozcan & Santos, 2015). Overall, many studies addressed ecosystem strategy and organisation from the perspective of single firms (Ceccagnoli, Forman, Huang, & Wu, 2012). This thesis has provided insights into the dynamics of why existing ecosystems fail and why business ecosystem emergence is challenged in certain contexts.

A specific contribution of this thesis is the exploration of the dark side of inter-organisational relationships (Oliveira & Lumineau, 2019) in one failed sector from the perspective of the ecosystem rather than a single firm, and the contribution to emerging research streams on the dark side of ecosystems. The dark side of ecosystems was depicted in the work of: Dellermann, Jud, Lipusch, and Popp (2018), who illuminated the importance of control mechanisms to mitigate the risks associated with the deviant behaviours of ecosystem members; Guerrero and Urbano (2017), who illuminated that institutional conditions, such as government, market, and society, negatively affect entrepreneurial ecosystems; Mantovani and Ruiz-Aliseda (2016), who showed that when a leading firm loses market dominance, complementors become trapped in the prisoner’s dilemma; Mele et al. (2018), who highlighted the dark side of the actor’s agency, namely opportunistic behaviour to achieve self-interested benefits while participating in service ecosystems, and Heikkilä and Heikkilä

(2019), who showed that, from a public perspective, deregulated environments can be a failure while, from the perspective of individual global firms, they are considered a success. These studies confirm that successful ecosystem formation is a complex issue, and the success of individual firms cannot be taken for granted.

This thesis offered empirical evidence that enhances our understanding of the dark side of ecosystem orchestration and how it can manifest in various forms; it therefore contributes to the work of Oliveira and Lumineau (2019). The empirical findings presented in Chapter 2 highlighted that open-system orchestration processes can manifest the unintended dark side. By supporting ecosystem members to pursue their own business interests, open-system orchestrators can support siloed R&D thereby reinforcing the status quo. In the long term, they can fail to bridge value creation in knowledge ecosystems with value capture in the industry, thus also failing to create public good. The overreliance on strong ties between ecosystem members tends to develop isolated, siloed groups that are not well integrated with the rest of the sector and contribute to the failure to translate the knowledge created for sector-wide innovation (Granovetter, 1983). The level of structural embeddedness (Jones et al., 1997) and the collective intelligence of ecosystem members becomes important. Open-system orchestration can also incentivise opportunistic behaviours amongst ecosystem members to capture value for their individual benefit while preserving the status quo. Since the role of open-system orchestrators is to support members, there is a tension between the expectation of value creation from the use of public funding and the outcomes of those processes. Overall, while this case study was successful in knowledge creation, the mechanisms deployed in the national programmes did not effectively support knowledge reuse and value creation for one particular sector. This finding suggests that orchestration mechanisms are not the only reason for failure, but that the dark side of the sector dynamics also contributed.

The study of closed-system orchestration (Chapter 3) contributed to the discussion on what is a success and failure in ecosystems; thus, it aimed to illuminate the dark side of individual successful firms. Indeed, leading firms can simultaneously represent an individual success in value capture, and a failure to support value creation and capture by ecosystem members, thus forming an "*ego-system*" (Jacobides et al., 2019). The dark side of an orchestrator manifests in opportunistic selfish value capture and by doing so, damages the value creation by ecosystem members. The use of marketing strategies to change an environment to fit its capabilities perhaps presents a story of a successful, masterful and wicked orchestration processes executed by a closed-system orchestrator. To my knowledge, the use of marketing in ecosystems to drive direct network effects and the adoption of a platform to increase its membership has not yet been documented in ecosystem literature. As the mainstream built environment sector is infamous for its slow adoption of digital innovation, it is possible that the closed-system orchestrator had no choice but to orchestrate the environment with the use of marketing power in order to survive. As empirical evidence shows, successful firms can exhibit a disproportional power over ecosystem members by extracting value from the ecosystem, while others can be ambidextrously successful in supporting individual and collective success. However, the findings also indicate the importance of context for ecosystem orchestration. Taking the analysis further, the empirical findings present the duality of the observed phenomenon, as no ecosystem is "*black*" or "*white*". The success and failure of ecosystem orchestration depends on the perspective one takes and what is a success today can be a failure tomorrow.

A key finding of Chapter 4 is that the failure of the open-system orchestrator (presented in Chapter 2) and the failure of the closed-system orchestrator (discussed in Chapter 3) largely depends on the orchestration context, namely the sector that is failing to produce ecosystems. Specifically, empirical results illuminated the intentional preservation of the status quo by the sector's actors with power and resources, thus contributing to the discourse on power. An ecosystem orchestration can fail if the business models established in mature environments disincentivise actors with the power to innovate and evolve. These findings support the work of Ozcan and Santos (2015) on the turf wars between established but interdependent players who can disagree with the market architecture because of their history of industry dominance. However, the findings of this thesis extend their work by shifting the focus from dominant firms from different industries towards coalitions between co-specialised disciplinary communities within one mature sector; furthermore, it notes the importance of established business models in the sector as a structure of incentives, and thus the sector's context. This insight suggests that it may be difficult for ecosystems to emerge, particularly when dominant firms with power and resources are blindfolded by established beliefs and the misconception of profit gains in the sector while the inefficient and ineffective business model at the sector level is also established as a norm. It leads to conflict between innovative SMEs and the intentional preservation of the status quo by dominant firms.

Overall, this thesis presents an important empirical foundation in order to understand of how and why ecosystems fail to emerge, and to shed light on the darker side of ecosystem emergence and orchestration. The studies presented in this thesis highlighted that the mature sector could fail to support the emergence of ecosystems because of inherent system characteristics that also incentivise opportunistic behaviours. Although past work considered failed ecosystems (Gurses & Ozcan, 2015; Ozcan & Santos, 2015), and mostly from the perspective of individual firms (Davis & Higgins, 2013; Lucas & Goh, 2009; Tee & Gawer, 2009; West & Wood, 2013), the findings of the present thesis looked at how different sector actors and segments interact and why they try to preserve established business models even if they are inadequate. While previous studies largely contribute to the theories of power, this thesis emphasises business models at the system level, which suggests factors, such as system incentives, value articulation, and the need for change and cognition, as important as documented power relations and industry architecture. The findings support the assertion that actors in the sector adopt industry recipes as cognitive templates (Jacobides et al., 2016; Porac et al., 1989; Spender, 1989) but also confirm that the success and failure of individual firms are largely the extent of the system that drives and constrains actions of interdependent actors. Thus, this thesis expands the understanding of what drives a sector to preserve the status quo while failing to organise itself around a new ecosystem or to support emergence of new ecosystems.

5.2.3 The Importance of Industry Context for Ecosystem Orchestration

This thesis contributed to an understanding of the importance of context for ecosystem emergence and orchestration. A lot of emphasis in ecosystem literature has been placed on the role of a powerful leading firm and an enabling platform to organise an ecosystem with a top-down approach (Gawer & Cusumano, 2002; Iansiti & Levien, 2004b; Moore, 2006; Piepenbrock, 2009). Some scholars recognised the importance of context and its influence on a network's structure and outcomes (Möller & Halinen, 2017), very few have explored empirically it in depth (Piepenbrock, 2009).

The other stream has theorised the structural properties of the industry architecture that also contributes to the emergence of an ecosystem (Jacobides et al., 2006; Jacobides & Winter, 2012). In particular, the work of Jacobides and Winter (2012) clearly indicated that the industry architecture does not assume the presence of ecosystems but also does not eliminate the possibility of their presence. Jacobides and Winter (2012) explored the interplay between determinism and choice and provided an alternative focus on industry architecture to guide the agency and the constraints placed by the feedback structure of the system. The results presented in this thesis align with the work of Jacobides and Winter (2012). Indeed, I find that the division of labour and profits drive the capabilities of the sector.

While the industry architecture is an important concept for ecosystem orchestration, in this thesis, I find that additional contextual conditions also greatly influence the emergence and orchestration of ecosystems and business model innovation. First, I find that ecosystem emergence in B2B contexts is more challenging than in B2C contexts, as most successful companies tend to operate in B2C contexts and then extend their business to B2B contexts by becoming a "*hybrid company*" (Cusumano et al., 2019: p.19), e.g. Google, Amazon, Salesforce, etc. Second, although the industry architecture determines and guides both agency and capability development, I find that business model exist at two levels: individual firm and its ecosystem and the sector. The established business model at the sector level disincentivises individual firms from innovation and influences the decisions of individual firms. This suggests additional constraints on the process of ecosystem emergence and orchestration. A critical condition of the context illuminated in this thesis is the nature of the sector. I find that many businesses do not have a location factor that limits the business model menu, or a business model that depends on a larger network of actors outside the sector (such as the value of land, economy and highly regulated environments), or the need to deliver one expensive immobile building product to one client. The BE sector is the largest sector in the world and relies on many different actors (WWF). These conditions pose serious limitations to the sector's innovation potential in terms of organising the whole sector. Indeed, successful ecosystems thrive in deregulated environments (Jacobides et al., 2019). Furthermore, the built environment sector is one of the oldest sectors. The maturity of the sector also greatly influences the choices made by decision makers. The established routines develop capabilities amongst those decision makers that in turn can also blindfold them. This forms a general sector culture that limits the possibility of new ecosystem emergence. I find that leading actors in mature established sectors can lack the capability to articulate value at the sector level, and to lead and organise necessary complementors towards a new business ecosystem. Thus, a vicious cycle is created where the industry architecture and the nature of the sector reinforces existing capabilities that further drives the mindsets and decisions to preserve the status quo while the nature of the sector limits business possibilities.

One specific contribution is that the complexity and fragmentation of the sector is an insignificant factor in the emergence of ecosystems and orchestration, as successful and motivated firms actively interact with the environment by building the necessary capabilities (Piepenbrock, 2009) or by changing the environment to fit its capabilities (Penrose, 1959). For example, Intel is an excellent example of a component maker that has become an effective orchestrator while learning about its leadership role through trial and error. Intel has organised a complex fragmented sector towards platforms and complementors. This suggests an important implication for ecosystem orchestration as other contextual factors pose significant challenges. For example, Gawer (2000: p.296), who extensively studied Intel's orchestration processes, proposed that "*every industry that offers complex assembled products can potentially become organized in terms of platforms and complements*". While the built environment sector offers one complex assembled building product that lasts between 25 and more years with co-specialised teams for one single client, this thesis further questions whether every sector can be organised in terms of platforms and complements. While the computer and automotive industries have been able to progress with both digital transformation and platforms since the 1960s (Jacobides et al., 2016), the mainstream built environment sector actors have struggled to self-organise towards open business model innovation at both individual and sector levelwith platforms and complements as the empirical evidence shows. Perhaps the built environment sector shares similarities with the taxi industry; the taxi industry exhibits low capabilities, maturity, high fragmentation, the location factor and is an old industry, which is similar to the characteristics of the built environment. Nevertheless, the analysis indicated that a sector could be organised in terms of platforms and complements if certain conditions are created to support this transition, as evidenced by the case of Uber in the taxi industry and Intel. Although this thesis presents several constraints, it is agnostic and considers ecosystem emergence and orchestration an open-ended process where these constraints do not necessarily determine the outcome (Stacey, 1995). Further research is needed to determine the necessary conditions for ecosystem emergence as evidence of one closed platform-based business ecosystem clearly indicates the potential for more ecosystems to emerge in the future. This thesis laid the foundation for future work on the critical factors that hinder ecosystem emergence and orchestration.

5.2.4 Critical Constructs and Components of Ecosystem Orchestration

A final theoretical contribution of this thesis is the exploration of critical concepts and components of ecosystem orchestration by introducing a multi-level perspective. Prior research has tended to attribute the success of ecosystems to the role of leading firms, platforms and their orchestration processes, thus confirming a success bias in case selection (Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013). Related research explored different specific aspects of ecosystem orchestration, such as bottlenecks (Hannah & Eisenhardt, 2019), platform leadership (Gawer, 2000), capabilities (Helfat & Raubitschek, 2018), industry architecture (Jacobides et al., 2006), organisational forms (Piepenbrock, 2009), cognition (Porac et al., 2011), agency (Ozcan & Eisenhardt, 2009), and power (Ozcan & Santos, 2015). Although these specific constructs and components are critical, their relationships were vaguely articulated, as different studies examined specific components in isolation. By identifying these key elements of ecosystem orchestration, this thesis has made a step towards integrating, organising and positioning how they influence the outcome of ecosystem orchestration.

As such, this thesis builds on existing ecosystem literature, as a relatively integrated framework was developed in Chapter 4 to describe an order for the critical concepts and components, which add to the success and failure of ecosystem orchestration processes. Thus, this framework moves the locus of the discussion from a single component perspective towards a multi-level perspective while introducing institutional, structural and contextual facets, such as normative and cognitive factors. Moreover, the empirical framework demonstrates that concepts and components can be organised at three levels - *individual, organisational* and *system* - and while some can *enable* ecosystem emergence, others can be *built* during the process or can *fail* the ecosystem emergence and orchestration. To my knowledge, this is the first attempt to order the constructs and components of ecosystem orchestration in a systematized way with a specific focus on what constitutes the mechanism of orchestration.

While most studies on the failure of ecosystems attribute this to the role of cognitive frames, mindsets, industry architecture and power relations, I find that failures mostly happen at the system level through feedback loops which influence ecosystem dynamics at both individual and organisational levels. Thus, a related contribution is to highlight the difficulty of predicting whether ecosystem will fail or succeed. In particular, literature on network orchestration emphasised the importance of a "*strategic center*" to hierarchically structure and strategize value creation by its partners and reflect its conscious decisions (Lorenzoni & Baden-Fuller, 1995). As a result, a number of articles emerged offering descriptive mechanisms of how strategic centres or orchestrators achieved their successes. However, this runs contrary to the empirical evidence presented in this research. While many leaders who try to consciously get ahead may in fact succeed, many more will fail. The influence of a leading hub, or a strategic centre, is overestimated and holds an optimistic view on orchestration mechanisms set by an individual firm. The results of this thesis suggest that the success of an individual firm is largely the extent of system dynamics as firms are simultaneously constrained and enabled by the sector, its context and ecosystems. The empirical findings derived in this thesis highlight contradictory evidence that orchestration processes and leadership are not just critical to success but also can constitute a failure; moreover, the sector as the context of implementation plays a critical role too. Although evidence highlighted this contradiction between the literature and empirical evidence, it is important to note that the orchestrators presented in Chapters 2 and 3 do not seem to be legitimate for sector-wide innovation. A critical question that requires further research is *who can be an orchestrator in the built environment sector?* Overall, the analytical contribution of this framework should permit a deeper insight into the orchestration processes while laying a foundation for future research that aims to understand how other components of ecosystem orchestration influence ecosystem successes and failures.

5.3 MANAGERIAL IMPLICATIONS

This thesis also implicates practice in several important ways. The findings of the three studies imply key issues regarding failed ecosystem orchestrations. Based on the empirical results and conclusions, I offer several key recommendations for practitioners. A distinction is made between the recommendations for top management, who find themselves increasingly engaged with ecosystem strategies, and the recommendations to decision makers in the built environment sector regarding the deployment of BIM for sector-wide digital innovation.

5.3.1 Recommendations for Top Management

As the landscape of how firms organise themselves in the global digital economy has changed, top management find themselves challenged with digital disruption. This thesis offers insights into the critical constructs and components of orchestration mechanisms that leaders must consider while orchestrating their ecosystems. These constructs and components can *enable, build* and *fail* ecosystems, as presented in Chapter 4.

One general insight from this thesis is that ecosystems can fail and succeed for different reasons. Typically, the success of ecosystems is attributed to leadership and orchestration mechanisms, while failure is largely attributed to mindsets, leadership cognition, power relations and industry architecture. The notion of success and failure is also mixed when firms identify themselves as successful leaders but their complementors and customers may think otherwise. Successful firms may prefer to measure success factors from an ecosystem perspective to an individual firm perspective. As a result, top management must strategize within a broader context. In other words, in order to succeed they are challenged to understand the needs of actors at the ecosystem level rather than a singular firm or a component. The ability of single firms to articulate, create and capture value largely depends on the success of their partners in the same ecosystem and whether they do the same in return. Mutual support for ecosystem benefits can potentially change the feedback loops.

A related contribution is to highlight that individually successful firms can interact with the environment and, by doing so, they can utilise marketing power. However, those firms that use marketing power for self-benefit should be beware that their strategies can be potentially damage ecosystem actors, as exemplified in Chapter 3. In successful platform-based ecosystems, firms might not need to use marketing strategies. Another consideration is whether strategies adopted from B2C contexts are effective in B2B contexts. As further research is required, this thesis identified an important understanding that firms should be careful in adopting strategies from one context in another.

One specific insight is that, when creating ecosystem strategies, top managers, must anticipate the history of the sector, such as power relations, existing system incentives and established business models. In some contexts, established business models can be a strong motivator in preserving the status quo as in the cases of the built environment sector and the taxi industry. In such cases, successful ecosystem examples might create new markets without interacting with traditional sectors. Awareness of the institutional issues in specific contexts can prepare top management for uncertainty and to thus seek alternative strategies.

While powerful established actors in the built environment sector pursue the status quo, the top management of SMEs with their innovative potential can struggle to organise themselves, as they are typically dependant on the larger network and structure of the sector. Although the sector's nature and structure limit the menu of business models, there is evidence of innovative SMEs that self-organised to fit the traditional environment. By doing so, they changed their business models through interdependence and an internal platform without the need for a contractual relationship. New forms of business models are possible, even in traditional contexts with systemic constraints. The case of inter-organisational cooperation is unique and rare in this sector, as major players tend to organise themselves as large, vertically integrated firms to preserve control and power. Although this case was not presented and discussed in this thesis, it offers important validation of the potential of the networked forms of self-organisation in the traditional environments.

5.3.2 Recommendations for Decision Makers in the Built Environment Sector

The findings of this thesis offer useful insights into the systemic issues of the sector's struggle to innovate with BIM. It is possible that some decision makers would not agree with the evidence presented in this thesis when considering the complexity of the evidence studied and potential biases that can potentially occur during the analysis. However, major disagreements with the results are not expected as the empirical chapters were extensively discussed in various ways (privately discussed, presented and published). As cultural resistance is common in the built environment sector, some top managers might not be committed to accepting unfamiliar recommendations (Morrison & Milliken, 2000). However, I believe that the recommendations presented will be useful for policy makers and decision makers who want to make a change in the built environment sector. Therefore, several recommendations are offered.

Highlighting the importance of the maturity of the built environment sector and its established practices, cultures and mindsets, one of the common beliefs amongst practitioners is that the sector is highly complex, fragmented and unique, and is founded on a project-based approach to organisation. For these reasons any systemic innovation is hard to achieve

(Katila et al., 2018; Taylor & Levitt, 2004). However, by researching the evolution of other sectors, it became apparent that each sector identifies itself as unique, complex and fragmented. These characteristics influence the innovation outcome but do not determine it. This thesis provides empirical evidence on the importance of context. Indeed, the built environment sector has unique features that limit the menu of business model innovation but do not eliminate its potential. It is argued that ecosystems might emerge despite the limitation of location-based business models if the many components of ecosystem orchestration are taken into consideration. This thesis strongly recommends the careful consideration of the development of firm capabilities for leadership and context-dependent orchestration.

A more careful consideration of the constructs and components in the development of strategies is also necessary. Empirical evidence shows that, as long as the value propositions remains poorly articulated at the system level, effective legitimate leadership is absent, orchestration mechanisms are not context-dependant and the business incentives are not addressed, ecosystems in the built environment sector might continue to fail. As the manager of a health care client (CA08) indicated, the "*why*" at the beginning of a project is not typically well articulated, which is also relevant for "*why BIM*". The sector fails to measure the success of project outcomes. A key finding is that the failure to measure success and to capture value from investments will continue to persist as the "*why*" and value propositions at the system level are vaguely understood. A well-articulated "*why*" allows for the effective measure of project outcomes. As the interviewees reported, nowadays value capture in projects by disintegrated co-specialised teams is largely accidental. It is argued that a clearly articulated value incentivises disintegrated parties to encourage collective, rather than individual, value creation. The failure of the software vendor to define value on behalf of the sector in the Californian context provides fruitful evidence of this proposition. This offers another general insight into how much individual firms and decision makers are influenced by marketing strategies and the competitive dynamics of powerful incumbents.

Another important insight is the legitimacy of the actors who take a lead in the sector. The empirical findings illuminated that powerful international incumbents could have a disproportional influence on the market emergence in the sector. The challenge for leading firms is to change their attitudes from the desire to solely dominate the market to instead take a role in propagating mutually beneficial visions and trust in the ecosystem. Considering that prominent incumbents might not agree to such terms, these findings serve as a reminder to policy makers that new ecosystems might not emerge under certain conditions, such as turf wars between prominent firms (Ozcan & Santos, 2015), while established business models could disincentivise the sector's actors to innovate. Specifically, policy makers should investigate the corrective mechanisms for actors in power. Perhaps policy makers are faced with a difficult decision in '*choosing the winning side'* and thus allow large, vertically integrated firms to dominate the market. This thesis also offers a reminder that the built environment sector does not stand on its own but is dependent on many complementary sectors and, as such, the decision makers must open their boundaries to adopt a wider perspective on how one sector is dependent on the wider proponents of an ecosystem. The sector will benefit from a shift from siloed thinking to open thinking by partnering with sectors that can offer complementary resources, know-how and capabilities. Interestingly, until recently, complementary industries were largely disinterested in the built environment sector.

I observed that challengers, typically the outsiders, in the built environment are attempting to accelerate digital practices to become an information-intensive sector in the next ten years (Ribeirinho et al., 2020). Although it is difficult to predict the future, the empirical evidence further suggests that, if the system level incentives and feedback loops continue to act for the status quo, the investments made in the sector's digitalization by firms and governments worldwide might prove to be incremental and fruitless. A number of scholars have indicated and called for a structural change in the sector (Taylor & Levitt, 2004; Winch, 1998); however, evidence derived from this thesis strongly recommends an integrated view of the critical issues that collectively hinder structural change. As such, these issues are leadership, context-dependent orchestration mechanisms, mechanisms for mindset and cognition change, capability development and the most important new business models with clearly articulated value propositions for fair value distribution and capture. The case of Intel clearly indicates that, with effective leadership and investment in the development of capabilities (e.g. Intel and its complementors, partners) and by forming tight trustworthy relationships, the sector can make significant structural changes. To conclude, only those firms that actively seek cooperative relations to create value beyond their own interests can win. However, the behaviours of firms that seek individual value capture are largely guided by structural properties, e.g. established markets, mindsets and business models at the sector level.

5.4 LIMITATIONS

There are a number of limitations to this empirical research. The data collected on the Finnish and Californian ecosystems were initially dedicated to the implementation of Building Information Management in design and construction projects. Although the questions were dedicated to BIM implementation, the collected data were rich highlighting the dominant roles of TEKES in Finland and the software vendor in California. The evidence was compiled from the collected data and completed with an extensive literature review. However, additional data collections with specific foci on TEKES and the software vendor would have offered a more refined and complete picture of the orchestration processes. For example, in the case of TEKES, a leader of the SARA programme was not interviewed but this interview appears to be critical to understanding the failure of business model innovation in the sector. As such, the analysed evolution of Finnish national BIM deployment lacks an understanding of the activities in the SARA programme. However, the lack of information published online justifies the absence of data which would have helped to understand the SARA programme. In relation to the data collection in California, only one anonymous interview was conducted with the software vendor. The orchestration processes were constructed through the analysis of the software vendor's B2B customers and their involvement. Considering the siloed nature of the software vendor, it is possible that a further data collection on the orchestration mechanisms of the software vendor would have been impossible or fruitless.

There are also methodological limitations. First, the use of grounded theory has several limitations that are also associated with any qualitative research. Trustworthiness is a major limitation in accurately reflecting the integrity of the research study (Watt, 2007). It is the researcher's responsibility to take measures to validate the results (Corbin & Strauss, 1990). Although measures were taken to promote the validity and reduce biases, the case studies presented in this thesis are highly complex for one researcher to tackle. Moreover, studying a phenomenon, such as the evolution of one sector over a period of 37 years (the Finnish case), is prone to a subjective view of history that relies on published literature and interviewees' memories. This may have potentially biased the outcome or provided incomplete results.

Another limitation is that the failure bias in the cases may have painted a subjective picture of ecosystem orchestration, as failure and negative cases are prone to subjectification. By investigating failure cases, the researcher may gain insights from small pieces of data that could prove conflicting if key pieces of the puzzle are missed. Indeed, to collect enough empirical data to depict the failure cases, the researcher must follow the case from its genesis to its failure in real time. Although a detailed consideration of one context does not offer generalisability in a statistical sense, such generalisability is not the goal of qualitative research; its subjectivity and context-specificity are considered strengths rather than limitations (Willis, Jost, & Nilakanta, 2007).

The thesis draws its conclusions on purely qualitative data and the researcher's interpretations of the events. Although the researcher has extensively sought validation from external experts in the field, the study would have benefited from a mixed method approach by integrating system modelling, a configuration approach or statistical analysis. Overall, considering the limited evidence of failure cases and the emergent theory of ecosystem orchestration, the adopted interpretivist method based on grounded theory was appropriate to help the researcher develop and contribute new theories.

5.5 FUTURE RESEARCH DIRECTIONS

A few areas were identified for further research, both theoretical and empirical. The thesis explored two failed ecosystems in one sector and juxtaposed the results with successful ecosystems in other sectors. A number of critical constructs and components of ecosystem orchestration were identified and tested. The tested list of constructs and components is not exhaustive. Although these results may be generalisable, there are other constructs and components that could be usefully tested to provide a fully integrated view. Furthermore, with the continuous diffusion of ecosystem strategies across many sectors and the associated use of platform strategies, it is feasible that other constructs and components could be critical depending on the ecosystem type and context. Future research could provide a more complete integration of constructs and components within one integrated, meta-theoretical framework that attempts to create links using a configuration approach. Grounding and testing this framework empirically in specific contexts could thus extend and refine the work with more granulated and context-dependent orchestration mechanisms. It is expected that ecosystem differences may account for more variance in both long and short-term evolutions, and in B2C and B2B contexts affecting the performance (and therefore the survival) of ecosystems.

Despite the importance of mechanisms for value creation and value capture as recognised areas of inter-organisational relationships, this thesis empirically illustrated the importance of the logic of value articulation that was largely taken for granted in studies on ecosystems and platforms. The majority of research to date has not directly explored mechanisms for value articulation nor its direct relationship with value creation and capture within ecosystem contexts. This thesis made the first step to present empirical evidence that failure in value articulation directly contributes to the failure in value capture by some actors. This has laid a foundation for future research on the exploration of mechanisms that link value articulation, value creation and value capture. Given the importance of mechanisms for value articulation in ecosystem contexts, the further development of a more coherent and detailed formation of how these two concepts are theoretically and empirically linked would aid both academic and practitioner understanding.

The adoption of other theories to understand the critical constructs and components for ecosystem emergence and orchestration can be usefully researched. Indeed, ecosystems can be viewed as culturally, historically and geographically organised social phenomena. As such, a cross-national comparison of ecosystems that emerge in different contexts could be researched with the use of the comparative method offered by Ragin (2014). Ragin (2014) offers a technique that uses Boolean algebra to perform a comparative analysis of qualitative case-oriented studies by simplifying a complex data structure in a logical and holistic manner.

This technique is particularly useful in addressing questions that result from multivariate and conjectural evidence and when different conditions produce similar and contradictory results, such as the cases presented in this thesis. Other failed and successful cases of ecosystems could be added to the list for comparative study.

I observed that the characteristics of ecosystem concept and project networks in the built environment sector are surprisingly similar. The definitions of ecosystems provided by scholars perfectly fit the definition of project networks and the design and construction industry in general. For example, the definition provided by Jacobides et al. (2018:p.2264) that, "*An ecosystem is a set of actors with varying degrees of multilateral, nongeneric complementarities that are not fully hierarchically controlled*", can be used effectively to describe the networked nature of design and construction projects. The characteristics of ecosystems and projects also share a great number of similarities, such as co-specialisation, value creation and capture, complementarity, simultaneous competition and cooperation, and loosely coupled structures. The characteristics of ecosystems could be revisited in the context of the project-based organisation of the built environment sector. Perhaps existing knowledge about project networks in the DBE sector could provide useful insights into ecosystem concept in order to refine its definitions and theories. This thesis calls for a more contextualised definition of ecosystems as well as evidence of the generalisability of ecosystems across different sectors. As such, the concept of context could be further empirically researched in B2C and B2B ecosystems.

Another empirical observation is that, over the last two decades, an increasing number of industries have evolved from vertical integration to more horizontal structures, e.g. ecosystem strategies. In comparison, the built environment sector is re-integrating with BIM technologies meaning the opposite was expected. This shift from disintegrated practice towards vertical integration in the built environment sector while other sectors actively shift towards ecosystem types of organisation is an interesting phenomenon that requires further research. Future research could explore questions such as: *Why does this sector behave differently to other sectors? Why is this trend so different from other sectors when ecosystem strategies benefit other sectors?*

Future research could explore emerging business ecosystems in the built environment sector. With increased investment in the digitalisation of the sector, a number of start-ups have emerged. Future research could follow their evolution to understand how ecosystems emerge in heavily standardised industries with low investments. Considering that most research on ecosystems is from a focal hub firm perspective, research that analyses evolution from a small firm perspective and its relationship with global networks could provide a novel perspective with contributions to the discourse on power and growth of ecosystems.

5.6 CONCLUDING REMARKS

In conclusion, this thesis has investigated the orchestration mechanisms of failed ecosystems; this is a topic within ecosystem research that has not been well examined to date. Theoretically, a failed open and closed-system approach to orchestration led by public and private organisations was explored and the research theorised about critical constructs and components for ecosystem orchestration. These constructs and components have a clear order of functions that can *enable*, *build* and *fail* ecosystems. Empirically, this thesis explored two contexts with distinctively different conditions and orchestration mechanisms that manifested similar results and thus pointed to the importance of the sector's context. Empirical evidence clearly indicated that orchestration mechanisms are context-dependent, and the nature of the sector can seriously limit the menu of business model innovation. This thesis further contributed to the discourse on the dark side of ecosystem orchestration.

Theoretically and empirically, this thesis contributes to an understanding of ecosystem emergence and orchestration. It also offers important managerial implications for policy makers and practitioners in relation to sector-wide digital innovation with BIM. I hope these findings will be useful for scholars researching ecosystems and innovators attempting to change established business models in mature sectors with emerging digital technologies.

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APPENDICES

APPENDIX A: INTERVIEW GUIDE

A.1: Invitation Letter: Finland

Dear [Name],

I am writing to you on behalf of the whole team participating in the project ‘A Study of the Quebec-Finland Gap in Building Information Modelling (BIM) deployment: A Critical Perspective Approach’. You were identified with the help of Arto Kiviniemi as one of individuals who played a prominent role in shaping BIM practices in Finland. We sincerely believe that your participation in this project will contribute to better understanding of the specific mechanisms that explain the success of BIM in Finland on the one hand, and slow adoption of BIM in Quebec on the other hand. We intend to compare BIM deployment in Finland and Quebec at four levels: academia, government, industry and individual work. Therefore, we kindly invite you to participate in an open face-to-face interview in Helsinki during the period of 23-29 of February or 7-15 of March, 2015 to support this project. The project is led by prof. Albert Lejeune at Université du Québec à Montréal (UQAM) in Montreal, Canada, where I serve as a research assistant.

I, Gulnaz Aksenova, am a research associate at Management and Technology, ESG – UQAM, The Université du Québec à Montréal (UQAM), in Montreal, Canada. I will be coming to Helsinki on 23 of February – 15 of March, 2015 to conduct a series of interviews and we believe that your participation is extremely important for this research.

The interview will take approximately 90 minutes of your time. The place and time of the interview will be agreed with you if you decide to participate.

If you feel that you are unable to participate for some reasons, or you think that someone can provide us better insights or fits better to the research, please, feel free to forward this email. Any help and advice are very much appreciated.

Thank you for your time and kind perusal of this email. We will be looking forward to a positive consideration of our proposition and your reply.

Yours Sincerely,

Gulnaz Aksenova | BSc Arch., MSc, Ph.D. Candidate

A.2: Invitation Letter: California

Title: An empirical study investigating a strategy for value co-creation with BIM in business ecosystem of AECO industry

Ph.D. candidate: Gulnaz Aksenova
School of Architecture, Department of Digital Architecture, University of Liverpool, UK
***Email**: Gulnaz.aksenova@liverpool.ac.uk*
Ph.D. started on 1 February 2016 and due to be completed on 1 February 2020

Keywords: business ecosystem, design and construction industry, Building Information Modelling

Dear [Name],

I am writing to you on behalf of the whole team participating in the project '[*Title*]**'.** You were identified with the help of [*Key contact*] as one of individuals who played a prominent role in shaping business ecosystem in [*name of the organisation*]. We sincerely believe that your participation will contribute to a better understanding of mechanisms that facilitate and/or hinder the implementation of BIM in the business ecosystem of the construction industry in [*California*]. Therefore, I kindly invite you to participate in an open face-to-face interview in [*to be decided] during the period of [to be decided, example: 23-29 of February or 7-15 of March, 2018*] to support this research project. Your role as a committed member of the construction industry in [*California*] is particularly important for this research project where we intend to compare strategies for value co-creation in business ecosystem with BIM in Finland, UK and California.

I, Gulnaz Aksenova, am a second year PhD candidate under the direct supervision of prof. Arto Kiviniemi (University of Liverpool, UK) at the University of Liverpool, UK. I will be coming to [*California on 23 of February – 15 of March, 2018*] to conduct a series of interviews and we hope for your participation. The interview will take approximately 60-90 minutes of your time. The place and time of the interview will be agreed with you if you will decide to participate.

Your participation is extremely important to us to fulfil the posed aims. If you feel that you are unable to participate for some reasons, or you think that someone can provide us better insights or fits better to the research, please, feel free to forward this email. Any help and advice are very much appreciated.

Thank you for your time and kind perusal of this email. I will be looking forward to a positive consideration of this proposition and your reply.

Yours Sincerely,

Gulnaz Aksenova

A.3: Consent Form: Finland

UQÀM
Université du Québec à Montréal

INFORMED *CONSENT FORM*

TITLE OF THE PROJECT: *A Study of the Quebec-Finland Gap*

In Building Information Modelling (BIM) deployment: A Critical Perspective Approach

***PREAMBLE*:**

You are invited to participate in a research project which aims at explaining the gap between the BIM adoption in Finland and Quebec. Before agreeing to participate in this project, please devote your time to read the information below carefully. If there are words or sections that you do not understand, do not hesitate to ask questions.

***IDENTIFICATION*:**

Project leader**: Albert Lejeune**

Tel**: (514) 987-3000**

Department: **Management and Technology, ESG - UQAM**

Email**: Lejeune.albert@uqam.ca**

Address**: School of Science and Management, Université du Québec à Montréal**

Case 8888, succursale Centre-ville Montréal, (Québec) H3C 3P8

Members of the team**: Daniel Forgues (ETS), Hamid Nach (UQAM)**

Associate researchers**: Hannele Kerosuo (The University of Helsinki), Arto Kiviniemi (The University of Liverpool) and Lauri Koskela (The University of Huddersfield)**

Research assistants**: Gulnaz Aksenova, Marie-Claude Plourde, Mamadou Diallo and Georges Rizkallah**

Coordinator**: Marie-Claude Plourde**

Interviewer**: Gulnaz Aksenova (PhD candidate, ETS)**

***OBJECTIVES OF THE* CONSENT FORM AND FUNDING (IF APPLICABLE):**

- *To present the general and specific objectives in clear and accessible language to the participants.*
- *This project receives financial support from CRSH, Program for Development of Knowledge (2014-2016).*

***PROCEDURE* OF TASKS REQUESTED FROM THE PARTICIPANT:**

Your participation includes an open interview with the researcher assistant and/or with research assistants. You will answer to the several questions that will identify the mechanisms that encourage or discourage the implementation of BIM technology in Quebec. The interview will take approximately sixty to ninety minutes of your time and is digitally recorded with your permission.

POTENTIAL BENEFITS:

Your participation will contribute to the advancement of knowledge through a better understanding of the mechanisms that facilitate or hinder the implementation of BIM In the ecosystem of the construction industry in Quebec.

***ANONYMITY* AND CONFIDENTIALITY:**

It is agreed that all the information collected from the interview is strictly confidential. Only research team will have access to the audio and transcript files. All research material and consent forms will be kept separately in a secure place at the office of the project leader for the duration of the project.

In order to protect your identity and privacy, your name will be identified with an alphanumeric code. The code of your name will be known as Finland_1 (and etc.). Digital recordings will be erased after two years, and your information and consent form will be kept for a period of two years before being destroyed.

I agree that excerpts from the interview will be disseminated through the scientific meetings or training, future scholars and that these excerpts will not identify me in any case.

☐ YES ☐ NO

VOLUNTARY PARTICIPATION AND THE RIGHT TO WITHDRAW THE INTERVIEW:

Your participation in this project is voluntary. It means, that you agree to participate in the project without any external pressure. You are free to stop or withdraw your interview at any time during the course of the research without any justification or prejudices of any nature. In this case, unless over wise stated, data associated with you will be destroyed.

Your agreement also implies that you accept the use of data collected from you for the research purposes such as articles, student thesis, conferences or any other kind of research and scientific papers. In this case, any information identifying you will be disclosed unless explicit consent is signed by you and over wise stated.

FINANCIAL *COMPENSATION* AND OTHERS:

It is understood that you will not receive any financial support as a compensation for your participation in this research.

***LIABILITY* CLAUSE:**

By agreeing to participate in this research, you are not giving up any of your rights, nor discharging the researchers, the granting agencies or the institution from their legal and professional duties.

AFTER THE *COMPLETION* OF THE PROJECT:

After the completion of the project, we would like to keep the data for the period of two years to support other research projects as well. The ethics of this research also apply to the long-term preservation of the data. You are free to refuse the secondary use of the data.

☐ I accept that my data will be used for other research projects

☐ I do not accept that my data will be used for other research projects

FOR FURTHER *QUESTIONS* ABOUT THE PROJECT AND/OR YOUR RIGHTS:

If you should require any further information about the project, your participation and/or rights as a participant of this research, or you would like to withdraw your interview from the project, you may contact:

PROF. ALBERT LEJEUNE, responsible for the project
(Name of the contact person / position)
Telephone: 514 987 3000 (extension number # 4844)
Email: LEJEUNE.ALBERT@UQAM.CA

The Institutional Ethics Committee for the Research Involving Humans of UQAM has approved this research project. For the information conserving the research team and terms of ethics involving humans, or to make a complaint, you may contact the president of the Ethics Committee by phone:

+1 (514) 987-3000 (extension number # 7753) or through email: CIEREH@UQAM.CA

***ACKNOWLEDGELEMENTS*:**

Your participation is very important for the realisation of this project and the research team would like to sincerely thank you for your participation, effort and time. If you would like to receive a written summary of the main results of this research, please, add your details below:

***SIGNATURE*:**

Hereby:

- **a)** I have read this information and consent form;
- **b)** I voluntary consent to participate in this research;
- **c)** I understand the objectives of the research and my involvement in the project;
- **d)** I acknowledge that I had a sufficient time to consider my decision for the participation;
- **e)** I also recognise that the interviewer has answered my questions satisfactory;
- **f)** I understand that my participation in this project is totally voluntary and I am free to terminate and withdraw the data at any time without any justification or penalty.

Signature of the participant: Date:

Name (print) and contact:

I, hereby, declare:

- **a)** I have carefully explained the participant what his/her role and rights in this research
- **b)** I have received the consent form for my personal hold;
- **c)** I have responded to my best knowledge to the questions regarding this research project during the interview

Signature of the interviewer: Date:

Name (print) and contact: Gulnaz Aksenova

A copy of the information sheet and signed consent form must be given to the participant.

A.4: Consent Form: California

UNIVERSITY OF LIVERPOOL

Committee on Research Ethics

Participant's Consent Form

Title of Project:	PhD Thesis: An empirical study investigating a business ecosystem strategy for value co-creation with BIM in the AECO industry

Researcher:	Gulnaz Aksenova (B.Arch, M.Sc., PhD candidate in Digital Architecture) School of Architecture, University of Liverpool Leverhulme Building, Abercromby Square L69 7ZN, UK T: +44 (0) 55 3398 9288 E: Gulnaz.Aksenova@liverpool.ac.uk

Write your initials in the box

1. I confirm that I have read and understood the information sheet dated 10/04/2017 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐

3. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and until the data has been used in any publication I can also request the destruction of that information if I wish. ☐

4. I understand and agree that my participation will be audio recorded and I am aware of and consent to your use of these recordings for this research.

5. I understand that I will not be identified in this interview and any subsequent publication or use.

6. The information you have submitted will be used in the PhD dissertation and may be used in journal and/or conference articles. Please indicate whether you would like to receive a copy of all publications where your information has been used. If you leave the box empty, it means that you do not want the material.

7. I agree to take part in the above study.

Participant Name	Date	Signature
Gulnaz Aksenova	Date	Signature

A.5: Participant's Information Sheet: California

Committee on Research Ethics

An empirical study investigating a strategy for value co-creation with BIM in business ecosystem of AECO industry

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Participant's Information Sheet

1. **Title of Study:**

An empirical study investigating a business ecosystem strategy for value co-creation with BIM in AECO industry

2. **Version Number and Date**

Form N 2110. Version 2.2 – 19/04/2018

3. **Invitation Paragraph**

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. Please also feel free to discuss this with your friends and/or relatives if you wish. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to.

Thank you for reading this.

4. **What is the purpose of the study?**

A central purpose of this research is to explore, describe and explain how evolution of new business ecosystems in AECO industry, as both the individual organisations and its environment (e.g. ecosystem that includes industry, markets, and institutions) are co-evolving creating and capturing value with the adoption of BIM to sustain ecosystem's health where each member of the ecosystem benefits from the adoption of BIM.

5. **Why have I been chosen to take part?**

You were identified as one of individuals who played a prominent role in shaping business ecosystem in your organisation. We sincerely believe that your participation will contribute to a better understanding of mechanisms that facilitate and/or hinder the implementation of BIM in the business ecosystem of the construction industry in your country/state.

6. **Do I have to take part?**

Your participation in this project is voluntary. It means, that you agree to participate in the project without any external pressure. You are free to stop or withdraw your interview at any time during the course of the research without any justification or prejudices of any nature. In this case, unless otherwise stated, data associated with you will be destroyed.

Your agreement also implies that you accept the use of data collected from you for the research purposes such as articles, student thesis, conferences or any other kind of research and scientific papers.

7. **What will happen if I take part?**

Your participation includes an open interview with the researcher. You will answer to several questions that will identify the mechanisms for value co-creation with BIM in the business ecosystem of your organisation. The interview will take approximately sixty to ninety minutes of your time and be digitally recorded with your permission.

8. Expenses and / or payments

The interviews will be conducted at any venue chosen by you. This is to ensure the comfort of the participant for the study.

You will not receive any financial support as a compensation for your participation in this research.

9. Are there any risks in taking part in the research?

You are free to withdraw your participation from the research at any time. If you feel any discomfort during the interview, you are free to stop it at any time. You can also refuse to answer any questions you don't want to answer.

The interviews will be transferred to the university's protected hard drive as soon as possible after the interview and after that destroyed from the original recording device. Only the researcher and her supervisors will have access to the original data

10. Are there any benefits in taking part?

Your participation will contribute to the advancement of knowledge through a better understanding of the business ecosystem strategies and value co-creation with BIM in AECO industry. You can also get the final PhD dissertation if you want.

11. What if I am unhappy or if there is a problem?

Research Governance support for the University of Liverpool has approved this research project. If there is a problem and researcher cannot help you, you can contact her supervisor, Arto Kiviniemi by email a.kiviniemi@liverpool.ac.uk. If he cannot help you or you want more information concerning the research team and terms of ethics involving humans, or you want to make a complaint, you may contact the Ethics Committee by email: ethics@liv.ac.uk. When contacting the Research Governance Officer, please provide details of the name or description of the study (so that it can be identified), the researcher involved, and the details of the complaint you wish to make.

12. Will my participation be kept confidential?

All the information collected from the interview is strictly confidential. Only the researcher and her supervisors will have access to the audio and transcript files. The audio file will be transcribed by the researcher. All research material and consent forms will be kept separately in a secure place at the office of researcher for the duration of the project.

To protect your identity and privacy, your name will be identified with an alphanumeric code. Digital recordings will be erased after the PhD is accepted.

13. What will happen to the results of the study?

The results from this study will be used in the researcher's PhD dissertation and possibly also in journal and/or conference articles. All published information will be anonymised.

14. What will happen if I want to stop taking part?

Participants can withdraw from the study without any explanation until the results have been used in any publication. Results that have not been published may be used up to the period of withdrawal only if participants agree for that to be done.

15. Who can I contact if I have further questions?

If you should require any further information about the project, your participation and/or rights as a participant of this research, or you would like to withdraw your interview from the project, you may contact:

Gulnaz Aksenova
Teaching Assistant, B.Arch, M.Sc.,
PhD candidate in Digital Architecture

School of Architecture,
University of Liverpool
Leverhulme Building,
Abercromby Square
L69 7ZN, UK

T: +44 (0) 55 3398 9288
E: Gulnaz.Aksenova@liverpool.ac.uk

Prof. Arto Kiviniemi
Professor of Digital Architectural design

School of Architecture,
University of Liverpool
Leverhulme Building,
Abercromby Square
L69 7ZN, UK

E: A.Kiviniemi@liverpool.ac.uk

16. Acknowledgements:

Your participation is very important for the realisation of this project and the research team would like to sincerely thank you for your participation, effort and time.

A.6: Expert Interview Guide: Finland and California

The following interview guide was used for data collection in Finland and California. The interviews included open questions and were partly based on the long interview process undertaken by McCracken (1988). The interview thread followed a similar procedure for each question but was not limited to it. For example, the first question is posed about the evolution of ICT in the industry from the beginning of the interviewee's career. The presented perspective was then contrasted with the "*interviewee's organisation and other organisations*", "*before BIM and after BIM*" or any other relevant comparison. As the interviewee presents their perspective on the evolution of ICT, I allowed them to speak freely about their observations while asking them to clarify specific terms that they used while using "*Floating prompts*" (Dohrenwend & Richardson, 1956) to repeat the key terms of the respondent's last remark.

Interview guide is presented below:

Background information about the project.

- The project introduction.
- Interviewer introduction.
- Request to sign consent form.

Background information about the interviewee.

- Could you tell me briefly about yourself and your position in your organisation?
- What is your present position in this company/organisation?
- What are your major responsibilities in the company/organisation?
- How many years have you worked in the industry?

First question: The historical perspective on the evolution of ICT in the sector and the emergence of BIM.

- Could you tell me about the importance and evolution of ICT in your organisation, industry and ecosystem from the years 1990-2000 and until the arrival of BIM? According to your perspective, from the start of your career how did it evolve?
    - **Contrasts:**
        - What is the difference between what you call "X" and the other category "Y"? (X and Y were introduced by the informant)
    - **Categories**:
        - Can you give me an account of all the formal characteristics of the point under discussion - key players, key actions, key events, etc.
    - **Memories of incidents** were used when an incident was mentioned by the interviewee, such as a “strange event” or a “surprising event” in order to show cultural categories and their interrelationships (McCracken, 1988).
        - What was striking?
        - What was surprising?
        - This contradicted what?
    - **Stimuli** – a timeline is presented with key events identified in the published literature to trigger memories.
    - Additional questions were asked if the conversation was not evolving:
        - Who were the key individuals and stakeholders? How did they help to initiate the programme in practice?
        - How do you see the role of institutions in industry renewal?
        - Where do you see the risks or hindrances in the ecosystem?

Second question: The emergence of BIM in the industry.

- Could you tell me about how BIM has emerged in the industry and your organisation?
- **Contrasts:**
    - What is the difference between what you call "X" and the other category "Y"? (X and Y were introduced by the informant)
- **Categories**:
    - Can you give me an account of all the formal characteristics of the point under discussion - key players, key actions, key events, etc.

- **Memories of incidents** were used when an incident was mentioned by the interviewee, such as a "strange event" or a "surprising event" in order to show cultural categories and their interrelationships (McCracken, 1988).
    - What was striking?
    - What was surprising?
    - This contradicted what?
- **Stimuli** – a timeline is presented with key events identified in the published literature to trigger memories
    - Additional questions were asked if the conversation was not evolving:
        - Back to your first experience with BIM, can you tell me how this technology has become important to your organisation?
        - What was the main motivation behind the adoption of BIM?
        - Which barriers did you experience and what caused them?
        - Which challenges did you experience and what caused them?
        - Which benefits did you experience and what caused them?
        - Which elements contributed to the emergence of BIM?
        - Why was BIM important in your organisation?
        - Which projects were successful/not successful and why?

Third question: The current state of BIM in the industry.

- What is the current state of the industry adoption of BIM?
- **Contrasts:**
    - What is the difference between what you call "X" and the other category "Y"? (X and Y were introduced by the informant)
- **Categories**:
    - Can you give me an account of all the formal characteristics of the point under discussion - key players, key actions, key events, etc.
- **Memories of incidents** were used when an incident was mentioned by the interviewee, such as a "strange event" or a "surprising event" in order to show cultural categories and their interrelationships (McCracken, 1988).
    - What was striking?
    - What was surprising?

    - This contradicted what?
- **Stimuli** – a timeline is presented with key events identified in the published literature to trigger memories
- **Additional questions** were asked if the conversation was not evolving:
        - What are the diffusion mechanisms and how they can accelerate the implementation of BIM?

To conclude:

- What surprised you the most about the sector?
- Is there anything else of importance you would like to add?
- Is there anything that we did not talk about that appears relevant?
- Could you recommend a relevant expert for the interview?

APPENDIX B: DATA STRUCTURE FOR CHAPTER TWO

The following are selected quotes of qualitative data for the discourse & textual analysis within Chapter 2.

<table>
<tr><th colspan="3">Aggregated dimension: Phase 1. Technology Innovation:
The Emergence of the Knowledge Hub with Pioneers, 1965-1983</th></tr>
<tr><th>Aggregated Themes</th><th>Second-Order Categories</th><th>Selected Evidence on First-Order Categories</th></tr>
<tr><td rowspan="2">Period 1. The emergence of a knowledge hub</td><td>Emerging knowledge hub in the industry</td><td>Focus on the computer simulations at the universities
“We did not have any laboratories, so, in order to do exercises - instead of doing laboratory exercises and tests - we did computer simulations from early on. I did my first computer graphics program in 1968, which generated 3-D stereo images. I did everything with computers from the very beginning. […] We were getting better and better. Not, of course, all the time. And all the time we did a lot of software development with students. At least some of us, I was one of them. […] when I visited universities, I saw a lot of students in the laboratories, physical testing, and so forth… We did not do much of it. So, this is one of the main reasons. We did not know what was really happening in other countries. From my point of view, it is the main explanation that I can think of.” (Researcher, FIN18)
The industry was motivated to speed up standardisation to create efficiency after IIWW
“We had official collaboration also when it came to building models, led by the Finnish building information foundation (Rakennustietosäätiö). Rakennustietosäätiö was around from the Second World War and they were founded by Finnish companies to take care of standardisation in the Finnish construction industry. Because, after the war, we had to rebuild a lot and it had to be very efficient. And it made sense to do standardisations of certain processes, definitions and specifications.” (Consultant, FIN04)
Open opportunities for start-ups with low competition
“There is a whole generation of people who started that [software development] in the early 80s and late 70s. They still are alive. Of course, many of them are coming up to retirement age. And they are selling these companies. I think some of them work with original management. Obviously, there was a kind of time window. If you want to set up such a company, you could do it in the 80s and nobody had this huge competition; everybody was more or less on the same level, the same position. Most of the companies these days would not be able to survive. Nowadays, it would not be possible to set up such a company because it would need a big investment.” (Researcher, FIN18)
Emerging product data models amongst industry visionaries
“The group of companies - architectural, engineering, and structural - were working together with the software company called Tekla. And they have established a project which was called ALVISR. These projects got a working system, and they did a couple of real models with that, which was totally done with computers, and it had a product data model inside. But it was not commercially valid because computers and networks at that time were not powerful enough. They had a connection with graphical terminals and mainframe computers (VAX750) with modem connections; it wasn’t practical for use. But in theory, everything worked.” (CEO, software vendor, FIN17)</td></tr>
<tr><td>Forming a knowledge hub by developing digital capabilities and cultural enthusiasm for technology</td><td>Forming a hub with high-tech champions (engineers)
“When I look backwards, I think that roughly my generation, when we got out of the university, we produced ICT everywhere in the industry. We were the first ones who had access to the computers. Once these people went into the industries, they changed everything.” (Researcher, FIN18)
Champions challenge the industry with new technological developments in 1965
“Tekla was established to challenge the industry with new technological solutions” (Quote_FIN17)</td></tr>
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		"Tekla was established in the late 60s. The name Tekla comes from structural analysis, it worked for structural analysis. So, I think it is also very important; they have developed software for structural analysis, dimensions, columns, whatever... They had software for everything. Most of the structural engineers had used that software already in the 60s. The company I think was established originally by several consulting engineering companies, who were shareholders and wanted to establish its capability to use computers in civil engineering. So, they were already visible in the 60s and, of course, having this company led to the fact that all consulting engineers were using computers and Tekla. Originally, there were some large computer centres here. Companies did not have their own computers; I think, in the early stages, I think they operated from abroad." (Researcher, FIN18) "I was borrowing these computers, they wanted to develop their software and they sold my software to Hewitt Packett. We were trying to commercialize this; we had quite modest results. I was providing some services to companies to generate 3-D images for advertisement. For instance, we used to make commercial images of buildings." (Researcher, FIN18) ***Finnish pioneers developed advanced systems comparing to AutoCAD*** "In the early 80s, Autodesk started to launch some software, like AutoCAD, which was a lousy system in those days. I remembered very well because I was a CEO of a small software company. We have looked at it and it was not good. We decided to do our own and we did. Then, of course, in the long run, AutoCAD became very powerful. But it came to the market in the early 80s and it was really bad those days." (Researcher, FIN18) ***Extensive development of CAD systems by pioneers in small firms*** "I think Tekla was one of the first who then introduced a service-based CAD system. It was called DOGs, Drawing-Oriented Graphic System, and they provided it from the service centre to remote (….?) And this became quite popular in the early 80s. It was basically the first widely used CAD system. […] Then, I want to mention a new company, which is Progman. They developed a System for heating and ventilation systems. I think it started probably from the design of ducts, which takes a lot of space in buildings. Later on, they added thermal simulation to do both 3-D dimensional CAD Design and also a simulation of the ventilation system. I probably have mentioned the main pioneers. For some reasons in Finland we have got quite a few small software companies, which were developing CAD systems at that time. Which is an interesting thing." (Researcher, FIN18) ***Developing internally tools for engineering services and precast cost and material calculation*** "Some of us developed programs for construction analysis. Now, you are lucky, people get to learn commercial software, but many of us developed these programs ourselves. […] So, people developed small CAD systems to do drawings in the late 70s. […] I think we used these technologies to design single family houses. Factory houses around the very late 70s. This was probably the first CAD system developed in Finland for the construction sector" (Researcher, FIN18) ***Technology enthusiasts were focused on technology more than business investing into immature technology*** "If you invest in technology that is not yet mature you might suffer from competition that might hit you. Something that is really strange, if we look backwards. Here in the 80s, we had a number of big brave software companies in a very small market, like Finland. I assume if people had a little bit more sense, they would not have established these companies for such a small market. **They were more interested in IT rather than business**. […] I think it was technology; it was so fantastic even to think about what you could do with these technologies; how much better you could do with it! I was really enjoying when I was able to develop some software that people use in their jobs. Certainly, software development is extremely powerful. Almost no limits what you can do with it. But it is so expensive, but maybe the next step should be the business development." (Researcher, FIN18) ***Enthusiasts adopted technology even if it was commercially not profitable because of absence of international competition and culture enthusiasm for technology*** "We are technology freaks. […] I think also that to some degree, it is because this is a small country; we were not afraid of international competition. It is possible to adopt technological

		enthusiasm, even if it is commercially not profitable in the short term. […] In Finland, unlike in international markets, we did not have international competition. As long as everybody thinks that playing with BIM was fun, everybody did it and they did not suffer from competition. But this technological enthusiasm can be dangerous, I think. (Researcher, FIN18)
	Lesson learnt 1. Incompatibility between tools slows standardisation	***American CAD systems entered Finnish market in the late 70s*** "Finland was attacked by international vendors, like CAD systems; nobody knew about them before. In 79 it had just landed in Finland; they were all over the place, getting their market share. They were looking for companies and trying to sell systems to these companies. Construction sector companies could not afford to buy these American CAD systems, like Bentley and so forth. It was just too expensive. A single workstation cost more than a single-family house - up to three times. […] The reason why some of the industrial companies could afford them was because [….] they saw the potential of this technology and they knew that prices would definitely come down. But if we invest early and we can learn, then we can stay ahead of the competition. It makes perfect sense. But, for construction sector it was not nearly impossible." (Researcher, FIN18) ***Industry realised the incompatibility between developed tools slows standardisation*** "But the competition also meant that, if one architect was using one system and then I was using another system, the designs were not to be compatible. That dilemma also sped up standardization." (Consultant, FIN04)
	Government set up TEKES to drive high-tech society	***Government established TEKES to drive high-tech development in the country*** "One important thing really to mention here is TEKES; TEKES was probably established in 83. […] **The setting up of TEKES caused turmoil in Finland**. Fuss, everybody got excited…. There was **a lot of money coming** in because people had read in the newspaper that TEKES had a budget for that. It was brilliant. **No one really knew what it was going to do, but the budget was X million FIN mark to support technological development in Finland**. It was not totally new because previously the Ministry of Trade Industry did provide resource funding for institutes. But TEKES was something more visible, **so this first type of innovation enthusiast, including people like myself and other guys, got very enthusiastic and started to see money in that."** (Researcher, FIN18) ***TEKES was a driver in motivating industry to start national R&D*** "TEKES shows how much importance technology has been given in Finland." (Researcher, FIN05) "Really, TEKES's investment, or actually industry investment through TEKES's support, made it possible to really develop early." (Manager, HVAC, FIN10) "TEKES provided some money to companies that otherwise would not be doing it at all." (Researcher, FIN01) ***TEKES was stimulating the focus on technology R&D for business development*** "Simultaneously, we had TEKES, the National Technology Agency, which started to fund universities and public companies and not private companies in the 1980s. But they changed their mind in the early 1990s because Finland had to create new businesses so we could get more work and a better reputation and possibilities on the market. That meant we could get support from the government for R&D work." (CEO, HVAC, FIN23) ***VTT was driving the research agenda in engaging academia & industry for R&D activities*** "The relatively large size of VTT and its resources for efficient technology transfer has been another such factor [driving force]." (Björk, 1994)
Aggregated dimension: Phase 2. Concept Development. Formation of the Knowledge Ecosystem for Knowledge diffusion, 1983-2002		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Period 2. 1983-1990. Abstract Development	*TEKES established the RATAS*	***TEKES established the RATAS research program to study the building product modelling concept*** "At the same time, there were some resource programs; it was not only TEKES but also the industry collaborating with VTT. The word RATAS comes from computer aided design

	research program	building, a Finnish word. […] The real development started in RATAS 2. This was the main breakthrough period and everything else was built on these." (Researcher, FIN18) ***RATAS was a unique programme globally*** "RATAS was unique at that time. Of course, Georgia Tech with Chuck Eastman was on top of the world for a long time, but in most places, it was totally new for industry actors." (Researcher, FIN20)
	Important role of TEKES in building BIM competence in RATAS	***RATAS helped VTT researchers to develop vision and theory of concepts*** "RATAS was a **theoretical exercise for thinking about the possibilities of building product modelling**. At that time, there were no computers or tools powerful enough that could be useful for big projects, and the group that was doing it was very small and visionary; relatively theoretically-oriented rather than industry-focused. Another main difference was the amount of resources. VTT research was creating a critical mass of theoretical understanding of this [concepts]." (Researcher, FIN20) ***VTT was crucial in creating a common understanding of BIM and Finnish national standards between TEKES, the industry and research institutes*** "**VTT had a lot of competent people who really knew about BIM and its possibilities**, its technologies and so forth. […] VTT was in RATAS programme and was creating a common understanding of BIM in Finland**. VTT's role was absolutely crucial**. Most BIM experts in the early 90s were working in VTT. But VTT also had a very close collaboration with the industry; there would not be any project where industry would not be involved. There was always a discussion going on between them about what would be the common goal. The main problem in RATAS was that they tried to develop the Finnish standard for the building product model but […] the software industry is global and we can't have national Finnish standards (Researcher, FIN20)
	TEKES's orchestration mechanisms in RATAS	***Engaging in international collaboration through research institutes like VTT*** "RATAS did not have much international collaboration. VTT had some connections with Stanford but, to my knowledge, not so much related to RATAS but research institutes and exchanges." (Researcher, FIN20) ***Establishing international collaboration with BIM experts in the USA and EU (Björk, 1994)*** ***Building collaborative engagement with Nordic countries and the USA (Björk, 1994)*** ***Sponsoring awareness of cutting-edge developments extensively through sharing in publicity and events*** "We had reports where we explained the concepts and structures and we had a lot of events those days. […] In those days, there were often events where hundreds of people participated. Several times a year. Some people, once they developed something, they would present their developments for those who were able to follow up these developments. Even during the 80s, if you would go to any place in Finland, or a consultancy organisation, they would know all the news about these technologies. This is quite exceptional, I think, compared to other countries. Twenty years ago, a consulting engineer or architect would know in this country. They did not have a deep knowledge, but at least they knew something. And I can't think how it would have happened unless TEKES was showing some money." (Researcher, FIN18) ***Paving the way for integrated computer-aided building design (Björk, 2009)*** ***Involving architects (Björk, 2009)*** ***Involving public client, Senate Properties, as an industrial partner*** "Senate Properties (SP) was active in VERA from the beginning but also they were industrial partners in RATAS programme. They have been following the development for a very long time. They had big resources; the problem was that it was not necessary that technically qualified people were in those roles. They had little resources to do things, they had project managers, and everything related to R&D, only if they had the time. […] In SP, it was not that important; they wanted to be involved but did not want to put a lot of resources into that." (Researcher, FIN20) ***Attempting to change the education for construction by the champions***

		“Also, going back into the history, in the late 80s, during the time of RATAS, we had a construction delegation, we went to talk to the Ministry of Trade, the Principal and the Rector of Alto University. We spoke about the need for a proper education in this country in the construction sector. It took 30 years to make it happen. Until now, we have got only three professors at the University of Alto, almost 30 years later. Academia in Finland has been lacking some of the academic side of BIM activities.” (Researcher, FIN18) ***Encouraging member’s exploration for complementarities without force*** “It was up to the companies themselves if they want to cooperate. You cannot force them. It would be a forced marriage as someone is selecting a husband that you do not want to marry. In construction, it is about collaboration and should be based on a feasible relationship. There must be real interest on both sides. […] Seminars we were organising, companies were presenting their work and if somebody was interested, they could find potential partners.” (Researcher, FIN20)
	Results of RATAS	***Developed a concept of Building Product Data Modelling, which was renamed by Autodesk to Building Information Modelling in 2002*** “Before 1993, I knew very little about BIM. We called it Building Product modelling. The BIM name came in 2002 when Autodesk started to use this term.” (Researcher, FIN20) ***Created breakthrough concepts that data could be used in many different intelligent ways*** “RATAS was the main breakthrough period and everything else was built on this. I do not see major steps forward. It is thinking, the results were not something like software. Of course, we did some prototypes. It was more like specific concepts. So it was more about clarification to everybody that you can use computers in an intelligent way, not just for the creation of drawings but to create data, which you could use in different ways. As long as you have a structural data you can view it in different ways and you don’t need to generate new data if you want, for example, to have another view. It was not rocket science but to make people understand this possibility, I think it was fundamental. (Researcher, FIN18) ***Disciplinary firms saw benefit in collaboration with the use of building product data modelling technologies*** “In the 1990s, when PCs became mainstream and AutoCAD was mainstream also, many Finnish companies started to think that now we want to collaborate. It was evident from the beginning that everybody wanted to collaborate between disciplines.” (Consultant, FIN04) ***Key leading firms established internal strategies to identify business opportunities with technologies*** “During this period, two of the largest building contractors in Finland, Haka Oy [Laitinen 1992] and Puolimatka Oy, defined company-specific CIC development strategies. An important ingredient of these strategies is to identify the business opportunities that CIC can offer for the firm in question. Haka has, in particular, stressed the importance of the building product model approach in such a strategy. Partek Oy, the market-leading manufacturer of building materials, has been one of the driving forces behind the TELERATAS system.” (Björk, 1994: p.18) “On the level of professional associations, the contractors' association carried out a fairly explicit CIC strategy via its funding of R&D. The association of building clients founded a separate information technology committee, which defined its own strategy. The architects' interests were being looked after by the CAD-SAFA association.” (Björk, 1994: p.18) ***RATAS network developed shared consensus of the importance of international open standards for technology development*** “It is absolutely crucial to have open standards and if you do not have open standards, you cannot share data. It was the late phases of the RATAS project; everyone who was involved in RATAS understood it. It is like a historical development, you understand, this does not work and then you think, why this does not work, and you start to understand that there was a strong consensus that we have to go international.” (Researcher, FIN20) ***Industry saw benefits in connecting building information to facility and property management*** “Yes, we started in the early 1990s, because we saw that we are building information during construction; we would hand it over to facility and property management. And that’s why

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<tr><td></td><td></td><td>we already had started to think about that part. And I was also a part of the RATAS project.” (Consultant, FIN04)</td></tr>
<tr><td></td><td>The first manifestations of the dark side of orchestration processes set by TEKES</td><td>Architects were threatened by the restructuring of the division of labour in industry with the building product modelling technologies
“I participated under the confidentiality agreement for the strategic agreement with some architectural associations, somewhere here in the early 80s. They got anxious about their role with this technology: is it beneficial to them or is it dangerous, and so on? If there are any ways to benefit from this technology, companies usually do not do that, because they would rather stay in something they have always done. It takes a lot of courage to change how the system works.” (Researcher, FIN18)
Exploring unsuccessfully the mechanisms to break the barrier of status quo sharing
“Many people believe that to break this barrier [status quo of sharing], there is only one solution to make owners meet these requirements. But the problem is that the owner himself doesn’t need it. But the structural engineer and contractor, they need it. They do not have a contract with the architect, so why would the architect serve contractors and clients? I left a client who required it and there was no point. But this was an early problem and we had already realized it in the early 80s.” (Researcher, FIN18)
TEKES mechanisms for funding of R&D incentivised public funding exploitation for self benefit
“The money itself is not a key thing, but people would do anything to avoid paying some taxes or get some public funding. It does not really proportional to the money itself, but it has some kind of impact, but this legal support would get them far. You can see that people can avoid a lot of trouble paying these taxes.” (Researcher, FIN18)
“Funding comes partly (usually 40-45%) from TEKES and partly (60-55%) from the industry. All projects are public on the headline level (name, subject, main partners), but the results of industrial projects are proprietary.” (Researcher, FIN20)</td></tr>
<tr><td></td><td>TEKES is setting expectations</td><td>Setting expectations that SMEs would merge to create powerful international vertically integrated organisations
“For instance, scenarios like multidisciplinary design consultants led by architects, that did not happen. In Finland we have different disciplines in different companies. It is like architects in one company, structural engineers in another company, HVAC engineers, telecommunication engineers, or information engineers – all these are different companies. The work would be much easier if they had technology, like BIM, to work with; it would be easier if they were in one company. And this is what was expected to happen in the early 80s, 30 years ago. So, in order to exploit these technologies, such companies would be set up. But this has never happened. But they are exactly what they were 30 years ago.” (Researcher, FIN18)
Setting expectations that contractual relations and liability issues will be solved
“There are also liability issues. Why would I give to somebody a BIM model if this person finds an error and he can sue me for that?! So, it is safer to give him a drawing. I do not understand this any other way, only if the client becomes more demanding. In the 80s by the way, 30 years ago, we did expect things would change much more, really.” (Researcher, FIN18)
Setting expectations that interoperability will be solved in five years
“Another problem is that interoperability with CAD systems would all be solved in something like five years, but this was thirty years ago. If I needed to update this vision, I would say that interoperability problems would be solved in five years so, the business stays the same, just time goes on.” (Researcher, FIN18)
Setting expectations that a business would scale globally
“It is one of the latest trends, at least in Europe, that there is a lot of focus on business models nowadays. Because technologies are there and they are not used effectively in this kind of business. It is beneficial to some companies, if they don’t pay somebody.” (Researcher, FIN18)
Setting expectations that the construction sector will renew itself with new technologies</td></tr>
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		"TEKES saw the potential in creating a platform to support the link development with the technology contributing to the biggest cluster of all. Big expectations have been placed on the construction sector to self-renew with the networked technology and services based on them." (Uusikylä et al., 2003: p.12) ***Setting expectations that open standards would solve the issues of interoperability*** "In the 80s, we thought we could solve all the problems with interoperability between CAD systems, which we had in those days. Also, those people who were buying positions, those who were buying systems, they were giving information about standards. Those days, it was the ISO step. After those steps, it evolved to IFC. So, people expected that IFC would solve these problems in a few years, but it's something that didn't. […]. In the sense, this is a controversial statement for me; a standard can have a negative impact compared to what it aims to do. So, the development of interoperability standards can be the biggest a barrier to solving these problems. It has a local market in that way. […] But the commercial companies do not want to see a standard, the leading companies, they do not want to have a standard. […] Software companies assured that this couldn't be done. It is not a technical problem for interoperability; you just need a little bit of programming. But there is really a conflict with commercial service to create a standard, because certain companies didn't want to have it." (Researcher, FIN18) ***Setting expectations that technology firms would be merged and form powerful international software companies*** "I think that we were expecting that, in the 80s, the small companies were focusing on different subdomains of the construction industry like heating and so on. They would gradually be merged and become powerful international software companies. This has never happened, which is quite amazing. […] 30 years of enthusiastically working, first in the world, it will just go away. This is the big drama of this pioneering... I thought that Sweden was much better in business; they would come here and buy these software companies, merge them and invest some capital into that stuff, competing with the world players, which would go to CAD, Bentley and other software companies. It would be possible with the knowledge, which we have in this country, but all these companies, which are software developers in the small market, some of them sell abroad, but they are not major players in the international market. I do not know why." (Researcher, FIN18)
Period 3. 1991-1995. Depression: Knowledge Loss & Gain.	*Environment: economic crisis*	***Industry lost knowledge through diminishing labour market and bankruptcy of firms*** "People change; knowledge disappears from the organisation and there is one very important reason. In the early 90s, a lot of companies disappeared completely, some companies, which used R&D stuff, so people were fired. Many people in the front had to leave and search for other jobs, so this knowledge has just disappeared. This was very dramatic. I think we needed to redo a lot of stuff in the 90s because people disappeared. […] Well if you look at the history, what happened here is that more or less knowledgeable people from the industry had disappeared and basically things had to be redeveloped because we had just lost people." (Researcher, FIN18) ***Dramatically changing business environment*** "Depression was kind of dramatically changing the whole business environment in Finland. People were not studying and not going into the construction industry because there were no jobs. And nobody saw the future." (Researcher, FIN20) "Many construction companies went bust." (Researcher, FIN19) "The companies were suffering too much those days" (R&D CEO, general contractor, FIN08) "In 1994, the situation was still very grim. The recession in the early 1990s had very deep impacts on the Finnish AEC sector. Many companies, including some of the largest construction companies, were bankrupted and only very few companies were able or willing to invest in that situation. […] Many people lost their jobs, design offices became very small." (Researcher, FIN20) ***Accelerating adoption of CAD*** "To be able to survive, you had to be more efficient. The way to increase you design productivity is to use CAD, with the smaller staff you could still to do the job. It was speeding

		up the adoption of CAD. So, the few architects who still had design jobs adopted use of CAD at that stage much faster than it would have been happening without the depression." (Researcher, FIN20) ***Depression time was a shock that pushed the industry for change*** "In the beginning, everyone was very enthusiastic to change the industry, because people still remembered bad times from 1991-94. It was only about two years later, people wanted to do something so it would not happen again." (Researcher, FIN20)
	Key leading firms shifted their focus to technology development as a survival strategy	***Key leading firms invested in the development of digital capabilities as a survival strategy during the depression*** "TEKES was providing funding for R&D; they never fund anything 100%, so the companies must use also their own money or borrow it. As the R&D culture in the AEC industry is very weak, very few companies used that possibility. The main survival strategy in early 1990s was to reduce activities and lay off people. Granlund was one of the very few exceptions. They wanted to keep their best people and started significant R&D efforts as investments in their future, and also got significant funding from TEKES. As we now know, it was paid back later very well, although in the early 1990s most people in the AEC sector thought that Reijo Hänninen, Granlund's CEO, was crazy and were sure that the company could not survive with such a bold strategy. […] They did not fire people but rather invested in the development of programming capabilities because they understood that, while there are no jobs, they can learn and invest in the future be ahead of everyone." (Researcher, FIN20) "For our company it was critical because, when we had those severe days, we could work for the future and then, of course, what happened when the recession was over we had the ability, and BIM was one thing of that somehow, although it was not called BIM then. We had some ability to grow faster than the competitors. […] Then we started to invest more in the development. (CEO, HVAC firm, FIN10) ***Firms differentiated with new business ideas around digitalisation and expanded the scope of traditional businesses*** "When we had a recession in the early 90s - a depression here. Many architects had to come up with new business ideas, and our company [hidden] came up with the development of facility management." (Consultant, FIN04) ***Forward looking firms shifted their businesses to software development*** "My own company, which I founded in 1989, focused mainly on CAD education and consultancy. Because of depression, which we had in Finland, my company changed to software development in 1991. So, in 1991-1996, I was working mainly on software development in an AutoCAD environment and was basically developing architectural applications on top of AutoCAD." (Researcher, FIN20) ***Firms were actively developing technological tools internally*** "There was one guy who programmed that; he made a program and made it in several months. He was really working on it all the time, they really wanted to have the system and they've put in money to make this happen. […] It was an example; there is a limit, how reasonable it is to use your effort to make your own IT system. There are many people in Graphisoft, which are developing things. So, it is a cool thing to do that in your own office." (CEO, architect, FIN16)
	TEKES's support with funding to R&D paid off to the participating firms	***TEKES increased investment into the R&D*** "The depression time was a very interesting thing in the sense that it had several effects on our industry. At that time, the Finnish government made a very clever move, in my opinion. They were increasing the funding of TEKES and universities. Finland was investing more into research, development and education." (Researcher, FIN20) ***TEKES and depression time pushed the Finnish industries to become a high-tech society*** "That was a key issue that changed Finnish society into a high-tech society." (Researcher, FIN20)
Period 4, 1995-2002. Intensive Development of Industry	*Environment: rising enthusiasm for BIM*	***Industry was enthusiastic about the future with BIM*** "I think that everyone in Finland believed that this is something that will change how the industry works. And everybody wanted to know more. All this was based on the

Specific Technologies		developments, which were done in software companies during those years." (R&D CEO, general contractor, FIN08) ***TEKES was actively collaborating with the industry champions and VTT to find a common goal for R&D*** "There were really close relations, a network of some peers was close in sharing ideas and discussing things. It is difficult to put a border between TEKES and champions, because there were constant interactions between them, like business and friendship interactions. It was not so that TEKES was totally inventing the idea of VERA, but it was collaborating with the industry. We made a lot of interviews; we tried to find the common goal that the industry could agree on. So, it was not one side that would be doing things; all sides were trying to find the common goal, it was heterogenous. It was TEKES, champions and VTT, who also had a very strong role in that." (Researcher, FIN20)
	Establishing the VERA programme	***Establishment of VERA Technology programme in 1997 -2002 with a vision "management of information through the entire life cycle of the built environment"*** "It is necessary to get interoperable information from all participants in the process, because that would enable real as-built information and also an evaluation of the building's life cycle properties already in early phases of the design process. The Programme Steering Group and TEKES estimated that the realization of the Programme vision would have a positive impact on the AEC/FM cluster and on the whole of society on a national level. […] When VERA started in 1997 the industry was very eager to invest in new technologies. One of the main motivations was to avoid similar impacts in possible future recessions." (Researcher, FIN20) ***VERA programme was a framework with defined criteria to fund projects that fit to the criteria*** "VERA's outcomes were projects. And I would say that the important thing was that the Finnish construction industry took BIM as critical part of a strategy and it had happened already in 2002 when VERA was still running. Some of the projects were running after VERA as part of the programme. The whole concept of these technology programmes is complex and unique. It is like a framework and you are funding projects that fit your overall goals. Programme defined criteria. But all the proposals were coming from industry." (Researcher, FIN20) ***VERA focused on technology development hoping it would eventually lead to the creation of processes and services – Technology push instead of market pull*** "In addition to creating technology itself, there is a need to create services and work processes related to new technology. The way that AEC/FM projects are managed may involve significant differences from current practices if integrated model-based approaches become widespread, and various new information management services may be required. The VERA projects interviewed did not place much focus on these areas, but the need for work in this area will grow as technology enters mainstream use. […] Some pilot projects are beginning to address the issue of adapting work processes to better fit new technology, but there has been very little progress in this area to date." (Froese, 2002: p.12) ***VERA created demand and supply for the development of tools*** "We were able to create demand and supply, basically hand in hand. One of the problems is, for example, if somebody makes a software product too early, there is no demand for that, there are no users. The company is dying because nobody is buying the product, because people do not really see the value of that. On the other hand, if people are interested but you do not have the tools, people very quickly give up, because they think that \`this is a very good idea, but I cannot do it, because there is no practical way to do it\`. And providing the balanced development of these two things was very crucial in the VERA program. So, people at the same time decided to do tools to do what was the goal, and it was very important at that phase." (Researcher, FIN20)
	The VERA programme was actively supporting IFC and open standards	***Vera champions and TEKES demanded IFC implementation in Finnish software development*** "[hidden] made a decision that those that get funding from VERA must implement IFCs. It was one of the criteria. If a software vendor is not interested in IFC implementation, then they do not get funding." (Researcher, FIN20)

		Piloting the world's first integrated IFC project with Senate Properties, a public client, and the first test of Solibri model checker "HUT600, the world's first IFC project maybe, but there has also been development in the early days but that was not so widely used. For example, maybe architects were using IFC and we were using it, but not structural designers, and so on." (BIM manager, HVAC, FIN11) ***Significantly supporting the development of International Open Standards for model-based interoperability (e.g. IFC)*** "The VERA programme contributed significantly to the development of international standards relating to model-based interoperability, specifically the Industry Foundation Classes. These standards are critical to the success of the VERA programme's vision and the IAI was significantly strengthened through these contributions." (Froese, 2002: p.12)
	Actively engaging in the International Alliance for Interoperability	***Participating in the development of international standards by actively engaging with the International Alliance for Interoperability (IAI)*** "The main reason [participating in IAI] in that was that if you wanted to make interoperable software you could not make interoperable software at the national level, especially in a small market like Finland. Interoperability requires international standards. And that was the main reason. The whole software industry is basically international; you cannot have a successful software development in a small market. It is too small. That was something that I realised when I left my company and moved to VTT. Doing that kind of small-scale software development at a national level, the time was over at that time for it. You really need to think globally when you think about software, and standards even more so. […] The main problem in RATAS was that they tried to develop the Finnish standard for building product models but then, when VERA started, people started to realise that the software industry was global and we couldn't have national Finnish standards and it was a key success factor of VERA; we had very good international collaboration in IAI, we had very strong role in there. That was helping Finnish companies." (Researcher, FIN20) ***IAI was connecting USA and Finnish actors*** "IAI was connecting things. We had a lot of events when we had people from Stanford coming to Finland to our seminars and I also made several presentations in Stanford. Senate Properties met GSA in Stanford. GSA has learnt what Senate Properties were doing and also wanted to do something similar. And, for example, the first HUT report was written by Calvin Kam. It was the first time that Calvin was involved in BIM but later he was the person behind GSA's implementation." (Researcher, FIN20) ***Establishing formal arrangement to participating in IAI through Nordic chapter between Finland, Sweden, Denmark and Iceland*** "It was a very important phase, we actually had the Nordic chapter of IAI. We had one meeting in Helsinki after the first meeting in London. All Nordic countries are very small, and we decided we had much more if we established the Nordic chapter, so that Finland, Sweden, Denmark and Norway were in the same chapter. And that has continued in that way for a long time until, I would say, around 2002. Norway became really interested in buildingSMART… until that time they were not really interested. Sweden and Denmark, and Finland were active at the beginning. Norway was looking from the side. Then, Norway had a big delegation in Singapore, I think it was about 2000. They became interested and started to put a lot of money in these activities, like VERA was earlier. They wanted to have Building Smart Norway as an independent entity. Now the Nordic buildingSMART consists of Sweden, Finland, Denmark and Iceland. Iceland joined much later. Norway is now independent inside Building Smart. But, inside Nordic buildingSMART, we call national entities forums. And the importance of that was that national developments related to this were happening inside the IAI development of the standard, the international implementation and the demonstration of interoperability. It was a very important part of activities in the late 90s and early 2000, and we were showing interoperability potential at different events for data exchange between different software. For example, how it could make the design process more efficient. So, it was one of the vehicles to inform people." (Researcher, FIN20)
	Creating international	***Creating international networks for collaboration*** "A very good example is the founding of IAI. So, we had an excellent international network for collaboration. The VERA program was very international compared with other

	collaboration in Vera	construction ICT programs that TEKES had been running. The only TEKES programs which have been on the same level of international collaboration, were in space research; not even mobile programmes were as international as VERA." (Researcher, FIN20) "The VERA programme placed a high priority on international participation. This was particularly true with respect to the support given to the development of the Industry Foundation Classes data standards by the International Alliance for Interoperability, where VERA was one of the largest supporters and participants. VERA was also well represented in other international forums, such as conferences." (Froese, 2002:p.6) ***Establishing active research collaboration with Georgia Tech and Stanford*** "There was a lot of international collaboration with Chuck Eastman and Stanford; active interaction started in VERA programme. IAI was connecting things. We had a lot of events when we have people from Stanford coming to Finland to our seminars and I also made several presentations in Stanford." (Researcher, FIN20) ***Building long term relations with international software developers like GraphiSoft and VISIO*** "Influence on international development: (+) in addressing the development of the core technologies required to attain its vision, the VERA programme carried out several activities related to international development efforts. These included, for example, extensive participation in the International Alliance for Interoperability, research programmes, such as the Center for Integrated Facilities Engineering at Stanford University, and relationships with foreign software developers, such as Graphisoft and VISIO. This influence on international activities appears to have been productive, since VERA projects have been able to exploit these global resources more effectively than other groups." (Froese, 2002:p.12)
	TEKES increased investment in industry standardisation	***TEKES increased investment into the program because of industry's high interest in the technology*** "When the Programme started in 1997 the planned total volume was expected to be 28 M euro, of which 12 M euro was planned to be funded by TEKES and the rest by the industry. However, the industry interest on R&D projects in this area was so strong that the final budget increased during the Programme to almost 47 M euro, of which about 22 M euro was funded by TEKES. Four M euro of TEKES funding was used in the projects of universities and research institutes, and about 18 M euro in industrial projects. In total, the Programme initiated 161 projects, of which 48 were research and 113 industrial projects, which almost doubled, so, it is a huge increase of budget and that is very unusual. I do not know any other TEKES programs, which were in such a situation that the budget would be increased so dramatically. Very often, the budget is slightly smaller than originally planned. And I think this is very good evidence of interests in the results. There are several things in the VERA program, which I did very differently from all other managers of programs." (Researcher, FIN20) ***Heavily invested into IFC development*** "IFC development - Finland was very active in IFC development in those days. All this thanks to TEKES because they were funding this work." (R&D CEO, general contractor, FIN08) ***Implementing three stage feasibility reviews*** "It was my role to evaluate whether the projects were feasible or not. I did not make decisions; they were always made by TEKES. So, I make recommendations for the steering group and the steering group made recommendations to TEKES. I have never had a situation where TEKES would make a different decision to my decision. Usually, what I said to companies, I could not guarantee that you would get the money but if it was not a good proposal, I could guarantee that you would not get the money. It was important for people to understand that I was not decision maker. But if I had a negative evaluation of the proposal, it was 100% that TEKES would not fund it. Overwise, the whole role of TEKES would be absolute. Why would you negotiate with the companies if your word was absolute? (Researcher, FIN20) ***TEKES built holistic understanding of industry trends and advancements*** "TEKES had a holistic understanding of what was happening in the industry." (Researcher, FIN20)

	TEKES mechanism: building awareness	***Extensively showcasing interoperability potentials at the different events*** “The importance of that was that national developments related to this were happening inside IAI’s development of the standard, international implementation and the demonstration of interoperability. It was a very important part of the activities in the late 90s and early 2000, and we were showing interoperability potential at different events for the data exchange between different software. For example, how it could make the design process more efficient. So, it was one of the vehicles to inform people.” (Researcher, FIN20) ***Building awareness using emails and newsletters*** “Sending emails about or newsletters of where we were going to, like informing people where we were and when were the deadlines for next applications. For research projects, there were strict deadlines but for the industry there were no deadlines; they could make funding whenever they were ready. For research proposals, you had to have deadlines to be compared.” (Researcher, FIN20) ***Disseminating the industry with knowledge through 4-6 specialised seminars per year*** “Many of the people interviewed pointed to the VERA seminars as one of the most positive features of the programme. These seminars have had an effect of “seeding” the industry with a good base of people that have a basic understanding of the technology and the way that it works.” (Froese, 2002:p.12) “TEKES programmes had one conference a year. So, it was general, and no one was interested in that. In VERA, there were theme seminars that were focused on something like looking at the project that succeeded in that area. Then we had 4-6 conferences per year and had a huge amount of (300) people, which was totally unheard of in TEKES projects. Nobody was interested in the whole programmes, as it was too abstract, but people were interested in some respects. (Researcher, FIN20) “We had a lot of communication and seminars. We had 200-300 people participating; all the companies were very excited to participate, and they all wanted to know more about BIM. It was a big thing.” (R&D CEO, general contractor, FIN08) ***Heavily investing in publicity and marketing to create awareness and matchmaking of stakeholders in the BE sector*** “The widespread publicity of these things started from the VERA program, and TEKES gave many resources to do things.” (Researcher, FN20)
	TEKES mechanism: Building networks for collaboration and the exchange of competencies	***TEKES was a matchmaker for building networks*** “Funding is far more important and the other one is finding good partners. When you have a wider network, you know who might be interested in that. It is like a professor I can recommend people to help you interview. So they know a lot of people.” (Researcher, FIN20) ***Bi-directional import & export of expertise from Finland and to Finland*** “TEKES places a strong priority on increasing international connections through technology programmes. However, the connections have been unilateral in many cases, importing expertise into Finland. Only the latest programmes (especially VERA) have the direction become truly bi-directional. The strong domestic character of the construction and real estate industries has not opened up many quick and easy avenues for wide internationalisation yet. On the other hand, international connections have remained strong on the programme level, in the form of seminars and other general activities. Concrete support in creating international connections are needed at the project level.” (Uusikylä et al., 2003:p.41) ***TEKES created tight collaboration between industry and research institutes by demanding the involvement of a research institute or university as a partner for any industry project*** “Most people, almost everyone who was developing anything with IFC, were from VTT. VTT had their own budget like and any research institute could apply for funding for TEKES, but basic rules were, if it is an industry project, you must have a research institute or university as a partner. And for research institutes they had to have industrial partners. A feasibility study is that industry is interested, and ambition level is high enough for research institutes to participate. So, they were reinforcing each other. It was one of the main effects

		of TEKES funding, creating this tight collaboration between industry and research institutes." (Researcher, FIN20)
	TEKES mechanism: Sponsoring risk funding projects	***TEKES projects were a risk funding projects*** "One of the rules where you should not fund projects that will surely succeed. That was a risk funding. One of the interesting things, quite often the first version of applications, was about risks. People were saying there are no risks and it is a big mistake. No risk, you can go to the bank and get a loan. This is meant to be a risky project. TEKES did not have clear rules on how to evaluate risks. But other research funders indicated, if more than 20% of the projects were succeeding, you were funding the wrong projects. There should be some risk and potential to succeed. I would say work in IAI was really successful. But not everything. But it was not supposed to be successful at everything." (Researcher, FIN20) ***TEKES funded only domestic firms*** "International collaboration for projects - there were some but not many. The reason is that it is very difficult to put research funding internationally. Any research funding is available only for domestic companies. TEKES could not fund companies in the USA. The mechanisms for funding decisions had very different schedules. It is very difficult to coordinate so both sides can have funding at the same time on both sides/only way to do that was directly fund that it was possible to buy research resources outside of Finland but if we can prove that it does not exist in Finland but only for the research and not for the industrial partners at all." (Researcher, FIN20) ***TEKES funded only firms linked to the programme goals*** "We have anyone who had connection to AEC and software companies were participating. If the companies were not linked to AEC then it was difficult for TEKES to fund it. There was a large portfolio of programmes at TEKES." (Researcher, FIN20)
	Other International activities	***Largest public client in Finland, Senate Properties, and the USA, GSA, were collaborating to develop BIM guidelines*** "If you would look at Finland from United States perspective, Finland is a very tiny place and most of the people in USA do not see any difference between e.g. Hungary or Finland. If we have demands to have that in BIM files and everyone to have their voice heard by software developers in United States, nobody would listen to what Finland says. Small market area, they can do whatever they want. But, by joining forces with GSA, which is a big player in United States, they are managing all public buildings like White House, courthouses and so on. Whatever is in the United States. They are a big property owner. When Finland and GSA are united and they harmonize BIM requirements, it is not Finland and Senate Properties asking for those things, so, everybody would listen to what GSA wants. So, this has helped us to make a step forward. Not just trying to influence from Finland, so now, we have a big partner in US. That is why it was meaningful to harmonize these requirements." (CEO, software vendor, FIN17) ***Largest public clients signed an international agreement to support BIM with open standards to influence the BIM requirements*** "Like Autodesk, Bentley, and Graphisoft. […] that was in 2005 if I remember correctly. […] They are big owners of properties in Europe which are joining in, there is actually a very big group now. Property owners can really make these mandates, construction companies want to have work and if their clients saying that we want you to do these things this way, they will listen. And this is one of the reasons why this mandate had been done in many countries. […] When you have these mandates, it brings these things forward faster." (CEO, software vendor, FIN17) ***Sharing knowledge and developing first BIM guidelines for the GSA, public client, in the USA in 2003*** "In 2003 we did BIM requirements for General Services Administration (GSA) in United States (GSA). You can Find that from their website at http://www.gsa.gov/portal/content/105075. The first requirements BIM Guide 02 – Spatial Program Validation, which we have written, were about spatial requirements." (CEO, software vendor, FIN17)

	Positive results from VERA activities	***VERA developed positive vision and acceptance with little scepticism*** "There was surprisingly little evidence of scepticism among participants. […] The VERA programme should take some of the credit for creating a very "positive" attitude towards the whole area." (Froese, 2002:p.12) ***VERA programme positively contributed to the development of knowledge and expertise in the technology area*** "Another very positive outcome of the VERA programme is that it contributed significantly to the overall base of knowledge and expertise in this area of technology in Finland. This was achieved primarily through the VERA seminars and other presentations by VERA participants, and by the involvement of large numbers of people in the numerous VERA projects." (Froese, 2002: p.12) ***Fostered and supported "chicken and egg" cycle of creating demand for technology development*** "One of the strong features of the VERA programme was that it was able to foster and support a large amount of technology development: the middle phase of the research, development, and adoption lifecycle. […] One of the biggest barriers to technological innovation is the lack of support for the development phase of the research, development, and application lifecycle (as discussed earlier). Industry users won't adopt the technology before a fully developed suite of high-quality software applications are available, yet software developers won't invest the very large resources required to develop these tools until they have some confidence that the market wants the tools. This creates **a "chicken and egg" problem** that has stymied advancement in many countries. (+!) The VERA funding appears to have been significant in allowing many companies to break out of this cycle and develop new technologies with manageable degrees of risk. Many companies stated that they would have carried out little, if any, of their development without the VERA funding. The provision of funding to allow companies to pursue development projects that they would not otherwise attempt is probably the biggest single benefit of the VERA programme. (Froese, 2002: : p. 14:p.14) ***Success of the VERA programme created positive technological environment for the development of new, globally competitive products*** "Finland has a reputation as one of the leading countries in this area with many recognized world class experts, and the whole industry cluster with advanced use of ICT as a key role in its strategy - is of course very fruitful for the development of new, globally competitive products. Thus, it is obvious that the central results of VERA are many innovative software products, which have also gained wide international interest. In most other countries, the development has not been started on the same level, because the market potential has not been recognized yet. Analogy to mobile technologies is possible; a strong and advanced home market can enable early development and high competitiveness, also internationally. Time will tell if the software products for the AEC/FM industry can meet this challenge. The technological basis for the success has been created." (Researcher, FIN20) ***Finland gained an international reputation as a world leader in technology and in leaving positive impact on the progress of IAI's IFC*** "The programme established Finland's reputation as a world leader in this area of technology and helped to create international business opportunities for Finnish technology companies. Perhaps the most important international aspect is that the technological vision is based on the creation of standards for exchanging project information, and this is necessarily an international task. Support and input from the VERA programme had a significant positive impact on the progress of the International Alliance for Interoperability (IFCs)." (Froese, 2002:p.13) ***The Confederation of Finnish Construction Industries adopted BIM as a part of the technology strategy in 2002*** "As a result of that (PROIT), the Confederation of Finnish Construction Industries has adopted BIM as a part of the technology strategy in 2002." (Researcher, FIN20) ***Achieved a widespread adoption of the Product Model Concept as a part of the AEC/FM industry's processes and strategy***

		"The most significant impact of the VERA Programme has been the industry consensus about the importance of ICT and about the role of product model technology in the development of AEC/FM clusters. The industry as a whole recognises the central role of information management to improve productivity, quality and processes and identifies the use of product model technologies - changing from the traditional management of separate documents to a more holistic information management based on product models - as an important element in this development. This is, at the moment, a globally unique situation because, in other countries, this idea is accepted only in the research community, but not as a strategy of the industry." (Accessed in 2015 via http://cic.VTT.fi/VERA/Documents/documents.htm) ***VERA advanced the technological knowledge base and expertise in Finland*** "Another very positive outcome of the VERA programme is that it contributed significantly to the overall base of knowledge and expertise in this area of technology in Finland. This was achieved primarily through the VERA seminars and other presentations by VERA participants, and by the involvement of large numbers of people in numerous VERA projects." (Froese, 2002:p.2) ***The VERA programme was successfully led nationally and internationally. The leadership role is recognised as an important driver*** "By all accounts, the Programme Manager, Arto Kiviniemi, exerted a very strong and very positive influence over the VERA programme. He was an excellent champion, both nationally and internationally, actively promoting the programme with an infectious enthusiasm in 40 or 50 presentations per year. His administration of the programme appeared to be very good. Of particular note was his active participation in helping to establish many of the projects, and his leadership role within the International Alliance for Interoperability (which was particularly beneficial during a difficult time for the organization). (Froese, 2002:p.16) ***Big firms made a change towards BIM implementation internally after VERA*** "The task was to change industry. Of course, it can be argued that change was not necessary industry-wide, but the big companies definitely made a change. I think that the results of the VERA programme were very good. A change of industry culture so BIM became a core part of it. People have accepted the idea of moving away from 2D. It is a slow process to change the industry and especially the construction industry; there are a lot of laggards. They would not make any changes unless they had to. It is still spreading well. Nowadays, using BIM in Finland is business as usual. So, I would say that it was succeeding." (Researcher, FIN20) ***The results of digital transformation were expected to happen in 2013 after VERA happened*** "Basically, when it started, the programme (TEKES) told me that the real results will be seen 10 years after the programme ends. Which means they did not expect feasible results before 2013! In fact, it has exceeded, the SP guidelines and CoBIM were created in 2012." (Researcher, FIN20) ***VERA affected industry-wide innovation*** "When VERA started in 1996, […] now, the change is huge." (Researcher, FIN20) ***VERA produced leading software*** "Definitely, the Solibri model checker or MagiCAD would not exist without that funding. Without any doubt some software would not have happened without TEKES funding." (Researcher, FIN20) ***National efforts influenced the Finnish design industry to become the earliest adopter of BIM globally*** "BIM adoption would be on the same level without having created awareness. I think that Finland would be in the same situation as the UK before the mandate. After that, it was rapid but before that, there was nothing happening. There was no interest in BIM at all. But again, it is something trying to measure the benefits of BIM, so many factors affect success of projects and it is very difficult to isolate the reasons and claim that these are the reasons for success. In the same way, it is difficult to say because of TEKES's funding, Finland was definitely the earliest adopter if not the earliest adopted. Situation in late 2008. It was totally

		unique. Five years after the programme, the situation globally was unique in terms of the wide adoption of BIM and the use of advanced techniques." (Researcher, FIN20)
	The dark side of orchestration processes in the Vera programme	***Gap between the research and the implementation*** "I think it is the biggest challenge in any national system. For some people, making applications and getting research money is the main business. I can see at the EU level, loads of professionals are making money from R&D. It is not always about results. If I am genuine, it is seldom about the results. It is almost anywhere. Mostly, researchers are interested to get good results for publications, but they are not interested in helping companies to implement the results. Very often, the end result of research is a research report that you put on the bookshelf and that's it. It is almost impossible to start controlling that; as I said, the research money should be risk funding. If you start measuring results and require all projects to get results, you are moving into a bad area. You have to accept that some projects do not get good results. The problem is how to bridge the gap between the research and implementation. Because research never creates innovation, or very seldom. It is usually business that creates innovation. And now a lot of, and even sometimes, good results can be forgotten or disappear, and no one will remember them. And Silicon Valley has been a very good example because the universities have been a good mechanism to bridge that gap. How to move the research results from start up to business. Not perhaps in construction but in other areas. For example, Google - they have been building it. How to bridge gap between research and implementation – mechanisms as a gap for future research?" (Researcher, FIN20) ***Firms were avoiding taxes by subsidising R&D*** "Problem with TEKES system: even if you are avoiding subsiding the work, TEKES was strict. They are not paying for pilot projects or any project cost - they invest in the documentation of the results but still, even given money for R&D, can lead to a situation that companies do it for the money and not for the results. […] Trying to get as much research funding as possible and tax avoidance is one part, trying to subsidise R&D to get funding for that. I know some companies even though research funding is partial funding, it is never 100% but some companies are misusing the system again so they can record hours to do the research project at the same time. In some cases, they get more money than they are using for the work to conduct the research. Again, it is difficult to prove because no one speaks about it." (Researcher, Fin20) "The cost of research was deducted from taxes as any business costs or travel, you do not pay taxes for that. People would go far to avoid some taxes, but it is crazy, it means that your business results are lower before your taxes are lower and you are never paying 100%, so you are eating the profitability of the company. […] Taxing has nothing to do with TEKES; companies did tax reports, but it was an incentive. By putting money in TEKES's project, I can reduce it. TEKES was only making funding decisions." (Researcher, Fin20) ***TEKES had no effective mechanisms for the collective body of knowledge to be captured and transferred to the thorough the industry*** "Although it was a strength of the VERA programme that it was able to advance and disseminate a knowledge base in the target technology areas, at the same time, it is perhaps one of the largest weakness that there was no effective means of capturing the large, cumulative body of knowledge generated through all of the projects, and transferring this knowledge throughout the industry through detailed documentation, in depth training, etc. This appears to be a weakness of the TEKES technology programmes in general, rather than of VERA in particular, since the mechanism of company initiated, commercial R&D creates no incentive for this type of knowledge capture and, in fact, intellectual property and confidentiality issues can provide a strong barrier to knowledge transfer. Still, a vast amount of knowledge developed through VERA will be "lost" because of this weakness. One specific mechanism that could have helped to address this issue would be stronger ties with University researchers and with University and Industry based training programmes. There appears to have been little of this within the VERA programme, partly because this is not the mandate of the TEKES programmes and possibly because there may not be an appropriate faculty within Finnish Universities for this topic area." (Froese, 2002:p.2) ***Limited cross-fertilisation between programmes and projects***

		"In some projects there were people that were looking at the experience in other projects, but it was on a project level and if the project wanted to benchmark their processes, but it was not on a programme level. It is challenging - you can't. It is difficult to compare construction and airplane technologies. There were some projects, but not widely. In many applications, people, do not do their homework, they do not check where we are now in this area." (Researcher, FIN20) ***Unfocused project selections with loose connections to the programme's objectives*** "The programmes may become loose collections of development projects without a clear understanding of how the programme-level objectives are to be achieved. Consequently, in practical terms, individual organisations have trouble in linking their development needs to these general formulations. There appears to be a risk that project selection becomes unfocused." (Uusikylä et al., 2003:p.41) ***Forming informal communication with the interested parties in projects not knowing the overall objective of the programme*** "There were many instances where there was good interaction between individual VERA projects; for example, between companies developing software tools and companies using the software to design and manage buildings. On the other hand, many of the project participants did not have much of a sense about how their projects fitted within the overall programme." (Froese, 2002) ***Project identification mechanisms were informal and provided a great deal of flexibility for companies to define projects to fit their own business needs and opportunities without targeting specific work of high strategic importance*** "In identifying individual projects to fund, there can be a trade-off between the goals of individual projects and the goals of the overall programme. […] The programme may have suffered because it did not have any mechanism to target the specific work of high strategic importance. For example, some additional work on supporting software components (such as model servers), or work on capturing and recording the overall body of knowledge arising from the collection of projects may have improved certain programme outcomes significantly, even if they created no particular business opportunities for any one company. The VERA programme would have benefited from some mechanisms commissioning a small number of important strategic projects rather than responding only to projects submitted by others." (Froese, 2002:p.16) ***Lack of university involvement despite the TEKES strategy*** "The integration of research organisations into the programmes has been strongly emphasised by TEKES. However, there has been and still remains a certain reticence towards academic research within the industry. The research input and the involvement of universities and research institutions has not met all expectations. Combined with the thin research basis, this partly explains the lack of collaboration between enterprises and research institutions in the real estate and construction technology programmes." (Uusikylä et al., 2003:p.41) ***VERA struggled in activating facility owners because the focus of technology was on new construction while most buildings are retrofit*** "One of the central goals was not achieved. The VERA Programme could not activate sufficiently the facility owners to participate in R&D projects. Thus, the impact of the projects was too much focus on the production of new buildings, and one identified output – the modelling of the existing buildings - was not achieved." (Accessed in 2015 via http://cic.VTT.fi/VERA/Documents/documents.htm) ***Lack of support from top management*** "The challenge was that we never got this support from top management in business. It started as a technology push. It was a technology push more than a pull of business." (CEO, research org FIN14) ***The industry was exploiting the system and existing business models*** "Is it a part of system exploitation and business models. It is good to remember that there are no products where the price of the product would have anything to do with the production costs. Every product, the price for the phone is the willingness to pay. And the same with the

		houses, the price of the house has nothing to do with the production cost, it has everything to do with the market price. What people are willing to pay." (Researcher, FIN20) ***Inherent system inertia that people were not willing to change the status quo*** "Culture of the industry is another dark side. People are not motivated or do not have the capabilities or desire. Many people want to live in their comfort zone. You might be risking your job or career if you make something new and it proves to be a mistake. Many people keep the status quo; the status quo is a very strong motivator." (Researcher, FIN20) ***Small group of visionary champions distanced themselves, by virtue of their networks, from traditional industry*** "Finland is visionary and started from friendships. The development started from knowing each other and trusting each other and not from friendships. In that sense, it was leading to this small group of people that are moving much faster than the industry and the gap was increasing. It can be a problem [when] you have small group of champions that support each other. It can be also dangerous. […] And when you have a group of enthusiasts, of course everyone wants to move as quickly as possible. People are not necessarily thinking or recognising risks. In that sense it is the dark side." (Researcher, FIN20) ***The champions learnt the importance of business models for technological implementation*** "The technological part was absolutely necessary but not so today. I did not know how important contractual relationships and business models are. We were thinking about processes but if we do not change the contractual models, it is not going to succeed. It was a huge learning curve for everybody involved in the process." (Researcher, Fin20)
Aggregated dimension: Phase 3. Stagnation: Maturity Building, 2002-2015		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Period 5, 2002-2007. Practical Implementation. Failure of business model evolution	*Realised projects as part of the VERA programme have become standard practice*	***Realising the world's first IFC integrated project delivery, including customers in AURORA project, that become standard practice across all projects*** "In the AURORA project, I used BIM. It was a real BIM project. But, I think after that it has been the same thing, we had different BIM projects; all the projects have been done in the same way, even if they're not exactly BIM projects. When we don't have money, in any way, we use the same kind of system, but we would make it more precise if we got paid for that. But I think it has been happening during the last 10 years in the same way. Maybe you can say we have developed a routine here." (CEO, architect, FIN16) ***Developing the world's first common product modelling guidelines at the industry level in the PROIT project in 2002-2005, extending them in 2007, while involving Senate Properties, a public funder and collaborating internationally*** "We started this ProIT. The purpose of that was to start developing common guidelines for BIM. […] We made several guidance manuals for architects, structural engineers, HVAC and for construction companies. […] This was our big successful project in Finland. And we used BIM in different ways. We have tried to develop and implement BIM on site as well. (R&D CEO, general contractor, FIN08) ***PROIT project demonstrated benefits of BIM to the industry worldwide*** "It was very important in that sense that it was demonstrating the benefits of BIM in a very concrete way to the construction industry." (Researcher, FIN20)
	The dark side of the SARA programme: failure of changing business models	***Establishment of the SARA program to develop businesses and contracts were unsuccessful*** "SARA wanted to continue development on business models, but I really do not think that SARA was successful to the same extent as VERA. You will not find much information online." (Researcher, FIN20) ***SARA failed to change business models and contracts*** "The main thing did not happen was changing business models and contractual models. This was something to be part of SARA programme. VERA was creating processes and technologies, and SARA was expanding business models. So, its dark side of national development that business models are unchanged. Probably, it is more difficult to change business and contracts than changing technology, as people see more risks in that and if the clients do not see the benefits of having different contractual models, they are not willing to change procurement services. Unless you do it on a wider scale, you cannot prove the

		benefits. Show me the money is a very difficult notion when you are adopting something. That's one of the main challenges, how to prove that something is useful if no one has used that?! It is almost impossible!?" (Researcher, FIN20) "I think it is the biggest problem, the contractual conditions. Personally, I have never seen any problem, which could not be solved by information technologies or even theoretically impossible. It would always be done. But changing contractual relationships in the construction sector seems … impossible. because it has a huge tradition of status quo that the architect's fee cannot be represented at an extra cost. The traditional contract says that architects must deliver drawings. So how do you put BIM there? You would need to change contractual structure completely. We had one of the projects, which was called 'Ellegal'; it was a funny name. So, we have studied these barriers, but we did not find any mechanism to break those barriers. (Researcher, Fin18) ***Personality of SARA's project manager influenced the development*** "Much less activities in SARA and less impact, impossible to find the recorded results of SARA. It is the personality of the programme manager. The person who was running SARA from TEKES wanted to stay in a comfort zone. It is 95% type of person who does not feel that he should work more. A successful programme leader must be very active. […] It is not only because of the programme manager but it was an important part." (Researcher, FIN20)
	Industry entered a stagnation period	***The industry realised the business benefits are not moving forward, entering stagnation period between 2002-2015*** "We felt that things are not going forward, so we have a kind of stagnation. I do not know why that happened and would it ever have been done differently. […] After these years of stagnation between…2002-2015, even in RYM, pre-stagnation was visible there. Loads of projects but results were not significant." (Manager, FIN21) ***Slowing down the development*** "The development in Finland was slowing down during the SARA program. […] There were some companies that continued in SARA. All in all, interest was reduced and there was a battle fatigue. People got tired of fighting all the time." (Researcher, FIN20)
	Industry actors established formal arrangements to propagate the change in Finland	***Senate Properties mandated BIM for all public projects above 1ml euro*** "We have here our pilot projects that we had from 2007; mandatory to use BIM in our projects. First, it was in architectural models only. […] We do not have our own designers, contractors - we hire them. And we cannot say to them what kind of technologies they should be using. So basically, we tell him what we want, so, we kind of hope that they will be using it. But we cannot make them." (Manager, Senate Properties, FIN15) "In 2007, when Senate Properties made use of BIM mandatory, also Skanska started to use BIM widely in their production, and increasingly other construction companies also followed. So that was really a practical implementation on a wide scale. So, it became a kind of standard tool and a standard method in the industry. (Researcher, FIN20) "The only mandate that was implemented by Senate Properties (the largest public client in Finland) was in 2007 for public projects above 1 million euro. As a result, Senate Properties implements around 50 BIM projects per year. The number is constrained by the nature of the properties owned; 83% of all projects are refurbishments of existing buildings and often very small. (Aksenova et al., 2018:p.13) ***Senate Properties invested into the development of national guidelines for BIM implementation*** "Guidelines 2007; SP funded guidelines in 2007 with a budget over 100,000 euros. This was small money for SP." (Researcher, FIN20) ***Finnish forum in IAI was transformed into BuildingSmart Finland*** "IAI, we had a Finnish forum inside the Nordic chapter and the Finnish forum was transformed to BuildingSmart. Its function in those days it was not very active immediately after VERA or 2005; it was reactivated in 2010 -2011. Tomy Hentinnen took over as a chairman and became active. In last years, it was quite active. It was developing CoBIM based on SP guidelines and did the same thing in the infra sector. It was a very slow development at one point." (Researcher, FIN20)
	TEKES is changing the	***TEKES was changing the system from industry specific development to competition across sectors***

	funding mechanisms while losing hope in the construction industry	"To be honest, the system has been changing a lot many times. TEKES was criticised - Finland in the mid 90s by all studies had the best innovation system in the world. From the mid 90s to early 2003. Around that time frame. Then, they started to change the system; they started to put the same criteria on all projects regarding the industry. They did not think about the different natures of the industry. Partly, I understand that because some of the results in the construction industry were not that encouraging. It was difficult to defend them inside TEKES. Partly, some big companies did it just because of TEKES's money. And they were never really implementing results in practice. And when you see it from TEKES's side, it is a waste of money. Nevertheless, the changes they made were also destroying something that worked well at its best. I am not sure if it is wise. What they did, they fixed something which was not broken." (Researcher, FIN20) ***TEKES lost hope in the built environment sector*** "TEKES has been actually quite critical towards BE in Finland. They kind of have been given a lot of resources for these different BIM-based projects and at some point, they lost their hope; they felt that there are not enough results coming from the resources given, so they lost hope in the construction industry. We are not going to give many resources anymore. Shocks were different, that was a huge amount of money. BE was very lucky to have shocks, but the same attitude was still around from TEKES's people. It was like:" I do not think they will produce any results, but we need to give them money…". It was challenging and it has been like that for a while. TEKES's focus was shifting more and more to global growth to support companies that have global visions. They did not see those kinds of players in BE. But I see now it is changing because of excitement that was built in half a year in KIRA-digi and because of Fira. Fira was showing TEKES that it was possible to do things differently. And loads of opportunities within this kind of sectors. Fira was showing the way. The attitude of TEKES has changed to a more positive one. We have been discussing recently with TEKES that these successful projects from KIRA-digi can get funding from TEKES." (Manager, Innovator, FIN211) ***TEKES was sponsoring projects "for redoing things"*** "At VTT, I had some frustrating experiences. A new generation comes and reinvents what was already done and this also happens a lot in research, and even organisations as TEKES fell into this trap, they gave to people money to redo what others had done before. The European Commission also does the same..." (Researcher, FIN18)
Period 6, 2007-2015. Building Maturity	*Industry is maturing with incremental improvements*	***Industry lost interest in R&D and is not ambitious*** "I do not know if people are just tired from the long process and relatively slow progress and they are not so eager to do anything about it." (Researcher, FIN20) ***Leading firms adopted practical implementation on a wider scale with other firms following them*** "And then I would say that the third phase started from 2007 when Senate Properties made use of BIM mandatory; also, Skanska started to use BIM widely in their production, and increasingly also other construction companies followed. So that was really a practical implementation on a wide scale." (Researcher, FIN20) ***The adoption of mobile tools on the construction site accelerated processes*** "But now during the past one or two years, I've seen a significant increase in speed, and I think the main reason for that is that there are these mobile tools that are becoming more and more popular, and they are easy to use." (CEO, Business Management, FIN07) "So, if we look at the last 10 years, I think that everything else has been quite stable and mature; people were not searching for new directions but just improving little by little." (Researcher, FIN18)
	Shifting trends in the industry towards incremental improvement	***Depth of development shifted to the width of adoption and maturity building*** "That progress is more about the 'width' of how many people I was able to engage instead of the 'depth', how far we could stretch the knowledge and theory because the fundamental ideas are quite... […] Information technologies have mainly become cheaper, not better but cheaper, so more people can afford to use this kind of technology. It is not that technology gets better, but it is getting cheaper. I told you about my first computer in 68, it was about stereographic images. Of course, you can do that jillions times faster, but fundamentally programming or modelling, the thinking behind these have not changed. Often the

		development goes downwards and not upwards. It goes downwards in the sense that more people are engaged, and fewer people knew before. It is not that knowledge gets more sophisticated. It is a very characteristic of the technology, very calm and stable. Nothing fundamentally changes. Things are getting only cheaper and faster.” (Researcher, FIN18) ***A focus shifted to user interface and training*** “I think that now people have to focus on quite different things: development, training people which don’t have a burning enthusiasm for this technology, because here everyone who has been working with BIM have been very enthusiastic about it. Now it is really for everybody including people, which do not really care. So, it is a general trend in information technologies, more and more all technologists focus more on improving interfaces to make systems easier to use. […] Nowadays, it is not possible, so many people are using these things, so the main focus today is only on the user interface.” (Researcher, FIN18)
	Establishment of the RYM pre centre and end of stagnation	***RYM centre was established as centre for excellence*** “Establishment of RYM and other centres. I never understood the logic - what is the added value of the organisation in between if it cannot make decisions, it will have same system as you had before with programmes but under this organisation missing direct connection with TEKES which does not make much sense.” (Researcher, FIN20) ***TEKES stopped sponsoring the construction sector because it realised it is not getting evident benefits from investments*** “But it turns out to be so that the industry doesn’t seem to be very eager anymore to do that. Because last year RYM had two proposals for construction research programs, and very large, and TEKES rejected them. TEKES said that these programs were not ambitious enough, or something like that, and refused to fund them. And this got the industry partners very upset. Because they had used a lot of money to prepare these programs, proposals and now were not getting any public funding." (Consultant, FIN04) ***Absence of a strong driving force increasing dominant stagnation in the industry*** “It is a kind of stagnation in the Finnish construction. […] There is no strong driving force at the moment.” (Researcher, FIN20) ***End of stagnation: Phase of stagnation was visible from 2002-2015*** “When I came to [firm] in 2008, we talked about the same things as we talk today, so I think the journey has been relatively slow.” (CEO, Business Management, FIN07)
Aggregated dimension: Phase 4. Reconfiguration, 2016-2019		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Period 7, 2016-2019. Growing Open Digital Business Ecosystem by Shifting Mindset Towards Openness	*Environment*	***The private built environment sector is not able to renew on their own*** “We can see that those players in the built environment sector cannot renew themselves alone because if they could, they would have done it already.” (Manager, Innovator, FIN21) “So, BIM was raised from the bottom to the top and now we should need our government also. We are ready for that and we cannot go further if the government does not come to help us.” (BIM manager, HVAC, FIN11) ***The industry is motivated to continue the evolution but seeks help from the government*** “It is kind of incredible, everybody just wants to do something. […] What I have heard from the planning stage where organisations were involved. Everybody was so excited, eager to do new things. That it is a kind of movement started going and was impossible to stop.” (Manager, Innovator, FIN21) ***Ongoing discussions around the roles of the public (government) and private sector*** “It is kind of a discussion of what the government should do and what the private sector should do. There is a blurry line between them. This discussion is constant.” (Manager, Innovator, FIN21) ***Lessons learnt have re-configured the thinking process in the industry and academia to search for new mechanisms to enable innovation*** “The whole industry started thinking what to do now so it can be significant without the funding. Then, the private sector with RYM, shocks ended and in collaboration with academia, they started to think what to do next.” (Manager, Innovator, FIN21)

		“The private sector and folks at buildingSMART Finland and associations, they were planning their own project. Previous funding from TEKES was stopped. There was a period of not having any funding mechanisms or efforts from the government towards the building sector. **They realised something has to be done** and they suggested this new programme for the Ministry of Finance and at the same time, the Ministry of Finance felt that “hey, we are focusing on the same thing, maybe we should do this together”. They kind of forced the Ministry of the Environment and associations and the private sector to start discussing together and plan joint projects. And KIRA-digi was formed.” (Manager, Innovator, FIN21) ***TEKES joined FinPro to form Business Finland*** “In 2018, TEKES and FinPro joined, forming a new organisation called Business Finland.” (Soini, 2018)
	Ministry of Finance was setting the KIRA-digi project to engage public and private sectors	***Ministry of Finance established KIRA-digi project, a neutral communication platform, for public and private engagement to link everything that is connected to Build Environment*** “In the beginning of 2016, the Ministry of Finance decided to put two streams together [Ministry of Environment and BE]. Finally, we had a project where all the significant parties of the project development started to work together: government and ministries + cities, digitalities + private sector. We could be at the same table and develop things together. This has never happened before. The Ministry of Finance was leading it because it initiated the project. […] This is a challenging environment. I do not know how much you know about municipalities. In Finland, municipalities and cities have a lot of power and government. This means the relationships between them can be very challenging at times. If we look at the BE and the information processes from the public sector side, the government wants to unify as much as possible so everything will be similar but because we have strong Finnish cities that can do whatever they want... So, we have different processes, so from information management, it is really challenging. And because they had so much power and whenever the government started to make any new developments, cities do not like it because they want to keep their power. They want the public sector to be more like an enabler of flourishing business. They want the government to serve the public sector. […] The overall aim is that we could develop together the foundation of BE information management in a way that all of this is successful. In a way, that the first part of Unified Information Management (IM) is about. We are looking at sub-projects that will develop certain things that we will have problematic things better. There are a lot of connections that BuildingSMART can do. But KIRA-digi can be an easy platform to bring the problematic stuff and have a good discussion how to solve it.” (Manager, Innovator, FIN21) ***KIRA-digi was a new communication platform for collaboration between public and private sectors*** “KIRA-digi period – I think a **open collaboration ecosystem is key in this period**. It is not only between companies but also between the public and private sector. Kira digi was the first project when public municipalities and the government were collaborating. That’s a huge thing and we understood what should be continued in the future and that’s why the Kira hub was continued coordinating that collaboration.” (Manager, Innovator, FIN21) ***Structure of KIRA-digi was streamlined like Private-Public Partnership*** “KIRA-digi was much better; it was not permanent and funded by government, it was much more streamlined.” (Researcher, FIN20) “The structure of the organisation was built like PPP project. The government with different ministries, cities and municipalities and private sector and associations. All three parties had an equal stake in the decision-making process. They wanted to organise this thing in a way to have a project office in the middle as neutral as possible. They would not have any tight or historical relationship to any of these parties.” (Manager, Innovator, FIN21) ***KIRA-digi was a neutral matchmaker and an innovation initiator*** “KIRA-digi is a community, innovation initiator or a matchmaker for building new partnerships through different kinds of activities. KIRA-digi are neutral facilitators of innovation ecosystems of BE bringing new funding opportunities, making ecosystem more visible and helping to scale new solutions. And also making the data flow across systems.” (Manager, Innovator, FIN21)

		Joint discussions between ecosystem stakeholders were not easy "It was not easy at all because the private sector and the Ministry of Environment had a lot of disagreements over the years. Finding a joint vision and goals. I was not involved in that part, I heard different stories, but it took quite a while, at least 1 year to get that going." (Manager, Innovator, FIN21) ***Resolving conflicts through open discussion by the neutral actor, Kira-digi*** "For us, it was easy; we were truly a neutral body in the middle and everything was open. Any issue that resulted in a conflict we were able to make an open discussion and have an open way of handing that. It evolved in a way that Kira digi was a platform to bring these issues to be jointly discussed and developed further; open discussion bringing conflicts to the surface. (Manager, Innovator, FIN21) ***Success of KIRA-digi is related to the manager's personality*** "Teemu was a project manager. Kira digi is a success related to Teemu's personality. He is good at networking, proactive. It is crucial that the person who is leading should like to speak, present and have strong opinions. Can convince people about ideas. […] It is equally important anywhere in the world. People need to have charisma. The most important is to be proactive. Typically, in many programmes a CEO is missing. You require all pieces in the puzzle." (Researcher, FIN20)
	Objectives of Kira-Digi	***KIRA-digi followed three objectives: unifying building information management across built environment, changing legislation to enable digitalisation, and experimentation*** "Three different plans of a project, like unifying building information management across the building environment, the idea to fund focused projects that would help to harmonise how to manage it in different processes, and starting to open data to the public. The second was legislation and the government's part; they both wanted to understand how to change legislation to enable digitalisation in a bigger picture within the built environment. And how governmental processes and systems should support it. And the third biggest part was experimentation; there was a lot of funding for it. That would embrace new digital opportunities and services. Then we started executing these three parts. The project office was small; there was only two people. We had really close collaboration with the Ministry of Environment because a part of funding came from there. That was a starting phase." (Manager, Innovator, FIN21)
	Mechanisms set by Kira-digi	***Setting mechanisms for the mindset change: Openly communicating about project results to set the right environment and shifting mindset towards open communication*** "So, the main goal was to get as much new experimentation as possible and as widely as possible. Of course, the review was based on the criteria of: 1) feasibility, is it realistic; 2) impact; 3) accessibility and openness; 4) innovativeness, creativity and originality. Based on those criteria reviews scored. The overall objective was to get companies and organisations to try new things. To develop approaches, the tool can provide new value. Some differences in focus as technical experiments and business models, operating models, process experiments. Basically, the key thing in the success was openness. It has to be communicated to all. The results will be open to everyone and even the competitors can read it and start utilising those learnings. It was a key thing. It was a process of mindset change, from a closed to open and collaborative mindset. There is still a lot of work to on that. but it was a good start. Symptoms to be seen that the mindset has changed a lot." (Manager, Innovator, FIN21) "We actually openly communicated about the projects and results; there was a phenomenon, organisations wanted to start showing off these new things that they are doing, and they let new business and collaborations afterwards. It has positively set the environment. and that has changed the operation within companies as well. They started to communicate a lot more themselves. The situation used to be that many companies do great things, but they are really poor in communicating that. Even in Finland, we do not really know, or people know but it is not widely communicated. Widespread public do not know how good Finnish companies are at the international level. It is one shift in the mindset that we did open communication and we input a lot of resources and money into communication. We hired parties to do content for these projects to show results. That kind of shifted the mindset towards open

		communication. Not just in Finland, but globally. They also started to do English communication about their projects and R&D innovation activities. That is one thing." (Manager, Innovator, FIN21) ***Eliminating any corrective mechanisms to focus on carrots than sticks to embrace experimental culture and open learning*** "Not really, the whole project was embracing experimental culture. That's one mindset that we wanted to change; traditional R&D in this industry has been a plan and you follow a plan and you stick to it and hope for the best. But in experimentation it is different. When you have an idea, you are actually trying in practice as [much as] possible with minimal costs. Come in with a solution on a day and try with minimal resources to get some results and then you learn whether it will work or not and learn where to put resources. In a sense, we wanted to embrace that mindset that there is no failure; it is only learning, and learning is a result. Other results do not matter as long as you learn. We did not have any sticks. If projects did not go as planned and if you learnt why it did not go as planned and utilised this learning in the next step. Or we had 6-7 projects that stopped already in the beginning because of some disagreements between partners or organisational changes or whatever and that's fine. We wanted to embrace that learning mindset and that's why we did not have any sticks. I think that is also Finnish overall culture that we do not punish people for bad results." (Manager, Innovator, FIN21) ***Demanding the results to be open while providing only 30-40% of funding to cover project costs*** "We did not have any other incentives but kind of, it was how we operated the projects. The project funding was one mechanism with 30% of total costs but the requirements are that everything is open; we did not give them much choice. That really worked for us and them. That was needed to start changing these minds." (Manager, Innovator, FIN21) ***Opening opportunities for other industries to collaborate with BE to challenge the status quo in the built environment sector through Kira-Digi*** "We identified some strategic partners we wanted to join. We selected key players, kind of. One of the goals, we wanted players from other sectors, like IT and digital service providers, that have never done anything in BE but have something to give because we can see that those players in the BE sector cannot renew themselves alone because, if they were, they would have done it already. We wanted new players to challenge the status quo. We started to involve that kind of player more and more. Digital services are growing, like Solida IT, and those kinds of players are going global themselves. Also, we welcome the outside companies that have something to give. We also want to increase [our] understanding of what is going on. Companies do not really know what is going on so those partnerships of the ecosystem could emerge." (Manager, Innovator, FIN21) "One example emerges from collaboration from games from the BE sector; there were experiments in trying AR, not just for visualisation but also integrating actually design and manufacturing processes for that. And some companies that have a long history in the gaming industry and the development of hardware, and through Kira Digi they found a way to collaborate with the BE sector. The companies, like Vario technologies that are building VR hardware that is actually you can experience VR with human eye resolution, and it is the first device in the world. Then, VR gaming, called Vake production, collaborated in other projects with BE players. They started to experiment with an approach where their expertise will be remote anywhere and you can realise this through the platform developed with VR and AR. You can have any person in the field and then you can utilise any expertise remotely, being a guide for the work to be done in the field. That was successful." (Manager, Innovator, FIN21) ***Complementing missing capabilities in the industry*** "We have seen that there is a lot of need for other kinds of capabilities. It is mostly engineering and technical out there. There is a lot of need for a capability for conceptualising, marketing, modelling end user perspective, service design, business model design. There is a huge need for these kind of capabilities in this field. If we can bring in more of that, I mean there are huge opportunities to make things better if we merge these two. (Manager, Innovator, FIN21)

		"With every project, we had a communication partner that helped them to rephrase their projects. Initially, project players wrote those contents themselves - what are the objectives, expected results. It was from a technical engineering perspective. It was not understandable. If you take people from the streets and show it and ask, do you understand what this project is about, probably 99% will say I have no idea! We had a communication partner who worked with all the projects that helped them to write those contents in a format that anyone could understand. That was one thing. Then, we also realised quite fast when those people are doing projects, when they are pitching, there was also a lot of need to improve how to communicate the results. We had a lot of pitching training. And in the end, we had results sessions when they pitched the end results. There was rehearsal and feedback and support to become better at that. (Manager, Innovator, FIN21) ***Establishing WDBE conference to generate mechanisms for global discussions*** "Of course, we are trying to do this on a global level as well to have these discussions in the global network; that's why we organise this WDBE conference so we could discuss it annually to help building a global ecosystem in this topic and also make things that happened elsewhere transparent for the Finnish ecosystem. I think it is important to have mechanisms and processes to give that discussion and evolution understanding on both a Finnish and a global level." (Manager, Innovator, FIN21) ***Generating opportunities to embrace the strategy of platforms and ecosystems in the BE sector*** "The biggest opportunity is related to platforms and a platform economy. How can we utilise that in the BE sector? That also provides global growth opportunities; we have experiments with digital platforms in KIRA-digi that can be scaled globally." (Manager, Innovator, FIN21) ***Establishing different funding mechanisms for each phase*** "Implementation phase. The initial phase was to do part 1 then 2 then 3. But that did not work. The challenge was that the funding mechanism was different in each part. […] 60% was private money and 40% was public money." (Manager, Innovator, FIN21) ***Attracting venture capitals to cover private investments*** "The private money came from venture capital firms and they wanted to invest more into scaling those results." (Manager, Innovator, FIN21) ***Selecting projects based on a point-based system with the help of the experts as reviewers*** "We had this pull of experts as reviewers. Usually, we had 10-15 people to read through all the applications and give them points based on those criteria. Then we had a meeting when we had all the applications in the order of how they were reviewed. Then we had a certain amount of money on each round to give away. The order was from 1-5. We ended a value tree as the level of quality. We would not finance any project that got less than 3.0. Then from that, the limit was basically on the amount of funding available; it was straightforward." (Manager, Innovator, FIN21) ***Establishing a clinic service for quick legislation to support experimentation giving Ministries a good overview of the challenges in the field and accelerating the process of development*** "In part 2, the legislation part, we ended up having a law clinic service for last year (2018) that served all experimental projects. Many of them started experimenting with new digital tools and services from scratch. So, they ended up having the limits of current legislation; for example, a start-up started to disrupt a real estate agency. It started to get agents out of the picture totally. They started to automate everything they do. They have AI for setting up the price of the apartment and automating documents and basically to automate everything that is possible. With that, they were able to lower the fee of consultants; for example, the normal fee is 4%. And with this digital service it lowered significantly to 0.74%. That was disruptive, like the UBER phenomenon in the taxi industry; they did the same to real estate agents. But there were some legislation issues there; for example, their service was based on the idea that the real estate agent does not go to the apartment him or herself but based on current legislation it was required. So the law clinic has helped to guide those projects with legislation but also getting input on those challenges from the field. It served as a catalyst for

		future legislation as well. It was free for anyone dealing with the digitalisation sector in the BE. At the same time, it was a free service; companies used that and the Ministry got a really good overview on the challenges in the field. Other examples are from a platform economy approach on electricity. We had an experiment on E-charging devices and platforms that anyone can start selling electricity to anyone else with their own price with this local device and digital platform. The electricity market is so heavily regulated, so it had issues. So, it was useful to have this clinic." (Manager, Innovator, FIN21)
	Results from the orchestration mechanisms	***Established Kira-Hub as an innovation hub to continue developing industry capabilities*** "Kira hub is a BE innovation hub; in Helsinki, we are looking at how can we bring and help develop those capabilities. […] Kira digi, as a project, has ended officially at the end of 2018 but we still have some things going on. […] We have got funding from industry associations to continue the work. As a Kira hub we are now starting to initiate new programmes. We had new elections, so the government is changing. So, the Kira digi fund came from the government. So now we are suggesting a new government with 25 million programmes for BE and hope that it will go partially to Kira hub to coordinate that programme." (Manager, Innovator, FIN21) ***Setting the spin over effect for BE actors that want to be a part of the innovation hub*** "500 firms participated officially but even more unofficially attended events; one result was also spin over the effect in what we did. There was a lot of companies that did not get KIRA-digi funding or did not apply but they also started to experiment with new business models and wanted to become part of a community and bring/communicate those as well. It was an interesting phenomenon." (Manager, Innovator, FIN21) ***Established funding mechanism for experimentation was successful*** "In experimental part 3, EU funding mechanisms for experimental development, in a sense the project cost 40%, was coming from the government and 60% was coming from the private sector. It was an initial source of 8 million of the overall budgets. It was simple to set up." (Manager, Innovator, FIN21) ***BE sector started to invest into the experimentation themselves*** "One result has been many of the companies from BE have, through these experiments, … started investing more in digital transformation themselves and they recruited new kinds of competencies in house. That's also one result happening during the projects with the companies in Kira digi." (Manager, Innovator, FIN21) ***The shift from closeness towards openness opened opportunities for inter-industry collaboration and ecosystem formation*** "The sector was so closed; it was difficult for outsiders to come in and offer their services and competence. So basically, we started opening up this communication; outside players also, it was easier for them to start communicating. The Kira digi experimental instrument allows outsiders to apply for experiments. And that kind of also made it visible for the field and new collaboration to happen. Other industries from ICT - companies that would bring competence on digital service side mostly." (Manager, Innovator, FIN21) ***Established wide scope for phase 1 and 2 that did not reach all goals but produced good results*** "Part 1 and 2, probably at the end of the projects, they did not reach all the goals that were set up for them. But that still delivered good results. The scope of the projects was so wide and large, you would not expect to solve everything in two years anyway. There is still a lot of work to do." (Manager, Innovator, FIN21) ***Experimenting in projects was embraced by the industry*** "We had six different open calls for applications. There was a process of review of application based on a pool of experts from different fields to go over these applications and give points to these projects. We did it from the beginning all the way six times until last call ended. It was an ongoing process of getting applications, reviewing, starting and beginning a new call. It worked really well. It was the biggest thing in the project; in the community, it was really needed, and they were embracing that." (Manager, Innovator, FIN21)

		Experimenting in projects made legislation issues and unified information management more concrete "The experiments started to go very fast and it was good because experimental projects made those issues more concrete. They gave a lot of input to parts 1 and 2. There were so many issues, so it is difficult to speak about all of them." (Manager, Innovator, FIN21)
	Thinking about the next phase: Scalability challenges	***Challenged by scaling the results from the experimentation to make an impact on a wider ecosystem*** "The biggest challenge at the moment is to start scaling these new tools and solutions as widely as possible. In Kira digi, we had experiments, and many have succeeded, but it is only small fraction of the industry, so the question is how to scale it to make a huge impact? We did an assessment of impact of Kira digi and the result was quite nice. So basically, the government funding was almost five million euros in two years, and the own funding part was eight million, and those projects were led by Kira digi led to another 22 million euro and it almost doubled in the project. Sixty percent was private money and 40% were public money. Public funding was from Business Finland continuation projects. The private money came from venture capital firms and they wanted to invest more to start scaling those results. That was a nice result already during Kira digi." (Manager, Innovator, FIN21) ***Positive potential impact from scaling the solutions*** "And started to analyse the underlying impact if we were able to scale it as widely as possible in Finland, what would that mean? So, we discussed with all the projects. Everybody tried to analyse and assess what it would mean. One project, Eerad, provided a digital platform for renting construction equipment so the realisation rate of construction equipment would be higher [with] a tracking feature of where that equipment is so nothing would get lost; based on an experimental project, they estimated that, with that approach, they could construction equipment management with 20% more efficient than the current process. The construction equipment market in Finland is 30 million, so 20% of that would be 600 million yearly. So, we did a rehearsal and did an estimation; if just these results would be implemented, we would have 5.5 billion annually. Now we are discussing to get that next level funding." (Manager, Innovator, FIN21) ***The scalability of solutions can aid the productivity leaps and digital disruption*** "We are now on the verge of actually realising some of those productivity leaps. Everybody is seeing those charts with decreased productivity but now I see some signs that it will change quite soon and that some projects were embracing lean and tactile digital solutions, they are getting already of 30-40% of productivity in singular projects. So, when we find a way to scale that, we can see a change in the next 5-10 years." (Manager, Innovator, FIN21) ***Embracing digitalisation to scale globally*** "The fact that Finland is a small factor does not bother anyone. Everybody says that construction is local, but now we are adding digital layers and absolutely bringing digital layers to everything that we do to user maintenance and equipment, so solutions are becoming more global and it is not only a digital layer but also a physical layer is becoming more global; manufacturing and different materials are global. There are so many opportunities are coming in the next following years; there are so many challenges, like carbon neutrality and climate change, circular economy. We start embracing it and we think digitalisation is the key in doing that." (Manager, Innovator, FIN21)

APPENDIX C: DATA STRUCTURE FOR CHAPTER THREE

The following are selected quotes of qualitative data for the discourse & textual analysis within Chapter 3.

Aggregate Dimension: Regional advantages as a driver for innovation	
Second-order Categories	**Selected Evidence on First-Order Categories**
External drivers of innovation	***Co-location with Silicon Valley incumbents drives internal innovation*** "My personal suspicion is that it [transition to a business ecosystem] would have taken [the software vendor] a lot longer to get there, had it not been sitting next to Silicon Valley, and had it not seen like, the sort of local pressure of everybody integrating with everything. It's an interesting thing to ask if [the software vendor's] proximity to Silicon Valley or was it also something that [the software vendor's] customers were specifically asking for? And, so it may very well be that." (Manager, Software Vendor, CA30) ***Following a trend: a rapid shift in the technology market towards business ecosystems*** "We're trying to envisage that (building a business ecosystem) […] but that's the idea. It's the trend, right? If you look at Salesforce, it is a platform, everybody is integrating with everybody. There is a rapid shift in the software sector away from building it all to partnering to provide it with all." (Manager, Software Vendor, CA30)
Internal drivers of innovation	***Desire to dominate the software market in "design to make" sector with an integrated platform for collaboration*** "[The software vendor] wants to take over the world, we want to do that by being the software that allows for business transformation through the use of technology. […] They're pushing the agenda they want, which is like this centralized collaboration platform from design to make. And we don't want to help you manage conventional processes better, we want to help you make a business transformation through leveraging technology." (Manager, Software Vendor, CA30) "This is what we have, we have monopolies." (Consultant, CA13) ***Perception of threat from disruptive innovations like Uber and Silicon Valley giants*** "What if Google or Facebook or one of those companies that are sitting on several billion dollars of cash reserve, and it's just spinning out money to do little test companies in the building construction market and just use it to dominate the supply chain? I think it's more threatening than a company that does some other CAD product because we understand it, we're playing on the same rules. Look at Uber, […] the taxi companies are not under threat from another taxi company, it's under threat from something completely different. If we are not innovating, not changing or we're not moving towards this vision of connected project delivery, we are not moving towards this vision of big data. Who will get there first? It's not going to be Nemechek; it's not going to be Trimble. It is going to be Google." (Manager, Software Vendor, CA30)
Vision of Future	***Long term goal: Strives to become a technology company with brand "design to make" like Amazon for "buying goods", and Google for "search"*** "The logo for Google, and they're like, okay, if you think search, you don't think search and search for something, we're going to Google it. And then they showed the logo for Amazon. It's like, if you don't think I'm going to buy something, you think, okay, I'm going to go to Amazon, right? Go to Amazon Prime. And then, you show the [software vendor's] logo. And they're like, we want [this] to be similar to that. [The software vendor] has been really pushing the future of making things, make everything into a slogan." (Manager, Software Vendor, CA30) ***Short term goal: market dominance*** "In the short-term play, we're looking to become the dominant construction platform. And that, frankly said, that the sector buys more of [the software vendor's] software. That's just market dominance right now." (Manager, Software Vendor, CA30)
Aggregate Dimensions: Platform Management	
Second-order Categories	**Selected Evidence on First-Order Categories**

Designing Platform	***Selling integrated platform for collaboration that provides a number of tools*** "[The Software vendor] is building design authoring tools and project management tools. And they're building fundamentally a collaboration platform. […] And [the software vendor] doesn't want to help you manage conventional processes better, it wants to help you make a business transformation through leveraging technology." (Manager, Software Vendor, CA30) ***Owning authoring tools (a collection of tools that form platform)*** "[The software vendor] have this huge opportunity because [it] also owns the authoring programs. [The software vendor] can start creating this common platform that allows collaboration." (Manager, Software Vendor, CA30) ***Authoring tools belong to different shareholders*** "[The software vendor] makes 80% of its money off of [Software 5]." (Manager, Software Vendor, CA30) ***Prospecting new business areas for platform integration*** "[The software vendor] is looking to broaden its markets. […] And the question is, where can [software vendor] be successful? What are adjacent industries to vertical construction that [software vendor] can be successful in?" (Manager, Software Vendor, CA30) ***Expanding services from design to construction allowing collaboration*** between ***disciplines*** "[The software vendor] have moved into document management and are trying to move into project management." (Manager, Software Vendor, CA30)
Monetizing process	***Business model transformation towards Software as a Service*** "In the past three years, [the software vendor] has been going through a business model transformation and is basically moving from selling the seats of software perpetual licenses to selling subscriptions as Software as a Service. And that's a shift to becoming a modern software company. Look at Salesforce; Salesforce was kind of born in the cloud, was one of the first one in the clouds, "I've always been doing this." But [the software vendor] had to go through a transformation." (Manager, Software Vendor, CA30) ***Customer support service depends on membership type and is a matter of scale*** "[The software vendor] has various pathways depending on who the customer is and essentially how much they buy. […] it's a matter of scale [of firm]. [Firms] who spend that much money tend to be international integrated firms. And these firms do in-house architecture, engineering and construction management; they're doing it around the world and they're doing the mega projects and they're doing probably infrastructure and oil and gas, they have different divisions, they just like the volume of people, they have just outsized any sort of national level kind of company, right. […] If you are just buying a little bit of software, you don't get much support. Unless you are really, really high level." (Manager, Software Vendor, CA30) ***Reducing the volume of feedback with new business transformation*** "We actually have probably more incremental engagement with these customers than we did with these traditional perpetual licensed products." (Manager, Software Vendor, CA30) ***Maintaining the traditional feedback loop using customer service*** "We have all the traditional feedback loops which are like the product team is talking to the customers." (Manager, Software Vendor, CA30) ***Focusing on large vertically integrated firms market segment*** "And this is in basically predominantly focusing on vertical construction, predominantly the US with some of the EU components into that." (Manager, Software Vendor, CA30) ***Monetization model through open API is nominal*** "[Software vendor] have some sort of monetization platform. Frankly, it is nominal right now." (Manager, Software Vendor, CA30) ***Complex integrated platform is sold for outrageous price*** "That's one of the things, the cost of the licenses is outrageous!" (Consultant, CA13) "You need a simplifying technology; there isn't a single simplifying technology that's out there." (CEO, Ai start-up, CA17)
Managing Platform Network	***Pursuing silo in business development amongst software vendor and vertically integrated firms***

	"One of the most advancements that we have seen in technological work and methodologies in this sector are from two separate silo groups. One is the software vendors there, they are very siloed. The other is either at the front line of construction." (VDC Manager, GC, CA11_1) ***Opening APIs for companies to build on their platform*** "We're now essentially building on the forge platform, which is a set of company, essentially instead of [the software vendor], API's. And the idea is that each of the products builds on these common API's so that there's more interoperability between these products. And it's also easier to integrate with, or build on top of, these core API's." (Manager, Software Vendor, CA30) ***Integrating with academia*** "[The software vendor] is dominant in design [platforms] in the US, right? It's taught in schools, if we pretty much have the corner on the market." (Manager, Software Vendor, CA30) ***Partnering with leading sector firms through academia partnership*** "They are a partner for us. Yes, there is a strategic relationship that we have with [the software vendor], but they are different. All these technology organisations of any size have known how important it is to create partnerships. So, it's an integration model, essentially." (Manager, GC, CA11) ***Developing varying levels of partnerships with complementors*** "[The software vendor] have varying levels of partnership with varying levels of people. Within [software 3], [software vendors also] work with other cloud computing companies that do construction solutions. And then some of them are smaller than [software vendor], some of them, very few of them, are equal size, but they get larger or an equal volume of construction business. [...] [The software vendor] has partnerships with, like, other sector organisations, like there was a partnership with Ads rate, which is a GIS mapping. [The software vendor] also has, like, thought leadership partnerships [and] a lot of partnerships, I can't even keep track of them all." (Manager, Software Vendor, CA30) ***Providing support for the advancement of leadership thought in the sector*** "[The software vendor] is doing some activities to advance leadership thought, or examples or supporting projects that have advanced viewpoints." (Manager, Software Vendor, CA30) ***Engaging with the sector through engagement program*** "[The software vendor] has a quite a program, a robust program of engagement with the sector [**participants].** (Manager, Software Vendor, CA30)
Competing in a standard war	***Limited support of open standards to prevent interoperability and to win the market*** "What's going to be the holy grail for me is that, if there was an IFC, and it had a standardized way of sorting 3D information and had a standardized way of having metadata in it." (CEO, start-up, CA16) ***Software vendors' inability to agree on a market share in order to establish open standards*** "The problem is these guys [i.e. the software vendors] don't talk to each other. There isn't a common language between… there isn't a common language with which these guys can talk to each other." (CEO, start-up, CA16) ***Preserving the power through limited support of open standards*** "They do, but it is not very effective. For example, [the software vendor] also supports IFC; it supports IFC, yeah, but it doesn't work well. It is not there yet. One of the biggest issues with the IFC standardization is that these geographic limitations that you have, [the software vendor] would want to cater it just to the American market very well; they don't want to get at the others." (CEO, start-up, CA16) ***Domination of the software market*** "[The software vendor] has the largest market share, but it is not a monopoly yet." (Researcher, CA05)
Managing platform appropriability	***Avoiding taking any responsibilities for the quality of data produced using their software*** "Software vendors are not responsible and do not want to take any responsibility. (PM, general contractor." (PM, general contractor, CA20) ***Astutely listening to the end-user's requests to maintain the status quo*** "I don't want to defend them, but I do think that [the software vendor] was forced by the customers to do things the old way. I think they sort of pulled back from trying to push for changes in the

	sector; it was 2-3 years ago, they tried to push something, and they gave up". (Optimization manager, CA23)
Pursuing self-interest and contradicting the sector's needs	***Pursuing self-interest*** "I agree that software can be a strategic player, but when it comes down to it, it wants to make money." (CEO, Ai consultancy, CA17) ***Designing software to sell, albeit not for end-users*** "They are designing software to sell software; they're not designing software for users, for what needs to be used." (Consultant, CA13) ***Designing the technology from the software vendor's perspective*** "Sometimes all these big software vendors, they are creating all these tools from the technology perspective, but not really understanding the construction process." (Business Manager, GC, CA04) They make mistakes though; they see things, not the way we see them." (Manager, GC, CA11) ***Cycle of technology upgrade is faster than the hardware upgrade and even faster than the development of user's skills*** "The speed of developing this thing is faster than the speed of the hardware that you're using for it. And all this is faster than the adoption rate of the users. And all of this is faster than the skills of the user." (Consultant, CA13)
Aggregate Dimensions: Ecosystem Orchestration	
Second-order Categories	**Selected Evidence on First-Order Categories**
Advocating for change	***Marketing the platform that connects design to construction, allowing frictionless data flow*** "Think about what [Software vendor] does. It does design, and then it takes it to make. It wants that to be as frictionless a process as possible. [The software vendor], they're providing the connection between design and construction and allowing data to flow from design and construction. […] It does design, and then it takes it to make. We want that to be … as frictionless a process as possible." (Manager, Software Vendor, CA30) ***Push the sector for change to buy more software*** "[The software vendor] wants to dominate the market [and it] very much wants to see the sector change. […] And, so the reason why [the software vendor] really wants to see change or is pushing for change in the sector is so that the solution that they're building is more applicable. […] And that, frankly, said that the sector buys more of [the software vendor's] software". (Manager, Software Vendor, CA30) ***Advocating for change through marketing is creating the strongest voice, thereby defining what BIM is*** "The problem, as I see it, is the influence that the software vendors have had and are having in defining what is BIM and how it should be used, both at the academic level, but also, and maybe mainly, at the practitioner's level." (VDC Manager, GC, CA11_1) ***Defining value of BIM and technology use*** "The problem as I see it is the influence that the software vendors have had and are having in defining what BIM is and how it should be used, both at the academic level, but also, and maybe mainly, at the practitioners' level. I believe that the software vendors voice should be just one among different voices – and definitely not the most important. When this is not the case, I believe then something is going wrong." (VDC Manager, GC, CA11_1)
Creating perceptions and disseminating stories through marketing power	***Establishing a perception that Building Information Management is equivalent to [platform's BIM Software]*** "BIM itself is obviously just a tool [Software 1] to achieve certain ends." (Optimization engineer, CA31) "We even get contracts and proposals that, like, require a Revit file at the end of the project because people wrote that and that means for them BIM. That is what they have as a BIM." (VDC Director, GC, CA25) ***Establishing a perception of a platform's importance in terms of collaboration*** "BIM is a powerful tool architects, structural engineers, and mechanical and plumbing engineers are probably at the forefront of. Digital technology integration [is] simply based on the value that the 3D and information data brings to their disciplines in design and construction." (PM, general contractor, CA10)

	Establishing a perception of the low capabilities of a competitor's platforms "My current firm was exploring ArchiCAD, … which I think is perceived a lot in California as being something outdated and no longer used. So that there's that perception." (Architect, CA09) ***Establishing clients' exaggerated expectations of platform capabilities*** "I'd say, the expectations on the client side can become exaggerated because of the salesman nature of the BIM world, and what they've been doing to promote themselves." (Architect, CA09)
Influencing clients to mandate the use of the platform to enable collaboration	***Promoting a "pretty picture" to sell the idea*** "They [software vendors] are out there boasting that 'Hey, that software can do all this stuff in 3D'. And they're showing all these pretty pictures that look like photographs. And they're selling that to the owner. And the owner sees that and says, I want that!" (Mechanical engineer, sub-trade, CA21) "Some people call this Hollywood BIM." (VDC manager, general contractor, CA01) ***Clients develop a desire to own the model designed in the software of the software vendor*** "The owners see BIM as this buzzword that they think is going to make the project better, but they aren't highly involved with the knowledge of BIM. And so, having clients with a high desire and knowledge of the buzzwords of what BIM is, it creates an expectation that may not be reasonable." (Architect, CA09) ***Establishing a perception of the need to mandate software use amongst clients to enable collaboration*** "A collaboration platform is only limited good. And like speaking, capitalistic, allow only limited stickiness if the contractual structures don't allow people to collaborate in an open environment." (Manager, Software Vendor, CA30) ***Clients design unreasonable contracts with unrealistic expectations*** "I would say, marketing strategies have made it into the client's understanding in how they write contracts. And then, when the architects and contractors are ready for contracts, they may not be checking with their tech group or BIM group. Even putting themselves into all kinds of very unreasonable requirements." (Architect, CA09) ***Clients require use of platform*** "It's just become the standard in west coast California, the standard for documentation for large-scale projects from the owner standpoint, from the owner's requirements. […] The client isn't going to do anything with it, but they want you to deliver it." (Architect, CA09) ***Top management agrees to*** unreasonable ***contracts to win projects*** "And then, when the architects and contractors are ready to sign contracts, they may not be checking with their tech group or BIM group. Even putting themselves into all kinds of very unreasonable requirements. [….] they're all the bosses that are older and have years of experience, and they go to sign their contracts and do whatever, and they go to their baseball games with the client, and so that's just not a concern for them. They're not individually incentivized; they're not going to see the problems that arise from a disconnect between the expectations of what you can do with BIM and the realities of how that relates to construction." (Architect, CA09) ***The supply chain is incentivized to purchase the platform*** "They use it as a marketing tool for winning projects." (Architect, CA09) ***Clients are paying the software vendor to improve the platform tools for the sector*** "I think that, even the clients, they're paying a lot of money to [Software vendor], so they would listen to what we say like in terms of improving their tool." (Business Manager, GC, CA04)
Aggregate Dimensions: Platform Limitations are Contradictory to What it was Marketed for	
Second-order Categories	**Selected Evidence on First-Order Categories**
Platform's inadequate capabilities	***Design capabilities of tools are limited*** "[Software 1] is offering benefits in terms of the production of drawings, I think, when it comes to using it as a design tool, there are still limitations there. Designers on my team, they often complain that [BIM Software 1] is rigid." (Architect, CA33) ***Inadequate interoperability between the platform's tools*** "There's a big barrier to entry. Because for some reason, [Software vendor] has not made it possible for details to transfer from [Software 2] to [Software 1]. […] The interoperability, it's as much as they say it is; it's not!" (Architect, CA09) ***Silo workflow between platform authoring tools***

	"[Software 1] didn't directly integrate with [Software 2]. […] So, rather than being just a disconnected program, […], so you can do some things, but it's a silo workflow," (Manager, Software Vendor, CA30) ***Inadequate seamless data flow between all digital tools*** "When I think of BIM, I always think of data, like a seamless data flow. […] I think that would be a very interesting workflow to see. Yeah, I have not used any workflow that talks about seamless data flow. You would use multiple tools from extracting data from one tool to another then add-ons are developed to extract that data. But for now, I've not seen a very efficient workflow that shows seamless data transfer." (VDC Integrator, GC, CA12) ***Additional tools are developed by the sector to achieve seamless data flow*** "So, some additional tools are being developed as well to utilize the availability of data, but I've not seen a very efficient workflow that shows seamless data transfer." (VDC Integrator, GC, CA12) ***Loss in design functionality since 2007*** "We tell [the software vendor] about the problems we see in their products. And about [the] loss of functionality. And we are frustrated and… but we keep trying because that's their business." (Manager, GC, CA11) "You can end up with really large models, and it's only really loading the information that's relevant to what you're working on. [Software 1] isn't built that way, right. So, you end up with really large file sizes, and you're not able to kind of effectively navigate or like operate the model." (Optimization engineer, CA31) ***Inadequate system architecture for prefabrication and, therefore, scalability*** "Market leading BIM packages, like [Software 1], don't support fabrication directly. […] Revit isn't really designed to be used for that purpose [prefabrication]. It hasn't been architected in a way that makes it scalable". (Optimization engineer, CA31) "Is that we have to dumb it down to make [Software 1] work. That just means, [Software 1] has a bad architecture. It's bad management of data." (CEO, Structural Engineer, CA07)
Limited value of platform for design and construction	***Limited value for prefabrication*** "Everybody wants Revit or Revit isn't developed enough for us to take what we do over here and actually produce all the stuff we need. It cost us more time and effort." (PM, sub-trade, CA21) ***Limited use of software by sector actors*** "So, they [the sector] use that software between 25 to 50% of its capabilities. If you go to 80% of construction projects, users [of platform] will probably use 25% of the capability of the software." (Consultant, CA13) "[The] whole [platform] suite is excellent. By far, you wouldn't use 90% of the programs currently." (Architect, CA09) ***Disconnect between the design and construction*** "And so, we still have this gigantic chasm. There's a disconnect between design and construction." (PM, Health Care Client, CA08) ***Supporting the status quo*** "Software and technology that we have in construction are specifically designed to support the status quo because they're mainly document production tools." (Consultant, CA13)

APPENDIX D: DATA STRUCTURE FOR CHAPTER FOUR

The following are selected quotes of qualitative data for the discourse & textual analysis within Chapter 4.

Aggregate Dimension: Individual Level		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Agency	*Variability in attitude to the same challenge*	***Variability in attitude to the same problem: "holy cow", "saw no opportunities" and "saw opportunities but did not pick up on the challenge"*** "Three companies with different attitudes to digitalization. First, [hidden] rejected the idea of technologies and did not see any opportunities to learn. Second, […] three top project managers saw BIM as the holy cow and saw the future, then they became CEOs of the same company driving it. Third, [hidden] did not have a bad attitude to BIM but did not see any strategic opportunity." (Researcher, CA38) "There are companies that are willing to cooperate and those that are totally against it and want to do their own thing". (CEO, structural engineer, CA07) ***Variability in attitude is related to competencies*** "Agency and capabilities are closely related. Variabilities are closely related to competences and skills. Typically, your attitude to the challenges is also affected by your knowledge and competences." (Researcher, FIN20) "Probably because people have different priorities, thinking and technical understandings, it takes quite a long time to understand its possibilities." (Researcher, FIN20)
	Self-interest or risk management ?	***Conflicting inward-looking business goals of suppliers*** "No one wants to play nicely. […] People want to say: *it is mine, but you can do whatever you want."* (CEO, Ai start up, CA17) ***Disintegrated and disincentivised stakeholders who tend to protect themselves*** "The industry has all these different handoffs, and everybody overdesigns everything, you know, to protect themselves. The architect is a separate company from the engineers; the general contractor is a separate company, and the subcontractors. And so, the whole process with a bunch of different companies, they're unrelated, you know, that work together." (CEO, VIF, CA32) ***Sector's stakeholders are not interested in the total cost of projects*** "The architect they're focused on their dollars and everybody's focused on their individual dollars but not the total dollars! Nobody is focused on the total dollars." (Innovation Manager, GC, CA11) "The last thing they want to know is what it actually costs, right. And it's the same with everybody. The general contractor, the subcontractor, yeah, everybody had to present, everybody blows it up." (CEO, structural engineering firm, CA07) ***Changed orders derived from inefficiency are used as risk management for self-protection*** "What happens is your general contractors are on the job and they are really nice, everything's going well for them, they're checking how much money they can make but once they get to a point they start to lose money then they make the calculation and ask *do I want to stay in a good relationship in this or not*? And to the extent that they want to stay in a good relationship they'll just lose the margin to keep the owner happy. They even can make a small loss on the project because they really want the next job or there's a benefit to being in this relationship, but at some point, they'll switch, right. It may be early, may be late but then they will start to bury the project in changed orders, because they've been stockpiling paperwork through the project

		so they can use it when they need. So, **it's really a risk mitigation tool.** I understand how hard it's been for us to build systems to get people to really accurately project the final cost of the work." (Manager, health care client, CA08)
	Failed leadership by clients and other stakeholders	***Clients and other stakeholders fail to lead innovation in the sector*** "If you want value, you have to define value and you have to make value flow. It's simple as I told the owners, they have first to define what value is. **Many customers in [the] building sector do not actually do that very well.** And, they're not helped by the professionals they hire, by the architects. […] Then we have many owners that ask to build the cheapest building possible. They don't even think about value, they can't describe what value means to them. So, we are responsible for ourselves including the customers we work for in every business." (Innovation manager, GC, CA11) "My general observation is that usually, **clients do not have the capability to drive innovation**. The developers are financial people. I mean, they don't have IT people or manufacturing people or supply chain people, they don't have any of those people in their companies. So, they can't do what we are doing." (CEO, VIF, CA32) "**Leadership in construction does not exist from my point of view**. […] I see a lack of leadership every time that I go to the projects all around the world. […] There is a big problem with leadership; leaders in construction, they do not really understand what their role is. When we talk about leadership, people understand leadership as 'Hey, I am the boss and I tell you what to do'." (Consultant, CA13) "People at the top are bombarded with problems. So, they're not necessarily the people who are willing to try things. Typically, that's true in every organisation." (Innovation Manager, GC, CA11) "It would require somebody to really have the passion and position where he or she can really be driving things forward. […] It requires that this person gets this position where he or she can really make the change. […] I think that too **many people want to be in their comfort zone**. They do not want to fight and struggle all the time. But if you want to make a change, then you have to do it. You have to defend your views. You have to be very confident." (Researcher, FIN20) "There are so many developments which somehow seem relevant for construction, but there is **no vision for how to capitalize on these new possibilities**, and what should be the next steps." (Researcher, FIN05) "**The problem in companies now is to organise management and leadership**. Now when we started here [program], we had the background, software, technology but we didn't have those business managers who really create new ways of organizing businesses. […] We need top management in companies that understand professional leadership and management for the foresight and insight of management." (CEO, public agency, FIN14)
		Aggregate Dimension: Organisational level
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Capabilities	*Established competencies*	***Established competencies to work in adverse conditions hinder innovation*** "Contractors are really good at getting stuff done in adverse conditions." (PM, software vendor, CA30), "People know how to do what they've been taught to do and what they have done." (Innovation manager, GC, CA11). "That progress is more about 'width' of how many people I was able to engage instead of 'depth', how far we could stretch knowledge and theory because the fundamental ideas are quite... I would say 'simple', but quite difficult for many people to understand because of their background and the way they have been working always before. But, if you have some theoretical background, I'm not surprised to see the progress." (Researcher, FIN18) "The gap that somehow people still don't understand and are afraid of. That we do it as it has always been done, and if we do something otherwise everything would go wrong." (PM, public client, FIN09)

	Skills variability in the labour market	***Biggest problem is lack of skills & talents, & expensive training*** "The outrageous price of personnel training and the cost of software licences. […] We don't have enough talent here. But it's also learning the talent that works for you, and where their strengths and weaknesses are, and how to partner with them, with people to make a stronger product." (Manager, Sub Trade, CA21) "This situation between people, skills, and technology, there's a big gap that we have to breach." (Consultant, CA13) "It's easier to write the software to integrate it than it is to train people to use a tool that is not familiar in the industry." (Engineer, vertically integrated firm, CA31) "Efficient use of BIM requires changes to the design and construction process. More efficient design tools lead to increased confusion in a multidisciplinary design process. The possibility to rapidly make major changes in design requires more efficient information exchange capabilities. The tools at hand are not up to the task. Efficient collaboration is hard to achieve and requires too much technical knowledge/skills. This breaks the process. The short-term answer is to facilitate collaboration." (PM, public client, FIN15) "Then this creates problems for companies; we kind of know what we need but we do not have resources to do that or experts to do it just the way they need to." (PM, GC, FIN24) ***Variation in the capacities and capabilities of individuals*** "I just assumed that companies were a lot more sophisticated in financial projection capability. And we found that some companies are very sophisticated. We found that some big companies have absolutely no idea if they're making money or not, believe it or not. A **100 million company in annual revenue has no idea if they're making money or not**. So, we've uncovered the things that, in a lonesome agreement or a GMP, you would just never be exposed to that. But once you open the book with profit and risk and profit sharing, all of a sudden, you start to go like: "WOW, this sector is a lot more dysfunctional than I thought." (PM, health care client, CA36) "Don't have the full capabilities, the full understanding of the capability of the software." (Consultant, CA13)
	Variable levels of knowledge and understandin g	***Industry actors do not fully understand the concept of innovation (VDC, BIM, Lean, IFC, etc.)*** "A lot of people when you start talking to them and you start asking questions about virtual design and construction, they can respond in the conversation with you but I'm not sure that they actually understand virtual design and construction in the way that CIFE would explain. You think that you are gathering information on this topic and you're talking about the same thing but you're not talking about the same thing." (VDC manager, GC, CA11_1) "Especially in this domain people have different levels of understanding of knowledge." (Researcher, FIN18) ***Marketing strategies by "Evangelists" (e.g. for VDC, BIM, Lean and etc.) articulate value propositions on behalf of the sector*** "So, I will tell this from my academic foot because I guess that the industry maybe will expel me if I say this today. BIM is something that absolutely needs to be revisited… so, it's like a Greek mythology; we got monsters with three heads, this is a monster with millions of heads, it has taken so many paths that now it's a big monster. Maybe academics and the industry should stop listening to the software vendors and make a big revision of what BIM is. But I guess practitioners are not ready to listen to this from me or anyone else. The problem as I see it is the influence that the software vendors have had and are having in defining what is BIM and how it should be used, both at the academic level, but also, and maybe mainly at the practitioner level. I believe that the software vendors voice should be just one among different voices (and definitely not the most important) that need to be heard when trying to define, and mainly implement, BIM. When this is not the case, I believe then, that something is going wrong." (VDC manager, GC, CA11_1) ***Limited understanding of business model innovation***

		“Architects do not understand the difference between revenue and profit”. (CEO, architect, CA24) “I do not know how it changed how we make money… How we make money is how we perform the job right?” (PM, GC, CA20) “There seem to be as many definitions and purposes for business models as there are managers in construction. The results of the interviews indicate that the managers in construction neither understand the concept properly nor exploit any similar value creation analysis in their business. The interviewees had significant problems describing their companies’ business models and value creation logic, pointing out the lack of analysis and understanding of customer values and needs in the project delivery process.” (Pekuri et al., 2013: p.21) “In many organisations in the construction industry, change management is not really professional. Managing it well is relatively rare.” (Researcher, FIN20)
	Scarce resources	***Low margins (1-10%) and low investment into R&D*** “Their margin is very low. So, they may have, 4 billion dollars of revenue per year, but if their margin is only 2%, so they made $40 million, right, Intel typically makes 50% margin”. (CEO, Ai start up, CA17) “Low margins that do not create enough incentives to invest into R&D and as a result it does not create a return”. (CEO, start up, CA35) “Probably most large construction companies in the US do support research. I'm not sure to what degree whether it is that much.” (Innovation manager, general contractor, CA11) ***Cost of licences is outrageous*** “I try to push technology from time to time, ‘hey, you know, why don't you guys go test this out?’ But the cost of the licenses is outrageous.” (Consultant, CA13) ***Training each individual is costly for singular firms*** “This is a very good idea, but I cannot do it, because there is no practical way to do it”. (Researcher, FIN20) “We kind of know what we need but we do not have resources to do that or experts to do it just the way they need to.” (Consultant, CA13)
Aggregate Dimension: System level		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
System Exploitation	*Industry is not incentivised to innovate*	***People are not motivated to innovate*** “From a system point of view, I don't think people are motivated to innovate. I mean, to be honest, people are motivated to make money and they're not motivated to do things completely different.” (CEO, Ai start up, CA17) “To think about incentives to make people work in a different way.” (Researcher, FIN20) “I think that people don’t like the change and that’s one thing.” (CEO, software vendor, FIN17) ***Process is built with unrelated parties that have no incentive to be efficient*** “Everybody who's in the industry have an incentive to be inefficient and so they are. […] developers are our customers and then you have architects, engineers, general contractors and subcontractors and all of those parties cost. So, say it's in their best interest for things to be inefficient because the less efficiency the more hours they tend to build. So as a consequence, they don't make any effort to make things more efficient because it just takes money out of the developer’s pocket.” (CEO, VIF, CA32) “The architects, engineers, the general contractors and subcontractors, they make more money the more inefficient things are, so they're not going to be the ones who drive efficiency as they are not incentivized to do it.” (CEO, VIF, CA32) “It has been a competition; contracts are separated, and everyone is selfish. That has been a situation on the market until now.” (CEO, HVAC, FIN23) ***People do not want to change***

		"But the problem is culture…. people don't want to change." (CEO, Ai start up, CA17)
	Appropriated established industry rules	***The established rules of the game*** "The rules of the game have been established […**]** people do not need to change." (Innovation Manager, GC, CA11). "It is very hard for outsiders to play according to new rules if 99.9% of the industry does not play by those rules and innovators are seen as a risk." (CEO, start up, CA16) ***The system is broken but I know where it is broken*** "AutoCAD is broken, too. But we've been using them for 20 years. We know where they're broken. My guys every single day are doing workarounds in the software because of the software shortcoming. But it's part of our process. And they've been doing it for so long. They do it without thinking. And they don't even know that they're doing it because the software is broken." (Manager, sub trade, CA21) ***The status quo is a strong motivator*** "Many people want to live in their comfort zone. You might be risking your job or career if you make something new and it proves to be a mistake. Many people prefer to keep the status quo; status quo is a very strong motivator." (Researcher, FIN20) "It comes down to people being afraid of losing their jobs by giving the technology companies a risk." (CEO, Ai start up, CA17)
	Appropriated commoditized business models	***There are different routes, but the outcome is always the same*** "At the end of the day, we still deliver a building." (PM, sub-trade, CA21) ***Business models with emerging technologies remain the same*** "Business models [of the sector] are from the 80s." (CEO, structural engineering firm, FIN04) "With the birth of technology, in this particular industry, all of the processes in the industry are exactly the same as they were in 1976". (CEO, Structural Engineer, CA07) "We have been developing technology, but the culture and the business processes have not been developed. […] the business models we have are from the 80s". (Consultant, FIN04) "New tools are introduced but basic practices have not changed." (CEO, software vendor, FIN17) "We earn money in the same way. That change is not dramatic." (Innovation Manager, GC, CA11) "You need a new business model, right? We do not have that…[…] We do not have a new business model for disruptive innovation." (CEO, Ai start up, CA17) "I am surprised to say relatively little progress has been made in the past ten years on BIM in the industry." (PM, client, CA28) "I am saying that BIM is not a key area of the business." (Manager, public agency, FIN12) "Maybe it is because we have been developing technology, but the culture and the business processes have not been developed. We always say that if this was just a way of developing a technology and not changing processes, you would never get the whole benefits that you should be able to get. I guess it has been the problem. We have been focusing too much on technology, which is enabling. […] So, you have to develop your business model in a way that can make it possible to use a technology efficiency. Because your business model is from 1980s." (Consultant, FIN04) "Now we have to look at the business model. It should change the thinking." (CEO, Public Organisation, FIN14) "Things have not changed much in construction." (Researcher, GIN05) ***Getting more money out of the construction process is like squeezing a stone with current constraints*** "Getting more money out of the construction process is like squeezing a stone with current constraints." (software vendor, CA30). ***Existing constraints were appropriated into the business models*** "**The dark side of the status quo is that the industry creates money from waste and some people do not want that change**. We still have a lot of construction

		companies that make profit from changed orders and they would hate the situation when there are no changes to orders, because their main business model is to find contradictions in design documents. […] Building design is so complex and in the traditional design, it was almost impossible to avoid mistakes. Definitely, there are partners who are benefiting from waste and mistakes and it is difficult to change, it is part of the industry culture." (Researcher, FIN20_1) "They are used to the current contract system. They know that there will be mistakes. So, to get to projects they have to make the lowest bid, but then they have to believe that they can profit if there are mistakes. Of course, it is risky if designers are doing a good job and it might not happen. **In the long run it is casino,** in the short run you can lose money, but in the long run you can win money". (Researcher, FIN20_1) "What are the constraints on the construction sector? What are the things that are keeping the construction sector from being efficient? What if we removed them? And, the contractors all hated it [removing the constraints] and it was not like a definitive sample of it. And they basically said, the contractor's feedback quite strongly is that you should not be removing these constraints, you should be helping us with these constraints. And I thought that was really interesting because essentially, **they have incorporated these rules into their business model. And so, while these rules are holding them down, and holding them down to that 4% profit, or that 1% profit, they are also keeping these constraints in the sector that are keeping them down, but they're also keeping them relevant."** (PM, Software vendor, CA30) "Seriously, that's how the industry is set up. **It's set up to manufacture change orders**; that's what's taught in school, how do you track change orders and it's amazing. […] If your entire process is set up based on fake stuff, you cannot improve it!" (CEO, structural engineering firm, CA07) "It had been so clear for a very long time that it is beneficial to use this kind of process. […] The process where you kind of waste 30% of costs is not so that somebody is burning the money, money just disappears. Somebody is making business out of that, out of these problems. Many construction companies are doing change orders or if you need to make a new element from the factory, so of course they would charge you to do that in a hurry. If work on site is late on schedule, they then need to work overtime. So, it would cost more, but people can be happy because they get paid more for doing over time. It is not always showing that money was wasted, someone is getting benefit out of that. In some cases, in the United States […] if you don't make any change orders, you get an invoice, and you see that your business is not going very well. […] **It is a traditional business that you would make more money from waste; it is still business.** […] I have been wondering myself why this is not going faster, because there is a lot of money wasted and energy wasted. The environment is wasted because of all these problems. We have all the tools; it is just a matter of using it." (CEO, software vendor, FIN17) ***Established fee structure: designers are paid by the hour and adhere to this model*** "Designers get paid by the hour. […] Even when you set up a shared risk-reward model, that designers are not necessarily willing to give up hours, they still want to build the hours. […] I think the design business model has to change in order for the outcome to really get more efficient." (PM, health care client, CA36) "Compensation model is for the number of hours spent or square feet measured." (CEO, start up, CA35) "It is a huge tradition of status quo. The architect's fee cannot be represented at an extra cost. […] You would need to change the contractual structure completely." (Researcher, FIN18) ***Business deal is an incentive for change*** "When the business deal is different then that's when you begin to see a deeper change and get different answers to your questions. […] But it seems if you can make a different offer in the market and create the capacity to do that, you end up changing

		a lot. You change, you use technology differently, you may invent, create technology, your social organisation, the way you organize the work and the way people in that place, work and relate to each other. It can be very different than what you see on most construction sites." (VDC manager, GC, CA11_1) "Now we have to look at the business model. It should change the thinking." (CEO, public agency, FIN14) ***Conflicting business incentives of supply chain actors*** "From a business point of view, what really seems to be the big issue is that the objectives of the general contractor and owner are not aligned. The objective of the contractor is to maximize the money that they can make on a project." (CEO, start up, CA16) "There are people who are very keen on BIM and sustainability. But how to put them together? It seems impossible!" (PM, public agency, FIN12) "We, as a mechanical designer, we do not have a partner to discuss our problems with and how we want to proceed. There is a gap of understanding when we are talking to each other. Of course, because we are at the bottom of the food chain in the project, it is a hard task for us because nobody can understand us. Not in every project, but it has happened also that we are trying to say something, that we should go like this and nobody wants to listen to us and then they do how they want to do it and then we are in trouble afterwards." (BIM manager, HVAC, FIN11) "If you do BIM, it makes life easier for structural engineer, as he can read your data easier. And you question yourself, why should you do something for them? So, why should I make an investment if it goes over there and I do not benefit?!!" (Researcher, FIN01) "We have a collection of, let's say, independent actors who probably have slightly, overlapping interests. It is not about the creation of a building model for the end-customer for use to the end of the lifecycle. That's far from it." (Researcher, FIN19) "The designer and contractor should be friends, but the world it is not like so. The contractor wants to make money and the designer wants to make good buildings and there is always conflict." (BIM manager, HVAC, FIN11) ***Architects are afraid of losing power*** "I participated under the confidentiality agreement for the strategic agreement with some architectural associations, somewhere here in the early 80s. They got anxious about their role with this technology: is it beneficial to them or is it dangerous and so on. If there are any ways to benefit from this technology, companies usually do not do that, because they would rather stay in something they have always done. It takes a lot of courage to change how the system works." (Researcher, Fin18)
	Failure of value proposition articulation for the use of Building Information Models	***Clients fail to articulate value for the use of Building Information Models*** "Is there a value proposition? So, my question to the owners: where's the value? If I give an owner right now a full 3d model that has all the stuff in it, most of them don't know what to do with it anyway." (PM, sub-trade, CA21) ***Failure in value proposition leads to failure in value capture*** "If you don't understand what value is, you have no good measurement system, for the chances of giving them value are quite low. A lot of what is delivered today, its value, is accidental. And it's mostly because you have experienced people who are willing to trust each other. And you hear stories about this all the time. And we have plenty of examples in [the firm]; we've taken the same people and put them on the different projects, and they failed because the owner didn't know what she wanted or something happened or their partners were not there. […] Then we have many owners who ask to build the cheapest building possible. They don't even think about value, they can't describe what value means to them. So, we are responsible for including the customers we work for in every business." (Innovation manager, GC, CA11) ***Process of value articulation "THE WHY" is not well understood*** "I'm not saying that open standards are wrong, but they don't focus on the outcome. The owners have to focus on the outcome. Then the process will follow. Let's say

		"that everyone did it. But nothing changed. I am challenging you. Yes, saying let's say we did it, but the outcome stays exactly the same." (CEO, Ai start up, CA17) "If you include project delivery owners and stakeholders, clearly defining the value of the building, the value definition phase, I think that that's not really a well understood phase. The phase before the start of design is a phase of value definition, which is "why", what problem are we trying to solve, what do we want out of the building in the long term. There's this thing called value capture at the end, which is also not in a traditional thinking process, which is like you're looking backwards to the beginning of the project and asking: 'are we capturing the value?' […] all these phases, value definition and value capture, might help to identify the gap. Because the biggest rework cycles are driven by imperfections and failures to really identify the WHY of the project." (PM, Health Care Client, CA08) ***The product has declined in value with every new wave of technology*** "The product of our design processes has not improved in the past 40 years and a strong argument can be made for the proposition that the product has actually declined in value with every new wave of technology, starting with using computer analysis for designing structures, because what used to be a thoughtful problem-solving process that resulted in well-thought-out constructible building details, became one of sticking something in the computer, slapping the numerical output on a drawing, and telling the contractor to deal with it." (Structural engineer, CEO, CA07)
	Established procurement models are the dark side of business models	***Unchanged procurement is the dark side of construction*** "It is really difficult to do on our industry; most clients do procurement in a traditional way and do not take any risks by changing the way they are procuring services. Procurement is a dark side. In my opinion, contracts are part of business models. Basically, contracts are defining legal obligations, payments, etc. you cannot separate completely. Procurement is a selection criterion for services, as well as a part of business models and a really-really important part of that." (Researcher_FIN20) "But when I look at, you know, how projects are procured. Those things have evolved slower than others, than other innovations." (VDC manager, GC, CA01)
	Business models are location based	***Existing business models have systemic constraints of location*** "It is a part of system exploitation and business models. It is good to remember that there are no products where the price of the product would have anything to do with the production costs. Every product, the price for the phone is the willingness to pay. And the same with the houses, the price of the house has nothing to do with the production cost; it has everything to do with the market price. What people are willing to pay. With mobile phones, there is no such thing as the location for a phone; you buy phone because of the reputation and quality of the product, so these companies have to invest in innovation. But in the building industry, it is the quality of the product, as long as it is good enough to be bought. If you think about California, the houses cost several millions, but the quality was bad. Most of the houses were cardboard, it is crazy. But as long as clients are willing to pay the asking price, but you do not try to develop it better because it does not pay back. It is part of the ecosystem because it cannot be changed. No matter what we do. If you are able to reduce production costs you can save money and of course from the client side so that no big construction mistakes are made when you own the house, that, of course, the client wants to match the price with the product. Then, I do not think it is r**ealistic to think that the construction industry will ever be like a car manufacturer or mobile phone**. The situation is so different." (Researcher, FIN20) ***Business models are organised around the optimization of production costs*** "It is mainly the optimization of production costs. If you would like to make a better building, buyers will be interested so it will be easier to sell. The waiting time between when the product is ready and how long it takes to sell is an important part of the profit. The longer it is on your hands, the more money you lose. Basically, making the product better than the competition is making it possible to sell it. Then,

		reducing production costs directly affects your profit because the market price is not in your hands." (Researcher, FIN20)
	Established contractual relations	***Contractual relations are the status quo*** "Because of the contracts in construction, it is very difficult to align goals and benefits. […] I think it is the biggest problem, the contractual conditions. Personally, I have never seen any problem, which could not be solved by information technologies or even theoretically impossible. It would always be done. But changing the contractual relationship in the construction sector seems impossible because it has a huge tradition of status quo." (Researcher, FIN18) ***Disconnected contracts, process, and BIM use*** "Contracts are over there, what we do to build is here, and then we have BIM over here and they are not really connected." (Innovation Manager, GC, CA11_1) "The part of an agreement is that the architect has to supply the BIM model. And usually, the term BIM mode is dangerous. Anything can be a BIM model. Everybody can have their own BIM. So, we have to say IFC model compliant or compliant to anything else. It is not enough to say a BIM model; you have to be careful I am exporting a model. Anything I am exporting is a model. I can say that I am exporting a model." (Researcher, FIN01) "The contract models that we are using in our industries, they are both very bad for the collaboration." (Researcher, FIN20) "Alliance type of contracts are coming also to Finland. It is a reality. Again, to rely only on those new ties in contracts, it is too slow because they are such a small percentage. So, there should have been more of new contracts to change the processes. […] To gain real collaboration in a way that you are not just hiding behind your contracts. That's the key area." (Manager, HVAC, FIN10) "The current contracts don't really emphasize collaboration, so everything is fine as long as the project is going well. But, if there are any problems people should do extra work, and if not, they can hide behind their contracts. […] We, as building owners, suffer the most, because in the end we have to pay the bills and deliver a building. […] I think BIM has increased collaboration and increased the need for new contractual frameworks." (PM, public client, FIN15)
	Industry evolution, maturity and siloes	***Static nature of industry*** "Industry has been so static that many people do not have any experience in managing big changes. But in our industry, people are used to the situation, it does not change. And that is why they are afraid, and it is related to culture. It is human nature; most people like to stay in their comfort zone and keep things as they are. But if the changes are a normal part of the process, it will become normal." (Researcher, FIN20_1) "I am still a bit astonished about the construction sector, one of the things I have been trying to say is to start looking at these small residential buildings sector, but they say: 'No, No, it does not apply'. But I think it really, it does apply because then you are much closer to what you do in the engineering industries, you develop and make it better and better. And in the big residential projects you do not do that. They do not get better!" (Researcher, FIN19) ***Sector actors are in their siloes*** "Their construction guys are in their own silo, even though they have I mean, we service design and construction, but it's the same people all the way through." (CEO, structural engineering firm, CA07) "There are so many silos involved. You cannot change one, you have to change many, you have to change how people interact, how the information is shared, how the labour is divided between different players. You have to change the ecosystem more or less." (Engineer, vertically integrated firm, CA23)
Aggregate Dimension: System level		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**

Power of Received Traditions	*Cultural barrier to innovation*	***Culture is the biggest barrier to innovation*** "The culture of the industry is another dark side. People are not motivated or do not have the capabilities or desire." (Researcher, FIN20_1) "But the problem is the culture…. people don't want to change. [..].] the industry falls into a category of societal habits. […] I feel like that is why there's no innovation because we're in the parable of the cave." (CEO, Ai start up, CA17) "In my experience, the biggest problem is not a technical one but more of a cultural one. There is sort of established norms on how people work, and people are so used to it and it is so ingrained that people do not question it anymore. I think that is a big barrier to innovation." (Optimisation engineer, vertically integrated firm, CA23) "It is not the question of technology or money; it is all about people." (Consultant, CA13) "This biggest challenge that we have, beyond the technical aspects, is changing people's attitude and culture on how we do things and getting people to really actually be open to doing things differently, not just default to doing them the same way that they always did." (Superintendent, GC, CA25) "Business culture is low. Culture and business processes have not been developed." (Consultant, FIN04) "This is more for people and culture, I think, not about the technology. The culture is that we do as we have done for 100 years." (PM, public client, FIN09) ***A culturally challenging industry and therefore financially challenging*** "Conservative attitude in the industry is very bad in the sense that most people want to see results. The attitude is let's see what happens; the construction industry has an attitude that it is the second mouse who is getting the cheese. There is a truth in that as there are a lot of companies that sit back and wait. It makes sense for them". (Researcher, FIN20_1) "Culturally challenging and therefore financially challenging." (CEO, start up, CA35). ***Conservative short-sighted industry and is trained in a very conservative way*** "Conservative industry and trained in a very conservative way. It is a very short-sighted industry. Not enough science-based decisions, very ad hoc solutions vs long term solutions." (CEO, technology firm, CA35) "I believe that it is because the construction sector and facility sector are so old fashioned. That is the reason." (Manager, HVAC, FIN10) ***People were neglected in the sector for a long time*** "The people, as part of construction, have been neglected for many, many years. And for many different reasons. One reason is that: 'hey, we help improve the skills, the capabilities, that skill of this guy, he is going to go with somebody else! Therefore, we don't invest in people.' And this is what I've seen for many years. I say we have to change this because all the time there is a focus on technology, technology and technology! A fool with the tool is still a fool, right?!" (Consultant, CA13)
	Fragmented established mindset is critical to innovation	***Established mindset for old ways of doing things*** "The culture of the industry is 'I have always done it and will continue doing it.'" (PM, software vendor, CA30) "People are used to bad business." (Researcher, CA37) "Everybody wanted to use BIM, but they want to use it exactly the way they had always worked." (CEO, GC, FIN07) "People who are making decisions, they are may be too old. What I can see is that youngsters want to use it, but they do not have the possibility of using the models and that is because of middle companies, middle bosses. They are so hard as they do not want to take on anything new to them. They want to make the same mistakes again and again." (BIM manager, HVAC, FIN11) ***Mindset is critical to evolution of the sector*** "It's like way too much focus, especially now with the development of all this technology, way too much focus on the technical, which we already have lots of

		technical development, not enough on the mindset. […] But the mindsets… they're very short in the mindsets… there's no role model, there's no leadership." (Consultant, CA13) "Understanding that the contract is not important; the mindset and behaviours are important, and the collaboration is important." (CA11_1 manager) "At the end, it is about mindset and culture. Am I only going for the money regardless of the means or will I provide value for the client and do I see the project as a whole or just part of it? There are different players; for example, [GC firm] always does what is right for the client. So, this mindset is happening more and more. IPD gives structures to embrace but a change in mindset is more important." (Innovation Manager, public agency, FIN21) ***Mental model or mindset is established to view elements separately*** "I think that one of the worst mindsets that we have in construction has been inherited from project to project, from generation to generation and is the mindset of fighting fires. […] they are very short in the mindsets…there's no leadership, there's no role modelling, right? The mindset says […] you have to suffer and to sweat blood, because we don't learn from project to project […] each project is unique […]. And, I think that one of the worst mindsets that we have in construction is this has been inherited from project to project, from generation to generation, and is the mindset of fighting fires, right? We have to be busy all the time, and being busy doesn't mean that you're productive, or that you're efficient. […] We have to move from the fighting fires mindset to the look-ahead mindset." (Consultant, CA13) "The view in the industry, including here in this company, is fragmented". (Innovation Manager, GC, CA11) ***Established mindset of a risk transfer attitude*** "The other problem is the transferring of risk. When I transfer risk as an owner, I have the false sense that risk is not going to come back to me. We keep playing ping-pong with risk." (Consultant, CA13) ***No one in the supply chain fully understands the process*** "I have never met anyone in our industry who would understand the whole process from all participants' viewpoints. It is very difficult to gain that knowledge. And it is amazingly usual that very competent and experienced people in our industry have very little knowledge about how others are using the information that they are producing." (Researcher, FIN20) ***Individuals are more preoccupied with immediate benefit than long term investment*** "It is a very short-sighted industry." (CEO, start up, CA35) "We are very practical and very technical in construction. That is perhaps the reason we have been able to get results very fast." (Consultant, CA04) ***Project manager driven or product driven?*** "Project mindset vs product mindset. In a product mindset it is about retaining knowledge and generating automation. Project centric means they create a lot of files, it is like in Hollywood, people come together to create a movie and then the team disbanded and created a new one to create a new movie." (CEO, technology firm, CA35) "I think a lot of challenges implementing BIM have to do with focusing on a project rather than a product/ solution." (Researcher, FIN19) ***SMEs do not want to grow*** "Companies want to stay small and family-oriented; they do not want to grow." (CEO, technology firm, CA35)
	Established accepted norms of practice	***The fish is the last on to discover the water*** **"The fish are the last to discover water.** […] Well, it's your environment, it's your environment. It's the way things are. So, what does fish know about water? Exactly right now, we take the air for granted if the air disappeared, we would die quickly just like the fish. […] Now this you know, this has lots of problems, but you never have enough time to figure that out because you're always caught up swimming in

		this fishbowl. Now we're saying, 'This would be a better fishbowl, would be a perfect fishbowl?' No!" (Innovation manager, general contractor, CA11) ***Established norms that people do not question anymore*** "If you're just used to doing things one way and that ways been taught to you in a university or college and in practice, and this is what you've been doing for most your career, why would you think of anything? Why would you question the practice that you have been taught and have been doing most of your career?" (Innovation manager, general contractor, CA11) "There's no innovation because we're in the Plato's parable of the cave." (CEO, start up, CA17)
	Systemic mistrust	***Mistrust by clients of the sector*** "Clients do not believe that it is the best solution to hire the same team over and over again. They are afraid that if you are familiar with this engineer, you would be teaming against them. […] I worked in the industry for 20 years and I never had the situation when I worked with the same team. It is always starting from scratch. It is deeply inbuilt mistrust; if those guys know each other, they will play against me. There should be some reasons which are difficult to prove because no one says, and perhaps they want to keep options open, so their hands are not tight." (Researcher, FIN20_1) "[The client] said, I have all these bills. I don't know if these guys are lying to me or not. I don't know if these guys have done the work that they are claiming to have done in the bills or not. So, if you could tell me precisely if these guys have done that work, I'd be very happy." (CEO, start up, CA16) ***Trust is key to innovation*** "I told you earlier that the key to innovation is trust?! I trust him to do the right thing. He trusts me to do the right thing. And therefore, we get the job done. […] Most engineers will not communicate with you. You're going to do it my way or else that's it." (CEO, structural engineering firm, CA07)
	Business culture is low	***Business culture is very low*** "Market is very fragmented, it is local, the level of technology use, the culture of the business is very low. You have said people are very keen on technology in Finland, they are but the culture of the construction industry is to make as cheap as possible and as traditional as possible. 'If I do not need to change anything, then I am happy'. So, fragmented market and culture of the business area." (Researcher, FIN12) ***People are used to bad business*** "Software market is not a real problem, but people use it as an excuse because they got used to bad business, an excuse for not doing it, making money from change orders." (Researcher, CA38)
Aggregate Dimension: System level		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
Complementors of the Sector	*Need for inter-stakeholder and inter-industry collaboration*	***Need for inter-stakeholder and inter-industry collaboration*** "It's all about how government and business and academia sort of triangulate on the issues and cooperate and also share information. […] Improving the areas of inefficiency caused by a lack of collaboration or poor collaboration, is where much of the improvement will be. And this in itself requires collaboration work to improve. We need to be educating and developing professionals in every category of the building industry with this collaborative vision and ability." (CEO, architectural firm, CA24) "Smart cities require smart buildings, but smart buildings require smart cities. It is a chicken and egg problem." (CEO, start up, CA35)
	Traditional education defects mindset	***People are educated in silos, but academia have started to open to multidisciplinary*** "Trust in construction in Finland is on a much higher level than anywhere else but still there seems to be mistrust. Silos come from education which creates mistrust." (Researcher, FIN20)

		Conservative industry and trained in a very conservative way "It is a chicken and egg problem: education defects the mindset of the sector and the sector does not use education to push the boundaries of what is possible. […] Conservative sector and is trained in a very conservative way". (CEO, start up, CA35) "The people on the construction site, they have a technical education." (Site Manager, GC, FIN06) ***Little innovative work is coming from academia*** "So few good papers are published from academia, so little innovative work coming from academia. If you look at most work, it is volumetric. A lot of surveys with anecdotal data from someone else who was a postdoc as an independent work. There is nothing created in academia with new knowledge that we could use in the industry, for example. Nothing I see is new; it is the same in Stanford and Berkeley." (CEO, technology firm, CA35) ***Chicken and egg problem: Education defects the mindset of industry and industry does not use education to push the boundaries of what is possible*** "I would say is that they are not using education to push the limits of what's possible; unfortunately, education defects the mindset of all people in the industry, it is chicken and egg problem again. I would say people are smart and skilled in the industry, but they are not applying to push the boundaries in the hard way, and honestly they need more people like me to push the boundaries, they need more cross pollination. And we need more open-minded thinking. Everyone including the owners." (CEO, technology firm, CA35) ***Education is key*** "I do believe, especially after all those years, that education is key. You need to train a new generation with a new way of thinking. When I was younger, I heard this wisdom from older people: bullshit, we can do things faster. It takes so much time to train a young generation. But when you look how things have gone wrong, I think it is important to train and educate a young generation with a new way of thinking. If you imagine a University becoming significant player in BIM education, can you think of any university that exists on this planet? I do not know any. You cannot get quality education on BIM." (Researcher, FIN18) "Educational background of my employees was not so high. I had only 3 people with a master's degree; one in marketing, two in business. When you think about the educational level, they never understood me when I was talking about the business concept, its development and so on. This is one of the challenges, we have to change business management thinking." (CEO, public agency, FIN14) ***Many of the people within the schools have been trained in the past*** "The people within the schools have been trained in the past. […] it's hard when educators are equally afraid of innovation as everyone else". (CEO, Ai start up, CA17) ***Academic research does not provide quality papers or fundamentally new ideas*** "“So, few good papers are published from academia, so little innovative work coming from academia. If you look at most work, it is pretty volumetric. A lot of surveys with anecdotal data from someone else who was a postdoc as an independent work. There is nothing created in academia with new knowledge that we could use in the industry, for example. Nothing I see is new; it is the same in Stanford and Berkeley." (CEO, start-up firm, CA35) ***New generation reinvents what was already created or lost*** "New generation comes and reinvents what was already done and this also happens a lot in research, and even organisations as [a designated funding agency] falls into this trap. They give money to people to redo what others have done before. The European Commission also does the same. […] I have not seen anything new." (Researcher, FIN18) "Knowledge is destroyed and rebuilt each time." (CEO, start up, CA35)

		“We have also lost a lot of knowledge along the way.” (CEO, structural engineering firm, CA07)
	Software vendors	***Software vendors lock-in users to preserve control*** “There are some drivers against it; market-leading information technologies companies do not want their customers to change a system, because all of this work is locked into a specific system, so you do not see these software companies, like Autodesk, as supporters of interoperability”. (Researcher, FIN18) ***Selfish interest of the software vendor to make money*** “I agree that the software can be a strategic player, but when it comes down it, wants to make money.” (CEO, Ai start up, CA17) ***Software vendors use marketing power to define the value proposition with the use of BIM*** “Maybe, academics and the industry should stop listening to software vendors and make a big revision of what BIM is. But I guess practitioners are not ready to listen to this from me or anyone else. The problem, as I see it, is the influence that the software vendors have had and are having in defining what BIM is and how it should be used, both at the academic level, but also, and maybe mainly at the practitioner level. […] When this is the case, I believe then, that something is going wrong.” (VDC Manager, GC, CA11_1)
	Low diversity	***Low diversity in ideas. Need for more outsiders to cross-pollinate*** “People need outsiders and diversity, more cross pollination. An open mindset and not just for the industry but for owners too. Silicon Valley is a microcosm. There is small cross pollination. There are a few start-ups, but they are small. We need more. And it takes time.” (CEO, technology firm, CA35) ***Built Environment is a closed group*** “Actually, the Built Environment sector in Finland and has been quite a closed group in a way that it is difficult for outsiders to come in. If you want to come in and disrupt things differently it has been very difficult. Established companies keep boundaries really strict and they traditionally have been hiring only people from certain degrees and universities and not people from outside areas. It has been a closed community and I have heard that from others too. But now things are changing a little bit. When industry is so closed and with few players, the market is not working as it should be.” (Manager, Innovator, Fin21)
	Potential disruption from the outside	***The rules that change has to come from the outside*** “The disruption, whatever it is, the rules that change has to come from the outside, because, you know, going back to this idea of received traditions, or how we learn to do something. How do you take years of training or years of these operational models and say, wait a second, I don't have to do it this way?” (PM, software vendor, CA30) “I see too little organized innovation taking place within the industry. Tools and information management have evolved profoundly over the last 10 to 15 years, but business processes have remained the same. That leaves doors wide open for outsiders to radically change the business.” (Metsi, 2018) ***Industry on its own is not able to change*** “It's all about how the government and business and academia sort of triangulate on the issues and cooperate and also share information.” (CEO, architectural firm, CA24) “Now, from our side, we are pulling it as best as we can, but I think it would go a little bit faster if the government were pushing or pulling. It is people not money.” (PM, public client, FIN09) “We are now at a level that we cannot evolve more, in my opinion. We need the government for that.” (BIM manager, HVAC, FIN11)
Aggregate Dimension: System level		
Aggregated Themes	**Second-Order Categories**	**Selected Evidence on First-Order Categories**
	Uber	***What are the business drivers of Uber?***

Intervi-wees' Suggestions to Compare the Built Environment Sector to Other Sectors		"What is the key driver for Uber? You should study that. Do not have answer for you, but they give services to users like better quality, cheaper. You can use it easily. It is value for money. You are at the top of the value chain and your business model is scalable. Where was it created? I think it was in San Francisco. It is scalable; you can do it in SF and Helsinki. Where is the scalability of local construction process? What are the key answers? **Customer value – they will pay everything + Scalability. When you are doing the doctoral thesis, I would strongly recommend you compare other business areas. And Uber is an excellent example.** Very traditional business, all over the world, very regulated and when you look at other areas, you can find thousands of those. Then, when you have a little bit of imagination, you can think about similar cases in construction as drivers." (Manager, TEKES, FIN12) ***Why didn't taxi companies invent Uber? It's because they didn't have an incentive to invent Uber!*** "You just have to know why taxi companies didn't invent Uber, it's because they didn't have an incentive to invent Uber. […] what Uber is doing, which is having a software active to dominate a car, is not a complicated strategic idea". (CEO, VIF, CA32) "Look at Uber, they just kind of moved into cities with their lawyers and they said, we don't do medallions, we don't need to follow the rules because of XYZ. So, it's not like, you know, taxi companies were under threat from another taxi company; they're under threat from something completely different". (Manager, Software Vendor, CA30)
	Toyota	"When I visited Toyota, there used to be a big Toyota factory over here, close by, but now makes Tesla's. And the problem with Tesla's is they can't produce cars like Toyota can; they can't actually build them, the quality cars fast enough, because they do not understand this stuff. […] **This industry has a long way to go to reach Toyota's level of collaboration, but they do it with partners**. But the interesting thing about Toyota was that they were open to receive visitors from Ford, Chrysler. All their competitors got to see what Toyota was doing, but their competitors had the fish problem. They came and saw what Toyota was doing, […] but they literally didn't believe what they saw, because they knew it couldn't be true. They were like the fish. They just, they could not understand anything other than the environment they were in. There was no other way to build cars than to have a giant factory. […] So they saw the factory the first time, several times and they couldn't believe it. That just can't be true because they only have their reality. That's true of all humans and fish". (Innovation manager, GC, CA11)
	General Motors	"You have to have a financial business deal that supports teams working in the interests of the project, the team needs to know that they are collectively at risk. […] Everyone has the same story. I tried to do it without that [business deal]. And then I had projects that kept failing. I think General Motors has been through the same thing, I think [client] as well. […] they need to be incentivized to work together to make the project well […] but the business deal still doesn't make it all work and just creates an environment in which everything else seems to make sense to everybody because, in order to win, you need these other things. But if you don't have that, it's all about intent and goodwill and intention, which when a project hits, and hits really hard, there is a very high risk of just falling apart and everybody will default to "I got to save my own company". (PM, Health Care Client, CA08))
	Semiconduct or	"30 years ago, chip design was similar to the building sector in the sense that many teams were involved in designing all kinds of the chips. […] and they all had their own tools, and they did their own thing. Again, in the end, the chip was put together. The particular thing about chip design is that, once it is designed, think of it as it goes to the oven; the outcomes are either it is working or an inexpensive piece of glass. It was very hard to design a chip that worked first time, and that also coupled with how costly it was to design something new, you had to stop the whole factory to try the new thing. The chip these days costs like 2 billion. So, if you don't use it for a week, that's a tremendous amount of your resources. They were forced to rethink, and they

		were forced to go out of their silo environment where everyone was used to their own thing and throwing things over at each other. Construction these days is about throwing it all over the wall.” (Engineer, vertically integrated firm, CA23)
	Manufacturing	“In your research, you could ask a question: What if manufacturers had to make a building, how would they make them? Because now they just make pieces of the building. What if they made the entire building? How would they change the entire ecosystem?” (CEO, Ai start up, CA17)