THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

The emergence of innovation ecosystems: Exploring the role of the keystone firm

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Abstract

During periods of technological change, firms seek new collaborations and sometimes even reach out to competitors in order to obtain new resources and competences. Understanding the collaborations surrounding new technologies has implications for firms pursuing opportunities with new technologies. The notion of ecosystems is increasingly used in literature to address value creation activities involving a network of firms. The purpose of this licentiate thesis is to understand the emergence of new innovation ecosystems. Previous research on ecosystems recognizes "keystone" firm as the anchor that ensure growth and stability in the ecosystem. However, the activities that foreshadow the development of an ecosystem and the role played by a prospective keystone firm in the emergence of an ecosystem is undertheorized.

Based on a longitudinal case study of a technology development program at an automotive firm, the findings presented in this licentiate thesis show how the joint venture established by the incumbent firm led to the development of a modular technology. The main findings illustrate how the incumbent automotive firm attracted a network of actors that develop innovative solutions and other complementarities for the technology. The network of actors developing offerings for the modular technology, in turn, facilitated the incumbent firm to position itself as a keystone firm and orchestrate the emergence of a new innovation ecosystem. The thesis contributes to theory by showing how a firm can orchestrate the emergence of an innovation ecosystem and position itself as the keystone firm.

Keywords: Technology, innovation, ecosystem, dominant design, autonomous cars

List of appended papers

Paper I

Pushpananthan G. and Elmquist M., Lindlöf L. (2018). The transformation of the automotive firm in the age of automation, *EURAM conference, June 19-22, 2018, Reykjavik, Iceland*.

Paper II

Soderqvist J.B. and Pushpananthan G. (2019). The blind leading the mute: Formal leaders' potential to facilitate institutionalization of the agile myth, *EURAM conference 2019, June 26-28, 2019, Lisbon, Portugal.*

Paper III

Pushpananthan G., Lindlöf L. and Rothoff M. (2019). Role of tactics in R&D projects, *R&D Management conference, June 17 -21, 2019, Paris, France*

Paper IV

Pushpananthan G., Elmquist M. (2019) From a joint venture to an innovation ecosystem: Lessons from a longitudinal study of an autonomous car project. *Manuscript submitted to an international journal.*

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Table of Contents

1. INTRODUCTION

1.1. SETTING THE SCENE

Over the past decade, technology has advanced at a rapid pace resulting in automation and digitalization of industries. This dynamic environment, characterized by fast changes in technology, has created a need to revisit established theories on value creation and explore how firms in today's digital economy establish competitive advantage during times of technological change. The most habitual question in strategy and management literature has been about how firms compete when new technologies emerge? Some technologies immediately substitute the existing technology while others may take decades to become mainstream. The pace of substitution, depending on various factors, differs greatly (Anderson *et al.*, 1990). A number of seminal works have shown that new technologies alter the competitive landscape, leading to the entry of new firms in an industry (Schumpeter, 1942; Teece *et al.*, 1997). When new technologies and competition enter an industry, established firms (incumbents) struggle to survive which often lead to waves of creative destruction in the market (Adner *et al.*, 2016; Schumpeter, 1942; Tripsas, 1997) (e.g., Kodak disrupted by digital photography; (Vecchiato, 2017)). Interestingly, during such technology shifts, some incumbents survive and prosper whilst others fail (Tripsas, 1997). Amongst the survivors, few are quick to leverage the new technology to regain leadership position whist others take years or decades to gain dominance in the new technology (e.g., Apple gaining leadership in smartphone and PC industry from the verge of bankruptcy). Thus, incumbent firms have both succeeded and failed during times of technological change. In literature, technology is often cited to be a major reason for the success and failure of firms. Whilst a shift in the technological landscape often leads to shake-outs in an industry, the reason for incumbents' failure is much broader than just the technology per se. The lack of foresight, unwillingness to share profits, path dependence etc. have been attributed as reasons for the failure of incumbents (e.g., (Anderson *et al.*, 1990; Suárez *et al.*, 1995; Teece *et al.*, 1997; Tripsas, 1997; Utterback, 1994).

Today, digital technology is altering the basic tenets of value creation as customers increasingly seek not just stand-alone products but also services that cater to their preferences. Internet and Communication technology (ICT) has broken down the barriers to compete as start-ups challenge industry leaders with radical innovation. This is evident at the success of multinationals – yesteryear start-ups – such as Amazon, Facebook, Tencent, Uber who dominate their respective industries and sometimes even carve out new industries. The establishment of new or hybrid industries is a result of the convergence of technologies in products and services. For example, combining digital technology and taxi business has resulted in ride sharing firms identified as belonging to both technology and transportation industries (e.g., Uber, Lyft, Grab, BlaBlaCar etc.). Further, digital technology has broken down the traditional industry barriers as products and services are increasingly created by an amalgamation of firms from different industries working together. Such inter-firm collaborations transgressing industry boundary(ies) and traditional value chain hierarchies are often addressed as *ecosystems* (Gawer *et al.*, 2002; Linden *et al.*, 2009). This is partly due to the non-hierarchical nature of value creation activities, organic development of mutually beneficial partnerships akin to biological ecosystems, and the interactions between firms with completely unrelated business areas (e.g., Amazon acquiring grocery store chain Whole Foods; Apple launching credit card service in partnership with Goldman Sachs. In line with this trend, Adner *et al.* (2016, p.626) argue that understanding technology transitions and the pace of substitution necessitates the "examination of interdependencies in the broader ecosystem of

components and complements in which the focal technologies are embedded". However, investigations on such ecosystems has not addressed the question on how ecosystems emerge, partly due the ex-post definition of the term ecosystem (Gawer *et al.*, 2014; Jacobides *et al.*, 2018).

1.2. PROBLEM AREA

In a constantly changing environment characterized by rapid advances in technology, firms actively seek new resources and competences to create value. Organizational studies discuss how firms create value by using new technologies, new materials and methods to deliver new products and services (Clarysse *et al.*, 2014). Value chain thinking suggests an ordered sequence of activities and has been useful to understand the functioning of traditional industries churning out physical products (Allee, 2000). It has also been useful in explaining the linkage of activities within an industry (Peppard *et al.*, 2006).

However, the value chain concept is becoming redundant due to the digitalization of products and services (Peppard *et al.*, 2006). Instead, the notion of "value networks" is gaining importance as it presents multidimensional linkages between actors who combine their skills and assets to create value (Adner *et al.*, 2010; Clarysse *et al.*, 2014; Galunic *et al.*, 2001). Previous literature on organizational capability has mainly focused on the internal organization perspective, but less on how firms can manage and organize their innovation processes by collaborating with other actors in a network. The article by Moore (1993) on "business ecosystems" was the starting point for a number of articles using the analogy of biological ecosystem to conceptualize value capture in a network. In this context, it is especially interesting to examine how (and when) ecosystems emerge during a period of technology transition in an industry.

During periods of technological change, firms seek new collaborations and sometimes even reach out to competitors in order to obtain new resources and competences (Furr *et al.*, 2018). Also, the existence of interdependencies between innovations has been well documented in literature (Adner *et al.*, 2016). Further, literature on ecosystem recognizes "keystone" firm as the anchor that ensure growth and stability in the ecosystem. However, the activities that foreshadow the development of an ecosystem and the role played by the prospective keystone firm in the emergence of an ecosystem is undertheorized in literature (Jacobides *et al.*, 2018).

1.3. PURPOSE AND RESEARCH QUESTIONS

In order to contribute to literature on ecosystems, this research looks into the automotive industry wherein a technology transition (i.e., Autonomous Drive) has drastically altered the competitive advantage. **The purpose of this licentiate thesis is to understand how an incumbent firm orchestrates the emergence of an ecosystem and positions itself as a keystone firm.** The findings presented in this thesis are a result of a longitudinal case study of an Autonomous Drive (AD) technology development program at Volvo Car Group (Henceforth addressed as Volvo). Additionally, the study elucidates the implications of such collaborative endeavors from the perspective of an incumbent firm. By illustrating the collaborations set up by the incumbent firm (Volvo), the thesis shows the transition in Volvo's role from being an OEM in a traditional value chain to a keystone firm in an emerging innovation ecosystem.

The thesis will address the following research questions:

RQ1: How does a new ecosystem emerge?

RQ2: How does a keystone firm orchestrate collaborations in an emerging ecosystem ?

2. EMPIRICAL CONTEXT

The aim of the licentiate study is to better understand the impact of new technology on traditional industries. For this, the automotive industry was selected as appropriate to understand the impact of a new technology. The area of autonomous driving in particular, was identified as an appropriate empirical context to investigate the aforementioned research questions. In this chapter the developments of the industry will be summarized.

2.1. THE AUTOMOTIVE INDUSTRY

From carts and carriages pulled by animals to vehicles that drive themselves, the mode of transportation has seen massive transformations. Cars, in particular, have developed from being a luxury to being a basic necessity for most people. Yet, the evolution of the industry prior to the digital era is nothing compared to the rapid advancements taking place in the industry today. Recent trends in electrification, ride sharing and autonomous drive has drastically altered the competitive landscape of the industry (Lee *et al.*, 2016; Pelliccione *et al.*, 2017; Thomopoulos *et al.*, 2015).

Due to the increase in the amount of digital features in modern vehicles, competences and resources outside the OEMs' traditional value chain are critical (Bimbraw, 2015; Lee *et al.*, 2016; Mondragon *et al.*, 2007). This entails that cars are becoming complex product systems encompassing advanced software along with hardware (Burke *et al.*, 2004; Pelliccione *et al.*, 2017). The increase in the amount of embedded systems in modern vehicles coupled with advancement in internet and communication technology (ICT) has drastically shifted the innovation landscape (Mondragon *et al.*, 2007; Pretschner *et al.*, 2007; Townsend *et al.*, 2014). The automotive industry is now approaching the next major transformation: autonomous driving – propelled by an integrated interplay of both market and technology factors (Pinch *et al.*, 1987).

2.2. AUTONOMOUS DRIVE: WHAT IS IT?

The autonomous car (also known as a driverless car, a robotic car or a self-driving car) is a technological system that needs to sense the environment, detect the position of vehicle of the road, and make decisions on how to manoever the vehicle in a given situation (www.bosch.com). These vehicles rely on software to bridge the gap between sensor physics and the mechanical actuation of the vehicles (e.g., steering and brakes). The vehicle operates by using data from different sensors like radars, cameras and lidars which is then processed by algorithms to precisely compute the position, orientation etc. An autonomous car is thus a complex technological system combining multiple sub-systems that handle perception, decision making, and operation of the vehicle.

In the industry and in media, driverless technology is commonly addressed by many different terms, such as autonomous driving system, self-driving car technology, autonomous car

technology, autonomous vehicles, etc. For consistency and clarity, this thesis will address this technological system as Autonomous Drive (AD) technology. Autonomous vehicles have the potential to transform the entire automotive industry and alter much of today's transport infrastructure (Greenblatt *et al.*, 2015; Lee *et al.*, 2016). Still, standardization and established domain design provide a hurdle for the adoption of AD technology (Abernathy *et al.*, 1978; Anderson *et al.*, 1990). New technologies need a standard or dominant design that allows for widespread adoption (Brem *et al.*, 2016). The AD technology is increasingly developed outside the OEM's value chain and the established firms need to interact with actors outside the industry to access necessary resources and competences.

To summarize, the setting of the development of the AD technology in the automotive industry is considered a suitable case to study emerging innovation ecosystems. It remains to be seen how these developments will evolve and if the incumbent automotive firms will retain their current dominance in the industry.

2.3. VOLVO'S AD PROGRAM

Volvo Car Group is a Swedish car manufacturer that is considered one of the market leaders in the area of safety (Liu et al., 2004). In recent years, Volvo has expressed interest in developing AD and has invested hugely in its AD program[1] (VolvoCars, 2019). Volvo's strong safety and Advanced Driver Assistance Systems (ADAS) record makes development of AD technology a natural step for the firm. Due to the inherent complexity in developing autonomous cars, Volvo established several collaborations in the area of AD and the partners include many non-automotive firms. The main purpose of the AD program is to develop AD technology alongside the software and hardware systems required to produce a fully autonomous car. Volvo's AD program is based on three main sub-projects: the Drive Me project (a research initiative); Zenuity (a JV with Veoneer,) and the Uber project (redundant car platform). Drive Me involves several research platforms with various partner organizations (Victor *et al.*, 2017).

The software development is handled by Zenuity, a new entrant in the industry created as a joint venture between Volvo and Veoneer (previously a part of Autoliv) (VolvoCars, 2017a). Zenuity develops ADAS and AD software solutions for Volvo's AD program. Veoneer is a major automotive supplier with expertise in the area of automotive safety and production of seatbelts, airbags, collision avoidance systems, etc. Both Volvo and Veoneer have transferred their intellectual property on 'Advanced Driver Assistance Systems' (ADAS), know-how and personnel to the joint venture firm 'Zenuity' (VolvoCars, 2017a). Despite the shared ownership and assets, Zenuity is an independent firm and positions itself as an AD and ADAS software supplier (Zenuity, 2018). The AD and ADAS software solutions were developed in close collaboration with Volvo and are commercialized through Veoneer.

Volvo set up a collaboration with Uber, a global leader in the ridesharing business to develop base vehicles with latest technologies necessary for a fully autonomous cars (VolvoCars, 2016, 2017b). According to the CEO of Volvo, the Uber partnership is in line with Volvo's intention to be a supplier of AD ride-sharing services globally (VolvoCars, 2017b). The CEO believes

[1] AD program began as an internal project at Volvo. Later, it was reorganized into a program

that the alliance with Uber positions Volvo at the heart of the technological revolution taking place in the automotive industry (VolvoCars, 2016).

Apart from Volvo and Zenuity, several other actors such as Chalmers University, Autoliv, City of Gothenburg, Lindholmen Science Park etc. are involved in the Drive Me project. Thus, much of the innovation activity in developing autonomous drive technology is taking place outside of Volvo in a collaborative set up. The thesis is based upon research carried out at Volvo Car group. Findings pertaining to the AD program and references to Zenuity, Uber and other actors are based upon insights gained from the research carried out at Volvo's autonomous drive program.

3. THEORETICAL FRAMEWORK

This section contains a review of literature on innovation and ecosystem. The first part provides a general overview on technology and innovation in order to position the research context (i.e., technology transition in mature industries). This is followed by details regarding previous research on value networks and ecosystems where the thesis makes contributions.

3.1. TECHNOLOGICAL CHANGE AND INNOVATION

Innovation shapes the industries and determines the future of firms (J. M. Utterback, 1994) and is the most sought-after activity by firms in order to sustain their competitive advantage and technology is a key factor in innovation success. The knowledge economy and rapid advancements in technology has reiterated the urgency and need for innovation as it is central to firm competitiveness (Lawson *et al.*, 2001). Yet, very few large firms have been successful in carrying out innovation that are disruptive or radical in nature. Non-incremental innovation, the one that is considered to be quintessential for long term survival has been a conundrum for large firms as startups over the past decade have been successful at challenging large established firms in ways that have been never seen before (Latzer, 2009).

In today's competitive environment, leaders and managers are driving to build organizational capabilities to engage in innovative endeavors (Teece *et al.*, 1994). Large firms possess the resources and capabilities that are one of the greatest constraints for startups and small firms but there seems to be little evidence of positive relationship between R&D intensity and successful innovation (Klepper, 2002; Lee *et al.*, 2001; Tripsas, 1997). Interestingly, large firms' existing customer base makes them reluctant to undertake radical innovation that can cannibalize on existing customer bases and revenues (Govindarajan *et al.*, 2005; Tripsas, 1997). However, in today's digital world, the need to innovate – *not just occasional or incremental* – but systematic, continuous and radical innovation with a solid success rate is quintessential for survival (Lawson & Samson, 2001). Technological change underpins the innovation trajectory and serves as both creative and destructive force in the survival of firms (Utterback, 2004).

Explaining the dynamics of technological change is an important aspect of technology strategy literature (Adner *et al.*, 2016). The technology S-curve is an undisputed representation of both technology life cycle and competition between technologies (Adner *et al.*, 2016; Christensen *et al.*, 1995; Utterback, 1994). Contrary to previous knowledge that new technology becomes mainstream when it posits superior performance, Christensen *et al.* (1995) illustrated that technology transition can take place even when the performance of the new technology is inferior to the old. He argued that if established firms over-served on the main performance dimension, users who expect performance on other dimensions may embrace a new technology

even if it is inferior (to existing technology) along the main performance dimension. Interestingly, (Adner *et al.*, 2016) points out that literature on technology strategy focus on the supply side (i.e., firms developing the technology) and diffusion of innovation literature on the demand side (i.e., user adopting a technology). A deeper understanding of technological change however demands a holistic understanding that links technology evolution and technology adoption. Technology is often packaged in a system or a product and consumers assess the performance of the entire system rather than independent technologies (Adner *et al.*, 2016). Thus, in order to create value, firms must focus not just on the performance of the focal technology but on the entire system. Adner *et al.* (2010) opine that firms strive to be first movers with new technologies in order to establish a competitive advantage. However, to be technology leaders and introduce new innovation, a firm needs support from other actors to develop interdependent innovations Adner *et al.* (2010).

3.2. THE DOMINANT DESIGN BATTLE

Along with technology, markets play an equally important role, one good example is the QWERTY keyboard[2] standard which is indomitable due to its high market penetrations (David, 1985). The invasion of new technologies follows a predictable trajectory, through a process of variation, selection and retention(Nelson *et al.*, 2005; Pinch *et al.*, 1987). Initially, an established technology usually offers better performance (or lower cost or both) than an invading technology. However, if the invading technology has any merit, it rapidly develops and attains better performance than the established technology which by now has entered a stage of slow, incremental improvements (Christensen *et al.*, 1995; Utterback, 1994). Nevertheless, new technologies do not always obscure old technology and in certain cases, both technologies become stronger thereby rendering a symbiotic relationship (J. Utterback, 2004). For example, 'shaving blades and electric razors' or 'DVDs and movies in theatres', both remain successful and also complement each other (Utterback, 2004).

Technological discontinuity initiates an era of ferment leading to intense competition amongst the variations leading to the selection of a dominant configuration (Anderson *et al.*, 1990). During this phase, a dominant design is not yet established and marks the beginning of a new innovation S-curve. After intense competition, a dominant design is established by the early majority in order to overcome technical obstacles and facilitate commercialization. The established dominant design then becomes the standard architecture over which incremental improvements are made until another discontinuous technology leads to a new cycle of variation, selection and retention. The emergence of a dominant design paradigm signals the acceptance of agreed upon standards and these remain intact until overturned by a new design (Teece, 1986). For example, the wireless inductive charging technology for mobile devices had two technical designs, 'PMA' by Powermat Technologies and 'Qi' by Wireless Power Consortium (WPC). When the two leading mobile handset manufactures Apple and Samsung adopted Qi technology, it became the dominant design for inductive charging in the industry. Eventually, Powermat abandoned 'PMA' and joined together with WPC to promote the 'Qi' technology as the industry standard for wireless inductive charging. New technology thus initiates a period of intense competition and collaboration between firms in order to establish a dominant design. During this period, firms seek new ways to create value using the new technology.

[2] The survival of QWERTY keyboard is largely due to the "presence of strong technical interrelatedness, scale economics and irreversibilities due to learning and habituation" (David, 1985, p. 336).

3.3. VALUE CREATION IN NETWORKS

In a knowledge economy, the most pertinent question is perhaps to ask, how is value created? Normann *et al.* (1993) describe strategy as the art of creating value. Strategic activities involve the way in which a company links together its resources and competences to create value for its customers. Value chain thinking has been the most useful way to understand the value creation activities in traditional industries churning out physical products (Allee, 2000). The concept of value chain is useful to understand the linkage of activities within an industry (Peppard *et al.*, 2006). According to traditional models of industrial economy, every firm positions itself in a value chain with supplier providing inputs to firms downstream who then combine these inputs and pass it to next actors in the chain, either businesses or end customers (Normann *et al.*, 1993). In today's digital economy, however, the concept of value chain is becoming redundant due to the digitalization of products and services (Peppard & Rylander, 2006). The value chain approach presents little distinction between the actors in terms of their relationship with the focal firm (Adner *et al.*, 2010a). The importance of an actor with high bargaining power over a focal firm's ability to capture value do not change based on its position as a complementor, buyer or supplier. With advancements in internet and communication technologies (ICT), the physical dimension of the value chain is losing its relevance in modern industries. Thus, the traditional methods of analyzing competitive advantage (Porter, 1980), need to be revisited due to the emergence of the network economy.

In today's digital age, the creation of a superior product spreads beyond the boundaries of the lead firm (Linden *et al.*, 2009). The value chain approach suggests ordered sequence of activities whereas a network presents multidimensional linkages (Adner *et al.*, 2010; Peltoniemi, 2004). In a value network, value is created by a group of firms combining their skills and assets leading to the recombination of capabilities in the network (Clarysse *et al.*, 2014; Galunic *et al.*, 2001). The notion of networks is central to innovation and dates back to Schumpeter who argued that innovation arises from new combinations of ideas (Dodgson et al., 2013). An innovative idea starts out as a set of connections between neurons within the brain (Dodgson *et al.*, 2013) and a network of interconnected ideas manifesting into an innovation. Networks of people, firms, clusters and regions have been used as an analogy to advance the understanding of innovation. According to (Dodgson *et al.*, 2013) , "A network is any system that can be described by a set of things or actors, and the connections between them".

A value network extends beyond just transactions around goods, services, and revenue. The strength of the value network exists in the interactions between the actors (Aarikka-Stenroos *et al.*, 2017; Allee, 2000; Peppard *et al.*, 2006; Verna, 2008). It enables exchange of tacit and explicit knowledge, technical know-how, policy development, process and product knowledge etc. In a value network, a clear understanding of the expectations by each network member is crucial (Peppard *et al.*, 2006). According to Allee (2000), "A value network generates economic value through complex dynamic exchanges between one or more enterprises, its customers, suppliers, strategic partners, and the community". The participants of a value network can be identified from the standpoint of the focal firm, wherein all actors who influence the value delivered by the focal firm to the end customer are active members of the value network. Networks can have a multitude of meanings and definition. Value network is perhaps a way to envisage how value is created by multiple firms working together.

During turbulent market environment, firms seek new ways of collaborations with unlikely partners in order to sustain their competitive advantage (Furr *et al.*, 2018). Firms refrain from developing new products and services alone when there is uncertainty in the market due to new

technologies (Furr *et al.*, 2018). They instead try to engage with many partners in order to share resources and competences. This set up where multiple firms or actors collaborate together to develop value is often referred to as an ecosystem. Further, (Clarysse *et al.*, 2014) describe that the ecosystem construct is embedded in the idea of value networks.

3.4. THE ECOSYSTEM CONSTRUCT

The ecosystem approach was originally adapted from biology to the business context by (Moore, 1993) to illustrate a business ecosystem as network of actors characterized by interdependence and co-evolution. Two decades later, the use of the term in the field of management has proliferated (Scaringella *et al.*, 2018). An ecosystem consists of network of individual firms contributing their individual solutions to a common platform (or value proposition) in order to offer a complex value proposition (Adner *et al.*, 2010; Clarysse *et al.*, 2014). To create value to end customer, an ecosystem integrates complementary solutions developed by interconnected, yet independent actors (Dattée *et al.*, 2018). Today, the term 'ecosystem' has gained attention in research fields such as strategic management (Adner, 2017; Adner *et al.*, 2010; Jacobides *et al.*, 2018; Teece, 2007; Zhang *et al.*, 2007) and innovation management (Clarysse *et al.*, 2014; Gawer *et al.*, 2014). The concept of "ecosystem" has flourished in management and marketing literature (Aarikka-Stenroos *et al.*, 2017) with new conceptualizations such as "innovation ecosystem" (Adner *et al.*, 2010), "platform ecosystem" (Ceccagnoli *et al.*, 2012; Gawer *et al.*, 2014), "knowledge ecosystem" , and "entrepreneurial ecosystem"

Increasingly, management literature is also addressing value creation in the context of ecosystems (Adner *et al.*, 2016; Clarysse *et al.*, 2014; Dattée *et al.*, 2018; Jacobides *et al.*, 2018), thereby shifting away from the context of bilateral partnerships (Dodgson *et al.*, 2013; Madhok *et al.*, 1998; Teece, 1986). The strategy literature has predominantly focused on value capture and the firm's ability to establish competitive advantage by deploying its resources and competences and maintaining high bargaining power (Danneels, 2002; Teece *et al.*, 1997). This literature addresses the various roles played by firms in the value chain paying attention to the distinctions between focal firm, supplier, complementors, buyers etc. (Adner *et al.*, 2010). However, the bargaining power of a partner (a complementor, buyer or supplier) over the focal firm's ability to capture value is not analyzed as having an impact. The value capture potential of each actor, be it a supplier, buyer or complementor, is an important aspect of an ecosystem.

The ecosystem mode of operation replaces the ill-effects of vertical integration, hierarchy and direct control (Williamson *et al.*, 2012). According to Adner *et al.* (2010), although value chain suggests interlinks between various firms, the literature does not address the location of activities in a value chain and the difference between complements and components. In order to address the distinction between a component (e.g., software for hardware product; GPU in a computer) and a complement (e.g., mouse for computers; charging infrastructure for electric vehicles) and its role in enhancing the focal firm's innovation, the construct of an ecosystem has gained prominence in both academia and practice alike (Adner *et al.*, 2010). Industries such as biotech are typically organized as value chains where there is a clear division of labour between the different actors in the value chain (Clarysse *et al.*, 2014). However, ecosystems do not adhere to a linear value creation process. In an ecosystem, firms deliver value to end customers in a non-linear value creation process. Thus, an ecosystem can be broadly defined as network of firms with horizontal interdependencies (Clarysse *et al.*, 2014; Moore, 1993). In such inter-organizational networks, firms engage in both collaborative and competitive practices resulting a coopetition structure (Moore, 1993).

3.5. KEYSTONE FIRMS IN ECOSYSTEMS

In order to gain competitive advantage, ecosystem members need to exchange resources such as knowledge and the members should also be aware of their position, where value is created and how the relationships are established (Williamson *et al.*, 2012). By referring to dynamics between actors in a value network, business ecosystem theory Moore (1993) offers a new approach to collaborative relationships. Ecosystems, as the name epitomizes can "evolve through serendipity and self-organization" (Williamson *et al.*, 2012). A firm's resources and capabilities determine its role in the ecosystem and their relationship with other actors (Iansiti *et al.*, 2004). Not all actors occupy the same role or perform the same set of activities (Wulf et al., 2017). The development of an ecosystem is often attributed to a lead firm (or hub firm) that orchestrates various activities in the ecosystem. Iansiti *et al. (*2004) identify keystone, Dominators, Niche players and Hub landlords as the various roles that may be seen in an ecosystem. The keystone firms are considered to be the caretakers of the ecosystem who ensure the overall health of the ecosystem. Niche players on the other hand are seen on the peripheries of the ecosystem and channel important ideas and innovations into the ecosystem. Dominators or Landlords in turn are actors who seek to capture value, especially in a business ecosystem.

Iansiti *et al.* (2004) attribute two important roles of a keystone firm, namely "creating value" and "sharing value" with participants. They further state that, "Keystones can create value for their ecosystems in numerous ways, but the first requirement usually involves the creation of a platform, an asset in the form of services, tools, or technologies that offers solutions to others in the ecosystem[…]Keystone firms leave the vast majority of value creation to others in the ecosystem, but what they do create is crucial to the community's survival" (Iansiti *et al.*, 2004, p. 13). The keystone firm plays an active role in organizing activities and ensuring the overall health of the ecosystem (Williamson *et al.*, 2012). By promoting and enhancing the development of an ecosystem, this firm can shape the structure and functioning of the ecosystem.

Importantly, Iansiti *et al*., (2004) acknowledge four important ways by which the keystone firm can advance the development of an ecosystem, namely:

- Establish links between participants and simplify interactions to improve productivity
- Ensure third parties are able to develop products efficiently
- Enhance robustness by incorporating technological innovations that provide support for participants in reacting to new and uncertain conditions
- Encourage niche creation by providing the technologies to all third-party organizations

Thus, the health of the entire ecosystem depends on the keystone firm and removal of it may lead to the catastrophic collapse of the entire network.

The knowledge sharing activities of a keystone firm depends on the nature of the value creation network. Closely or densely embedded networks consists of intense exchange of resources in the form of knowledge etc. whereas a more open network is not easily influenced (Ahuja, 2000) and the keystone has less significance in such networks. Furr *et al.,*(2018) identify subtle changes in the role of the keystone firm depending on the nature of the ecosystem, if it is a centralized or an adaptive ecosystem. In a centralized ecosystem, a keystone firm (addressed as a broker) "connects to partners but keeps them separate, forcing them to work through itself". On the other hand, in an adaptive ecosystem, a keystone (addressed as orchestrator) "connects multiple partners and encourages them to work directly with one another" (Furr *et al.,* 2018, p.61). Explicit knowledge is easy to share between the keystone firm and its partners whereas tacit knowledge is embedded within a firm and its cumbersome for external actors to access or relate to its context (Adner *et al.*, 2010; Iansiti *et al.*, 2004; Williamson *et al.*, 2012).

The nature of formal and informal inter-organization relationship in an ecosystem also influences how the participants access and share knowledge (Wulf *et al.*, 2017). This also influences the trust and willingness to cooperate with each other. In this regard, the role of a keystone firm is crucial for the flow of knowledge throughout the ecosystem. Keystone firms can control and orchestrate the ecosystem by developing rules of engagement (Zahra and Nambisan, 2012) and maintain the flexibility of the ecosystem in adjusting to external threats and identifying new opportunities (Iansiti *et al.*, 2004).

4. METHOD

This chapter describes the methodological choices that have been used to address the research questions presented in chapter one.

4.1. RESEARCH APPROACH

A complex phenomenon, such as emergence of an ecosystem, wherein developments occur over time necessitates a long term perspective. This motivates a longitudinal study as it facilitates a deeper understanding of a specific context, i.e., how various agents (individuals) and units (teams) interact, and the underlying reasons for such interactions. Literature on ecosystem also highlight the need for longitudinal studies in order to understand the emergence of new ecosystem (e.g., (Gawer *et al.*, 2014; Jacobides *et al.*, 2018). Thus, the study tracked activities taking place within the AD technology development project at Volvo. The unique empirical context and the need to understand underlying reasons, motivations and opinions of individuals at the case firm warrants a qualitative study with longitudinal approach (Flick, 2014). In a qualitative study, the emphasis is usually on a "specific case, a focused and bounded phenomenon embedded in its context" (Miles and Huberman, 1994, p. 10). A longitudinal study facilitates a deeper understanding of a specific context, i.e., how various agents (individuals) and units (teams) interact, and the underlying reasons for such interactions. Further, in order to contribute to theories on organizational adaptation, innovation and change, it has been argued that it is necessary to "explore the contexts, content and process of change together with interconnections through time" (Van de Ven *et al.*, 1990, p. 215).

4.2. RESEARCH DESIGN

A single case study design was deemed suitable as it allows for in-depth investigation of a phenomenon (Easterby-Smith *et al.*, 2012). Yin (2009) has suggested that a case study design is suitable when the focus of the study is to understand "how" and "why" questions and to investigate events that are difficult to control or manipulate. Although case studies do not have a universally accepted definition (Dubois *et al.*, 1999), this research uses Yin's (1994, p. 18) definition: "a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". Due to the emergent and unique nature of the phenomenon, the research tended to be iterative (Dubois *et al.*, 2002; Siggelkow, 2007). The empirical data and theory were revisited concurrently to better understand the context. By moving back and forth between the empirical setting and theory, the research design is in line with the systematic combining approach (Dubois *et al.*, 2002). This meant that new questions emerged during the full course of the study.

Due to the interpretative nature of my research, I label it as "constructivist inquiry" (Lincoln, 1985; 2007). According to Guba *et al.* (1982), "positivist inquiry (quantitative) assumes a single

reality and inquiry findings are based on a single reality". Whilst a constructivist considers multiple realities as an alternative explanation for social reality. Constructivist inquiry deals with research that is interpretative, and non-experimental in nature (i.e., non-positivist). This leads to abductive reasoning of the findings based on sense-making and perceptions of case (Gioia *et al.*, 2013). Data was collected ethnographically through observations, interviews and secondary sources. This type of data collection wherein the researcher is immersed in the case setting, as a 'participant as observer' can be described as an ethnographic method (Anderson, 2009; Yin, 2009).

4.3. DATA COLLECTION

As part of the ethnographic method, I participated in team discussions and weekly meetings which allowed for collecting observational data in the form of field notes. Unlike other data collection techniques where researchers tend to ask specific questions, ethnography involves visiting the subject's location (field) in order to observe and listen in a non-intrusive manner. On the other hand, participant observation is a way to be in direct spatial relationship with the study object and enables the researcher to ascertain if what the interviewees say they do and what they actually do in reality tally (Mulhall, 2003).

To address the technique used to collect the field notes, I will use the term 'participant observation' to emphasize the fact that observations, along with interviews, were used to collect data whereas ethnography is my overarching research method. According to Atkinson *et al*., (1998, p. 249), "Both ethnography and participant observations have been claimed to represent a uniquely humanistic, interpretive approach, as opposed to supposedly 'scientific' and 'positivist' positions". Distinguishing between 'ethnography' and 'participant observation' has been problematic and controversial, as scholars have used them interchangeably (Aktinson *et al.*, 1998). It has been argued that all forms of social research are a form of participant observation, because a researcher cannot study social contexts without being part of it (Atkinson *et al.*, 1998).

Table 1. Overview of data from the longitudinal study use in the appended papers

Paper	Type of data	Study context	Data collection
1	Field notes, interviews, and secondary data	The industry transformation	2016-2017
2	Field notes, and secondary data	The shift in way of working at the keystone firm	2018
3	Field notes, interviews, and secondary data	The importance of tactical activities in a new technology development project	2018-2019
4	Field notes, interviews, and secondary data	The emergence of a new innovation ecosystem	2016-2019

Observational data, in general, is useful to identify nonverbal expressions, who interacts with whom, how actors communicate with each other, and catalogue events as they unfold (Kawulich, 2005). Thus, the field notes are an important tool to document observations and it helped to ensure that there is little distinction between what has been observed and what has been interpreted by the observer (Flick, 2014). Along with observations, interviews were carried out and allowed for gathering additional information or check the accuracy of observations and gain new accounts of a problem based on personal experience (Easterby-

Smith *et al.*, 2012; Maxwell, 2012). The interviews were conducted in a semi-structured manner as it allowed room to discuss interviewee's experiences and interpretations on various subjects (Flick, 2014). Both observations and interviews are useful to gain insights about non-contemporary events that took place in the past or ones that cannot be observed (Maxwell, 2012). Interviews were documented through recordings and later transcribed. A total of 26 semi-structured interviews were carried out. Along with interviews, field notes amounting to 700 pages was collected. Additionally, secondary data in the form of press releases, archives, etc., were used to supplement the observations and interviews. The papers appended in the thesis were written at different periods and focused on various contexts (See figure 1). The use of data in the appended papers is further illustrated in Table 1.

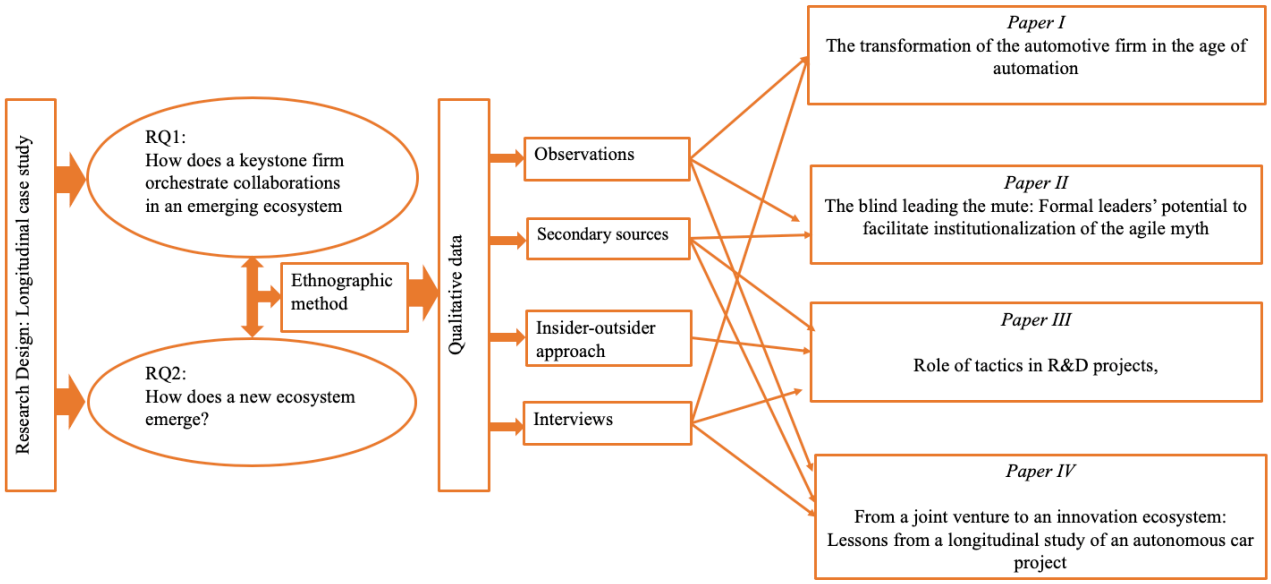

Figure 1. Relationship between research questions, type of data and the appended papers

4.4. DATA ANALYSIS

The exploratory and longitudinal approach renders the research process to be iterative where data is collected and analysed in parallel. One of the issues that I faced during the initial phase of my study was that data piled up very quickly due to the frequency of field visits. Over time the sheer volume of data required a structured data analysis process (See table 2). Gioia *et al.* (2013) acknowledged this issue by expressing that it is quite normal to feel "lost" in the data analysis process. The rich data gathered would provide little value if not processed in a structured manner. Thus, I decided to do the data analysis concurrently with the data collection (Dubois *et al.*, 2002; Maxwell, 2012).

The interviews were transcribed and analysed using the data analysis software NVivo. The field notes were coded using the Xmind mapping tool during the first year of the study and later using NVivo. To categorize and identify patterns in the data, codes (shown as 'nodes' in the software) were generated on NVivo (Easterby-Smith *et al.*, 2012). The data was coded into non-hierarchical user-defined nodes, and the coding process was guided by theoretical framework. A few codes from NVivo are shown in figure 2.

Table 2. Data sources and quantity

Data source	Participant(s)	Type of data	Quantity	Time period
Stakeholder interactions	Senior managers	Semi-structured interviews	26	2016-2019
Informal discussions	Senior managers and managers	Photos of White board discussions, audio notes	_	2017-2019
Weekly meetings	Engineers, Product owners, Senior managers	Field notes	700 pages	2016-2019
PI planning	All employees	Field notes	Occurs every 12 weeks (Since June 2018)	2018-2019

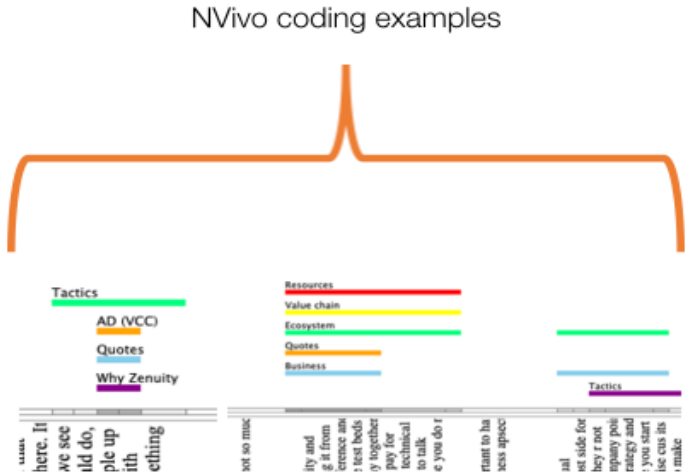

Figure 2. Examples of codes from NVivo

4.5. Research Quality

Any research undertaken by a single field-worker invites the question of validity and why the study should be accepted (Maxwell, 2012). Validity in general is concerned with the integrity of the results derived from the research (Easterby-Smith *et al.*, 2012; Saunders *et al.*, 2009). As a qualitative researcher, I intend to understand the phenomenon through relationships between different constructs. The validity of my research depend on the extent to which the findings provide a true representation of the phenomenon (Easterby-Smith *et al.*, 2012). In other words, validity delves into the integrity of conclusions generated from a research study (Bryman *et al.*, 2015). Although, the validity of results in not guaranteed by following a particular method, it is pertinent to discuss the relationship of the conclusion to the phenomenon studied (Maxwell, 2012).

To ensure valid and reliable results, as a researcher with constructivist epistemology, I used multiple methods to gather data (Golafshani, 2003). The use of multiple data sources in the form of interviews and observations helped access the experiences and perspectives of those in my case (Easterby-Smith *et al.*, 2012). Frequent interactions with the stakeholders at Volvo

enhanced the understanding of the program context. Through co-authoring papers with peer researchers, I also accommodated the perspectives and ideas of additional researchers. Johnson (1997) addresses this as "investigator triangulation". Thus, triangulation in terms of including multiple sources of data and collaborating with peer researchers are two initiatives I took to improve the validity of study results (Golafshani, 2003).

It is pertinent to discuss trustworthiness of my research due to my qualitative approach and abductive reasoning of my findings. Trustworthiness is especially important in a single case design. The case that I investigate is unique and findings from the study are rooted in a real-life context offering an understanding of the phenomenon, i.e., the emergence of an ecosystem (Siggelkow, 2007). Case study research has sometimes been criticized, as results are difficult to generalize beyond the scope of the case (Easterby-Smith *et al.*, 2012; Siggelkow, 2007). By clearly describing the research context and inherent assumptions in the study, the study is expected to be useful for future investigations involving ecosystems and develop knowledge in the field.

5. SUMMARY OF APPENDED PAPERS

In this section, the four appended papers are summarized. The main contributions of each paper are presented, followed by a table indexing each paper to the research questions presented in section one. The method is not presented in-depth here as all four papers are based on data from the same longitudinal case study, presented in the method chapter.

5.1. PAPER I

The transformation of the automotive firm in the age of automation– Early findings from a case study of the Drive Me project at Volvo car Group

In recent times, research on inter-firm collaborations address the fact that firms have increasingly opened up their innovation processes to collaborate with other actors, ranging from suppliers to customers and even competitors. This is due to the rapid advancements in technologies that often render knowledge and resources of incumbents obsolete. Automotive industry is often attributed as a mature industry with hierarchical value chains built around OEMs. Electrification, autonomous mobility and ride hailing services are leading to a huge shift in the resource and competence base of the entire industry. The advancements in sensor systems and software in modern vehicles has increased the interactions between OEMs and non-automotive firms. Autonomous Drive (AD) technology is seen as a radical technological shift with a potential to transform mobility as we know today.

The purpose of paper I is to understand the challenges that incumbent automotive firms face in the transition to autonomous vehicles. The paper is based on a longitudinal case study of Volvo's AD program. Insights from the project[3] revealed that the nature of activities in the AD program are in stark contrast to traditional projects in the automotive industry. The paper argues that the established value chains in the automotive industry is unfit for developing autonomous drive (AD) technology. Value chain thinking has been the most useful way to understand the functioning of traditional industries churning out physical products (Allee, 2000). The empirical observations at Volvo's AD program show that the value chain way of organizing

[3] Paper I & III address the AD program as a project. This is due to the recent transition of Volvo's "AD technology development" from a project to a program

activities between OEMs and suppliers is giving way for a value network. The type of collaborations and competences needed for the AD program necessitated that Volvo engaged itself in a value network where all actors possess significant competences and know-how. Further, high levels of complexity with technologies (such as GPUs, Cloud network, Lidar, Radar etc.) and uncertainty with legislation, technology standards etc. rendered the traditional waterfall way of working unfit.

Paper I makes two important contributions regarding the development of AD tech. Firstly, the development of value networks in the automotive industry due to the changing innovation landscape. Secondly, the need to shift from traditional waterfall way of working in order to handle the software development activities that is becoming a major part of development activities in the automotive industry. Paper I highlights the major differences between a traditional car development project and an autonomous car project based on new technology development.

5.2. PAPER II

The blind leading the mute: Formal leaders' potential to facilitate institutionalization of the agile myth

More and more firms are moving from plan-driven to an agile approach to new product development. New product development in a firm relies on formally designed plan-driven development processes. The formal processes are often complemented by informal structures and are considered indispensable to the development of new products. In recent times, many firms have embraced agile development methods in order to handle the dynamic environmental context (Rigby *et al.*, 2016). The popularity of the agile development approach has significantly altered the nature of planning and executing tasks. The purpose of the paper is to illustrate a paradox whereby agile development constrains the existing agility embedded in informal structures.

Firms deep entrenched in traditional structured development approaches (e.g.: waterfall) that promote formalized, sequential development style are increasingly attracted by the promises that agile provides. Agile is seen as a way to promote flexibility in the product development that is often seen as the weakness with plan-driven processes. However, the shift from traditional to agile is not without challenges (Dikert *et al.*, 2016) and is a conundrum for formal leaders pioneering the transition.

Whist informal networks and self-organizing employees inspire the formal adoption of agile, institutionalizing agile nevertheless leads to the disruption of informal networks and established relationships. This paradox is exemplified in the paper by drawing on theory of institutional work. The paper is based on a longitudinal case study from an AD technology development project that recently shifted from plan-driven to agile development. Using observations from a longitudinal study, Paper II exemplifies the role of formal leadership in the institutionalization of agile.

This paper maps activities inside the AD program and addresses the internal challenges encountered by the keystone firm of an emerging ecosystem. The findings address how formal leaders can address the institutionalization of agile and contributes to literature on agile development by underlying the conflicts that arise during a transition from plan-driven way of working to agile.

5.3. PAPER III

Role of tactics in R&D projects

This paper builds upon the data collected during the agile transformation at Volvo's AD program. The interest for this paper originated from the frequent use of the word "Tactics" by a senior manager (also my stakeholder at Volvo). He felt that the uncertainty and complexity in developing an autonomous car necessitated a tactical mindset. This invoked an interest in understanding the duality between agile and tactics. Both strategy and tactics are established in literature as essential for project success (Ackoff, 1970; Casadesus-Masanell *et al.*, 2010; Moe *et al.*, 2012; Schultz *et al.*, 1987). Despite the well-established importance of both tactics and strategy for project success (Slevin *et al.*, 1987), few academic works have addressed the use of tactics in Agile projects.

The purpose of the paper is to understand how agile methodology supports R&D projects in being tactical. It draws on data from the longitudinal case study and insights from the senior manager who is also a co-author of the paper (Asselin, 2003). From the data, four observations were selected to elucidate the need for tactics in the AD program and the impact of agile way of working in executing tactics.

The legal framework uncertainty: The regulatory uncertainty surrounding autonomous vehicles necessitated the AD project to be prepared for making changing to hardware and/or software. To handle this uncertainty, the project develops multiple tracks that gives flexibility in the development process.

The documentation trade-off: This an example from an agile team level. When a task to prepare documents explaining the codes, the team decided to find an alternate solution for the task assigned to the team. It was seen that agile empowered the teams to discuss the work and develop their own internal plans. The flexibility was a key aspect of agile methodology.

Handling unknowns: Due to the rapid advancements in sensor system, it is important for the AD technology to freeze the sensor system as late as possible. In order to handle this uncertainty, the project uses an Operational Design Doman (ODD) that frames the operational conditions under which an automated feature is designed to function. When there is new functional needs, the ODD can be expanded to incorporate more advanced functions.

Suppliers and components: Technologies such as Lidar, sensor, cameras, GPU, etc. are continuously improving in performance and cost. Also, suppliers of such technologies and services are often locked to a particular market or geography. Volvo needs to ensure that the AD project can handle emergent challenges pertaining to suppliers or technologies. This requires flexibility in the development process and an ability to handle changes in the supply network.

Literature on agile development methods abundantly illustrate its advantages in terms of being conducive for fast changes, cross-functionality, improved collaboration etc. In a waterfall way of working, focus is on reducing uncertainty and curtails making changes to plans. This is seen as unfit for developing new technologies where tactics is considered highly essential in handling emergent challenges. From observations and insider experiences, the paper argues that agile way of working allows for tactical activities in a new technology development project.

5.4. PAPER IV

From a joint venture to an innovation ecosystem: Lessons from a longitudinal study of an autonomous car project

Literature on ecosystem recognizes the lack of knowledge on the emergence of a new ecosystem as they are rarely studied in their emergent phase. Part of the challenge pertains to the rare occurrence of "new ecosystems" and the rather ex-post definition of ecosystems (Gawer *et al.*, 2014; Jacobides *et al.*, 2018). An ecosystem is described as a constellation of actors working together in creating value (Adner, 2006; Gomes *et al.*, 2018; Jacobides *et al.*, 2018; Moore, 1993), thereby rendering a shift from value chain perspective to value network (Peppard *et al.*, 2006).

Today, the notion of ecosystem is encompassed in more nuanced constructs such as hub ecosystem, innovation ecosystem, business ecosystem, open innovation ecosystem, etc. Literature on ecosystem attributes modular architecture as being vital to ecosystem attractiveness. However, achieving modularity is often seen as cumbersome process and largely dependent on the degree of control asserted by the keystone firm. In this context, it is important to develop new knowledge that explains how firms achieve modularity – accidental or intentional – in new technology development and the role of a keystone firm in using the modular technology to orchestrate the emergence of a new ecosystem. The purpose of Paper IV is to explore how an incumbent firm engages in collaborations to develop a new technology. To do so, the paper builds upon data from a longitudinal case study at Volvo's AD technology development project.

The resource and competence needs of the project pushed VCC to form a joint venture with Autoliv, a leader in automotive safety systems. The findings show that the joint venture (Zenuity) and the parent (Volvo) shared a "symbiotic" relationship. Zenuity intended to supply software for all OEMs which meant that it developed software compatible to all OEMs in the industry. Due to this set up, activities in the AD program were inherently aimed at establishing modularity. The symbiotic relationship between Zenuity and Volvo resulted in the development of a modular technology platform. Thus, the software development for AD technology through a joint venture, beyond the direct advantages of augmenting resources and competence, implicitly nurtured the formation of an innovation ecosystem.

Paper IV argues that the AD program achieved modularity due to the unique nature of its joint venture partnership. Further, the findings show how Volvo transitioned from a parent firm of a joint venture to a keystone firm in an emerging ecosystem.

5.5. LINKING THE PAPERS TO THE OVERALL PURPOSE OF THE RESEARCH

The four papers appended to this licentiate thesis are all based on the longitudinal case study at Volvo's AD program but are investigating different perspectives of the "technology development" program. Table 3 shows the relation between the papers and the research questions.

Table 3. Mapping the research questions to the appended papers

Research Questions	**Paper I**	**Paper II**	**Paper III**	**Paper IV**
1) How does a new ecosystem emerge?	☒			☒
2) How does a keystone firm orchestrate collaborations in an emerging ecosystem		☒	☒	☒

Paper I was drafted during the early phase of the study. During this phase, I focused on understanding the AD program. The findings (Paper I) highlight the network form of collaboration between Volvo and other actors. It also highlights the shortcomings of Volvo's waterfall way of working and argues for the need to change this development approach to better engage with other actors in the network. This paper sets the foundation for my focus on value networks and exploring the ecosystem dimension of the AD program.

Paper II and III discuss the AD program's shift from waterfall to agile way of working. These findings offer important insights on the changes in the way of working in the AD program. Paper II discusses the agile transformation at Volvo's AD program. In particular, Paper II highlights the challenges faced by a firm when changing its established ways of working and the paradoxes involved with institutionalizing agile development method in a large firm. Volvo's waterfall way of working created challenges with collaborating with other actors, especially software firms, such as Zenuity. The agile transformation was an important aspect of Volvo's efforts to improve the development work in the AD program and better synchronize development activities with its partner firms.

Paper III also shows the importance of establishing efficient ways of working to share resources and competences with other actors. This paper provides insights on the importance of tactics in R&D projects and agile as an appropriate way of working to facilitate tactical activities in a project. Again, although being on a project level, this paper contributes to the understanding of Volvo's transformation as a keystone firm. Literature on ecosystem highlight flexibility and awareness to the external environment as an important role of the keystone firm. Thus, agile facilitating tactical activities enhances Volvo's ability to adapt towards new challenges and opportunities in the ecosystem. Although both Paper II & III discuss Volvo's agile transformation, the findings are highly relevant to understand the collaborations in the ecosystem where most of the activities are centred around developing software features with many of the partner firms using the agile development method as their modus operandi.

Paper IV explains the various collaborations in the AD program with particular focus on the joint venture established by Volvo and Zenuity. The paper addresses the emergence of new ecosystem by focusing on the "symbiotic" relationship between Volvo and Zenuity. This was identified as a reason for the development of a modular technology platform, often cited as a

cornerstone of ecosystem emergence. The paper shows the increase in the number of collaborations and attributes it to Volvo's ability to embed modularity in its technology development. Most firms struggle to establish an ecosystem due to the difficult in achieving a modular technology platform. Developing modularity involves reduced development speed and increased cost. However, the existence of a JV with the responsibility to develop software and the JV's vision of supplying AD software to all OEMs implicitly resulted in a modular technology platform. Thus, paper IV shows the emergence of Volvo's AD ecosystem by tracing the origins of several collaborations in the AD program. An overview of the study is depicted in Figure 3.

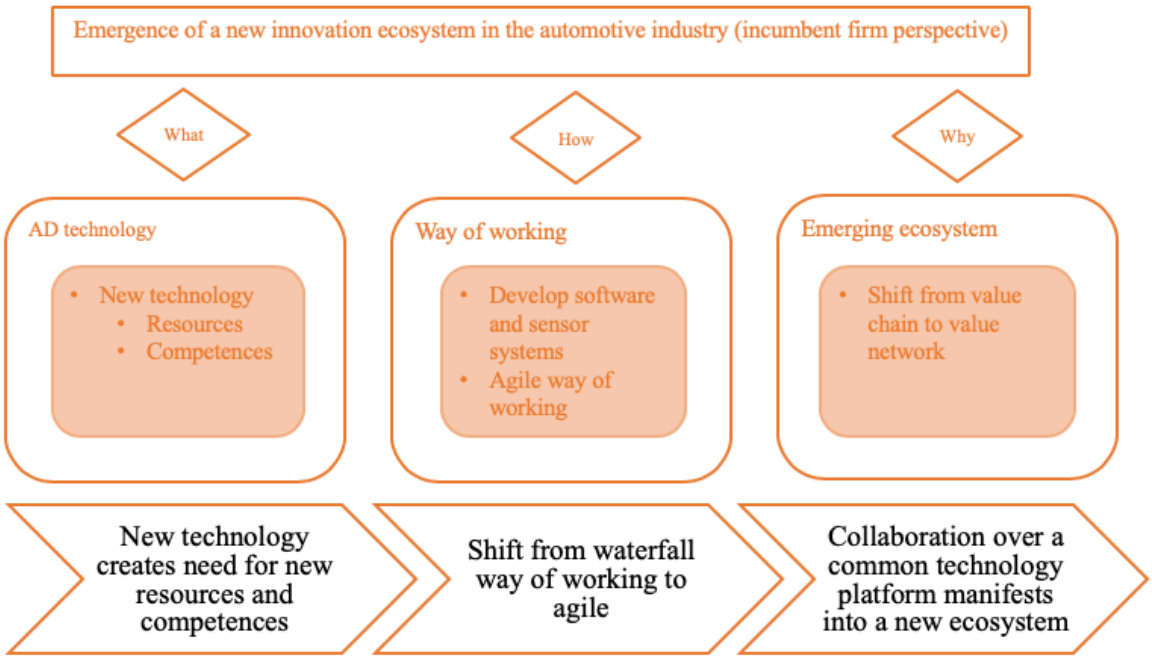

Figure 3. Overview of the study

6. DISCUSSION

The following sections discuss the findings of the longitudinal study in relation to the research questions and links them to the respective papers appended in the thesis. The final section revisits the research questions and provides a summary of the findings.

6.1. DEVELOPING A NEW TECHNOLOGY IN A VALUE NETWORK

Historically, the automotive industry has been a text book example of a value chain consisting of suppliers, distributors, Original Equipment Manufacturers (OEMs) and retailers. The advent of AD technology has altered the competitive landscape of the automotive industry. In the early phase of the longitudinal study, it was noticeable that the project had multiple partners from outside the automotive industry. AD technology is heavily dependent on software development and sensor fusion which necessitates that Volvo collaborates with non-automotive firms. These firms possess knowledge that the OEM's (Volvo) traditional value chain lacks.

The AD program consists of multiple actors who operate in a non-sequential manner where value is created independently of each other but aimed at enhancing the technology platform

(Paper I & IV). For example, Uber develops its AD features independent of Volvo's AD cars but shares the AD car platform with Volvo. This facilitates both Volvo and Uber to share the resources and competences to build the technology platform yet does not restrict them to pursue their independent business objectives. Similarly, Zenuity is allowed to commercialize its software solutions to other OEMs. This is in contrast to a value chain where development work proceeds in a sequential manner from raw materials, followed by manufacturing, and then distributing the finished goods to the end customers. The AD program thus departs from the value chain mode of operations that is usually the norm in the automotive industry (see figure 4). Instead, it is a collaborative innovation project where value is created in a network with all actors playing a vital role in creating and delivering value (Peppard *et al.*, 2006). However, this set-up was a significant challenge for Volvo as it is attuned to value chain mode of operations.

Further, Paper I highlights the need to change the traditional waterfall way of working in order to handle the software development activities that is becoming a major part of development activities in the automotive industry.

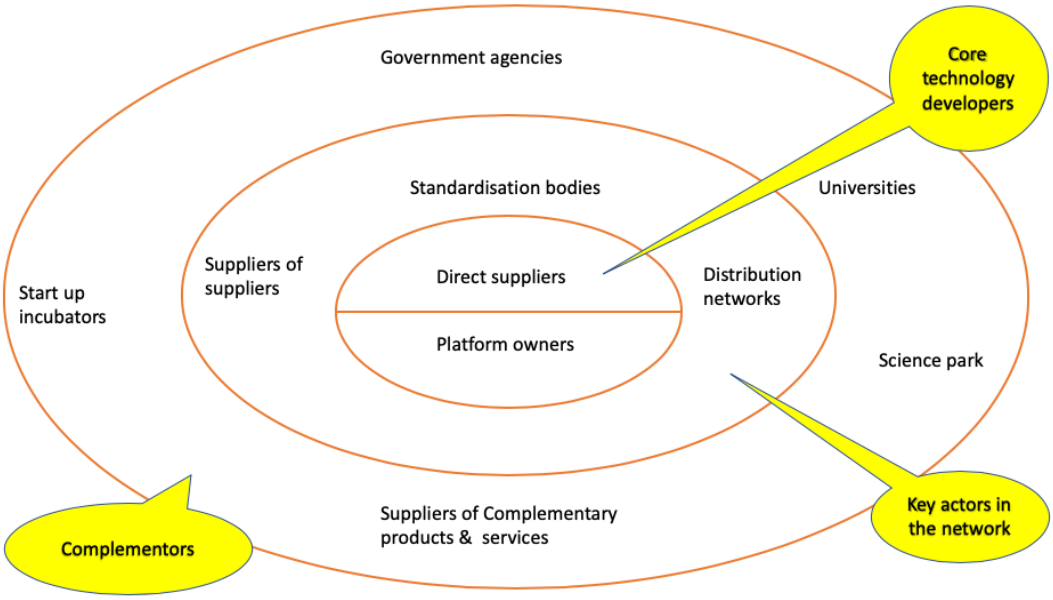

Figure 4. A typical value network. Adapted from Moore (1993) and (Alizadeh *et al.*, 2017)

6.2. AGILE TRANSFORMATION

Early on, Volvo's waterfall development method created bottlenecks in the project as most actors, including Zenuity, operated with agile development methodology (paper I, IV). The plan-driven waterfall way of working is tailor made for an industry steeped in the sequential value chain (Norman & Ramirez, 1993). However, with the increase in digital features, the need to develop software necessitated a change in the entire way of working. Initially, the AD program faced challenges due to the difficulty in adapting to value network and the waterfall way of working compounded the challenges in interactions between the actors (paper I). In order to synchronize activities in the emerging AD ecosystem, Volvo's AD program adopted an agile way of working. This was an important milestone in Volvo's path to becoming a keystone firm. By adapting to agile, which is acknowledged to promote flexibility, Volvo could

better address the challenges and opportunities in the ecosystem. It also helped Volvo synchronize activities with various actors in the ecosystem.

The findings in Paper I discusses the challenges that Volvo faced in developing AD technology due to its plan-driven waterfall way of working. Based on the empirical data, Paper I argues that Volvo needs to revisit its way of working in order to adapt to changing competitive landscape in the industry (i.e., shift in competition from hardware products or features to digital features or services). Paper I also highlights how Volvo's AD technology development project was constructed in a value network fashion. In 2018, as evinced in Paper I, Volvo made a shift from waterfall to agile development method. In seeking closer interaction with all actors, the AD program perceived agile development methodology as a better way of working in a value network. This further strengthened the claims made in Paper I about the need to shift the way of working to engage in value networks.

Given the advantages of agile development methods (e.*g., Scrum, Kanban, Extreme Programming (XP), Feature Driven Development (FDD), Lean etc*.) in developing digital technology, the transformation from waterfall to agile (especially in a large organization) is not without challenges. The transition from a plan-driven waterfall way of working to agile development in the AD program entailed significant challenges. Initially, employees perceived the shift to agile as difficult and challenging (Paper II). However, they also understood the importance of the transition and its impact on the future of the AD program. The agile transformation greatly improved the sharing of knowledge and resources between the various actors in the AD program (Paper III). Thus, paper II highlights how formal leaders can address the institutionalization of agile and contributes to literature on agile development by underlying the conflicts that arise during a transition from plan-driven way of working to agile.

Further, Paper III elucidates the usefulness of agile development approach in the projects ability to be tactical in the day-to-day activities. Literature on project management has adequately addressed the importance of both strategy and tactics for project success (Hadar *et al.*, 2008; Pinto *et al.*, 1990; Slevin *et al.*, 1987). Applying this theoretical framework, in Paper III, we identify that the previously used waterfall way of working in the AD program significantly restricted tactical activities. Thus, by addressing the importance of tactical activities in the AD program, Paper III sheds light on the usefulness of Agile way of working beyond the attributes highlighted in mainstream literature on Agile. Through various observational data and "insider-outsider" approach (Asselin, 2003), Paper III argues that the agile way of working facilitates tactical activities in a project.

6.3. MODULARITY AND ECOSYSTEM

The AD program began as an internal innovation project. The complexity of the project pushed Volvo to set up a joint venture with Autoliv. The JV was set up to develop the entire software system for the AD technology. To this effect, both parent firms transferred resources (such as intellectual property, personnel etc.) to the JV. Additionally, commercializing the AD software to all OEMs was also attributed as one of the reasons for setting up the JV. Thus, Zenuity (the JV) was allowed to develop products independent of Volvo's interference and functioned as an independent software supplier for AD vehicles. Paper IV identifies this as a key step in the emergence of the ecosystem.

Literature on ecosystems highlights the lack of empirical studies on the emergence of a new ecosystem (Gawer *et al.*, 2014; Jacobides *et al.*, 2018). This is primarily due to the fact that ecosystems in general have an ex-post definition and tracing the emergence of an ecosystem

needs a long term perspective. The longitudinal study at Volvo led to findings that add significant contribution to literature on the emergence of an innovation ecosystem. In Paper I, it is established that Volvo's AD program is embedded in a value network where all actors participate in the value creation activities in a non-linear fashion. In Paper IV, the findings from the longitudinal study explains how the ecosystem around Volvo's AD program emerged. Through interviews, observational data (participant as observer), planning workshops and stakeholder interactions, Paper IV identifies the role of a 'symbiotic' JV in the emergence of an ecosystem.

The JV, with its ambition to be a supplier of AD software for all OEMs, had to ensure that its features were compatible to all potential customer. Due to the dependence of the AD program on Zenuity's AD software, Volvo implicitly developed a modular system that interfaces with Zenuity's software. Developing modular systems are difficult in the early stage of a new technology due to the uncertain market potential of the technology. Further, focusing on modularity may increase the cost and slow down the pace of development. Although frustrating to develop, literature on ecosystem identifies modularity is an important element of an ecosystem as it facilitates in integrating complementary innovations and services onto a technology platform (Gawer *et al.*, 2002; Gawer *et al.*, 2007; Iansiti *et al.*, 2004; Jacobides *et al.*, 2018). With modularity being an unintended consequence of setting up the JV, Volvo was able to attract more partners to its AD program. Over time, the number of partner firms in the AD program increased significantly (see figure 5). Thus, Paper IV makes important contribution to the knowledge on the emergence of new ecosystem addressing the gap in the ecosystem literature (Jacobides *et al.*, 2018). By owning the technology platform and externalizing software development, Volvo could orchestrate the activities in the AD program and position itself as a keystone actor.

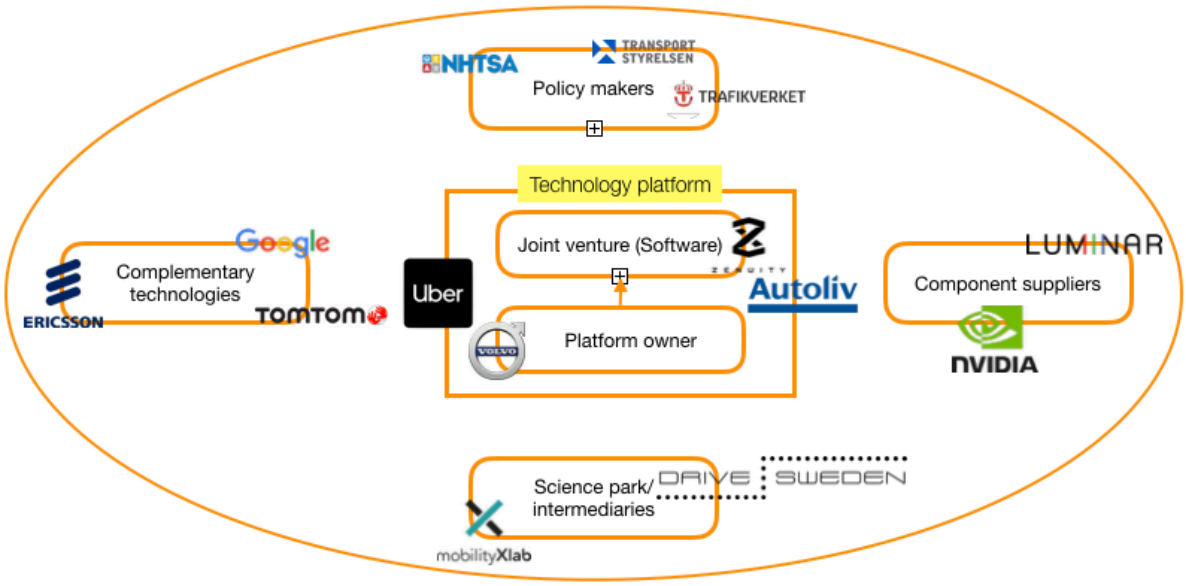

Figure 5. illustration of the emerging AD ecosystem (Source: author)

6.4. VOLVO AS THE KEYSTONE FIRM OF THE ECOSYSTEM

One of the biggest challenges that Volvo faced was pertaining to its plan-driven waterfall way of working that was unsuitable for new technology development project with high complexity and uncertainty. This also hindered Volvo's ability to coordinate activities with other actors (especially Zenuity). Also, AD technology is a complex system that consist of several digital technologies that needs to be integrated and processed by algorithms. This typically involves machine learning, activities that demand flexibility and adaptability. Volvo's waterfall way of working was unsuitable to carry out such development activities. The agile transformation significantly improved Volvo's ability to coordinate and cooperate with other actors in the emerging ecosystem (Iansiti *et al.*, 2004; Jacobides *et al.*, 2018). This, coupled together with Volvo's ownership of the base car platform and Zenuity's software, positioned Volvo as a keystone actor in the ecosystem.

Literature on ecosystems highlights the importance of the keystone firm (Adner *et al.*, 2016; Iansiti *et al.*, 2004; Jacobides *et al.*, 2018), that maintains the balance in an ecosystem and coordinates activities between the actors. The longitudinal case study argues that Volvo's 'symbiotic' joint venture facilitated the emergence of the AD ecosystem with Volvo as the keystone actor (paper IV). Although other actors like Uber, Baidu, Nvidia etc. had significant know-how and competences, Volvo was the facilitator of the partnerships and owned the base car (i.e., car platform) used for developing the AD technology. Volvo, as an OEM has the manufacturing, supply networks and infrastructure needed to integrate the AD technology into cars. The AD technology needs to be integrated with a product (i.e., car) for the end customer to perceive value. And, all actors in the network play important roles in the value that Volvo intends to provide its end customer (Dattée *et al.*, 2018). Thus, Volvo has to rely on all the participants in the ecosystem and ensure that all actors could coordinate activities with one another (Iansiti *et al.*, 2004). This positioned Volvo as a central actor that organizes activities and connects network participants (Iansiti *et al.*, 2004). Also, Volvo actively engaged with government agencies across the world (e.g., NHTSA in the U.S.; Transportstyrelsen and Trafikverket in Sweden) in order to facilitate the commercialization of AD technology (Paper IV). By holding key assets, supply networks and manufacturing capabilities, Volvo could play the role of an orchestrator in the ecosystem. All these attributes greatly helped Volvo position itself as the keystone actor in the emerging AD ecosystem (Paper IV).

Despite owning the core technology platform, Volvo did not hesitate to share value with other actors, *identified by Iansiti et al. (2004) as an important character of a keystone firm*. For instance, Uber pursues its own business interest in the area of ride sharing services and develop new offerings to suit its business needs (paper IV). Zenuity, on the other hand, develops its ADAS and AD software using Volvo's car platform. However, Volvo does not restrict Zenuity's ability to commercialize its software solution. This allows Zenuity to commercialize its AD solutions to all OEMs, despite Volvo being its parent firm and a key competitor to other OEMs (paper IV). Further, collaborations with technology firms like Nvidia allows Volvo to access critical knowledge and competences in the area of semiconductor technology. Firms such as Tesla, for example, develop their own propriety chipsets leading to closed technology platform (www.tesla.com/autopilot). Other actors such as Luminar, Ericsson etc., develop technologies or solutions that improves Volvo's AD technology. In line with literature on keystone firm (Iansiti *et al.*, 2004), by allowing others to develop services, tools, or technologies, Volvo shows that it is willing to both create and share value with other actors.

Thus, the keystone firm is the de facto coordinator of activities in an ecosystem (Iansiti *et al.*, 2004) and the shift from waterfall to agile way of working greatly improved openness and flexibility in the ecosystem (Paper III & IV). In an adaptive ecosystem (Furr *et al.*, 2018), the keystone firm needs to be flexible as it is difficult to predict the resource and competence requirements (Furr *et al.*, 2018). The keystone firms also needs to be wary of new trends and opportunities that may arise in the external environment. Thus, being tactical is of utmost importance in an adaptive ecosystem and the agile way of working greatly enhances the AD program's ability to adjust according to emergent needs (Paper III).

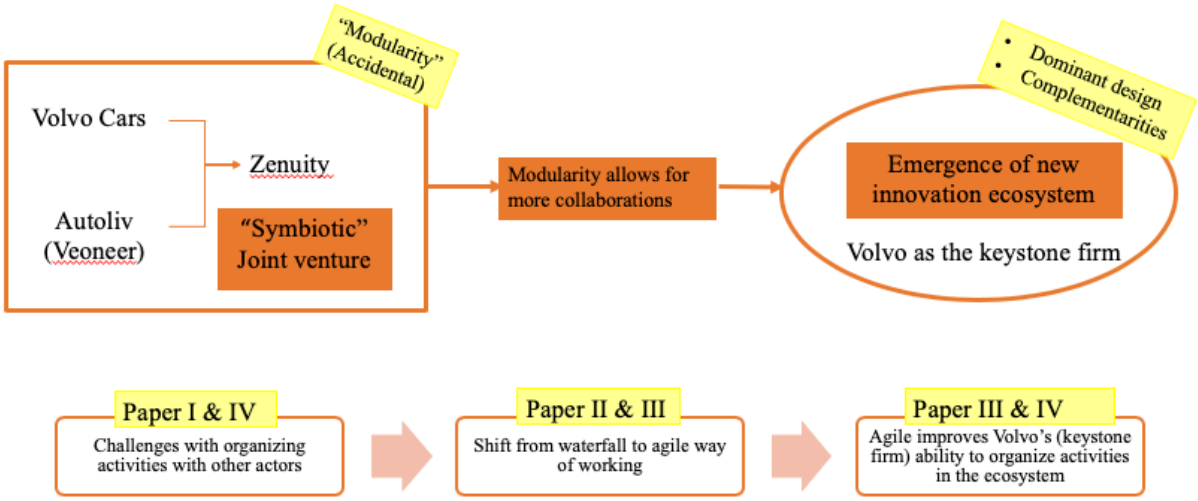

Figure 6. Volvo's transformation as the keystone firm of the ecosystem

6.5. THE EMERGENCE OF INNOVATION ECOSYSTEMS

The literature posits that all ecosystems consist of at least one keystone firm that coordinates the activities in the ecosystem. Further, modular platforms are quintessential for an ecosystem as they allow multiple actors to develop complementarities and integrate their value offerings with those of the platform. However, two questions pertaining to ecosystems remain inadequately studied. First, the factors that attribute to the emergence of an ecosystem. Second, how does a firm (incumbent automotive firm in this study), position itself as a keystone actor in a new ecosystem. These two important questions are addressed through this longitudinal study of Volvo's AD program.

How does a new ecosystem emerge?

Literature identifies that new technologies are often faced with unclear standards and lack of complementary assets (Adner *et al.*, 2010; Gawer *et al.*, 2007; Tripsas, 1997, 2009). This is a major challenge in commercializing new technologies. Standardization of a new technology is important to usher the development of complementary assets, infrastructure and government policies. Such challenges, pertaining to developing and commercializing new technology, are usually overcome by a network of actors working together in a manner akin to a biological ecosystem (Moore, 1993).

In management literature on ecosystems, modular platforms are identified as the cornerstone of an ecosystem (Scholten & Scholten, 2012). However, firms are often unwilling to embrace modularity in the early stage of a new technology development. This is because, developing modular technologies can be time consuming and expensive. Modularity often takes a back

seat and is often considered an irrational objective during the early stages of technology development, especially when market potential and customer demand for the new technology is unclear. Instead, modular technologies usually emerge during the late-cycle of a new technology when the management attention shifts to outsourcing, achieving economies of scale and reducing development costs.

However, from an ecosystem perspective, modularity forms the core of the ecosystem. In the longitudinal case study, it was evident that the formation of a JV to develop software implicitly resulted in the modularity of Volvo's AD technology. This can be seen as an important advantage of the AD program and resulted in the increase in new collaborations. The results contribute to literature on ecosystems by addressing how modular platforms can be developed and the role of a keystone actor in orchestrating the emergence of an ecosystem. By showing these factors that contribute to the emergence of an ecosystem, the case study addresses the question on how ecosystems emerge.

How does a keystone firm orchestrate collaborations in an emerging ecosystem?

The second contribution of this longitudinal case study is the illustration of the shift in Volvo's role from being an OEM in a traditional value chain to a keystone actor in an emerging ecosystem. Literature on ecosystems shows that the keystone firm enjoys several advantages, however, not all firms are capable of becoming one.

Findings from the longitudinal case study illustrated the efforts taken by the incumbent firm (Volvo) to become a keystone actor. Along with the development of a modular technology, a change in the way of working significantly improved the incumbent firm's ability to coordinate activities in the ecosystem. Literature on ecosystem highlights the role of a keystone firm in coordinating the activities and sharing of resources. In this emerging ecosystem, the complexity of the technology, the unclear market demand and the uncertainty in legislation necessitated that the entire ecosystem was flexible in adapting to change. In this scenario, implementing agile as a development method significantly improved the incumbent firm's ability to organize activities in the ecosystem. Agile, as a way of working that exemplifies flexibility and adaptability to changes in the environment, facilitated the incumbent firm to better coordinate activities in the AD program. With a modular technology and flexibility in the organizing activities, the incumbent firm was able to orchestrate the emergence of a new innovation ecosystem and positioned itself as the keystone firm.

7. CONCLUSIONS

This licentiate thesis set out to understand the emergence of an ecosystem and how an incumbent firm can position itself as a keystone actor in the ecosystem Through a longitudinal study, this thesis shows how the case firm (incumbent in the automotive industry) leveraged on its JV to establish a modular technology and attracted other firms to collaborate in the technology development. The ownership of a modular technology facilitated the keystone to enable other actors to develop complementarities. This, according to literature, enhances a new technology's potential to become a dominant design. The development of a modular technology through a JV, and the establishment of multiple collaborations to develop features and services for the technology platform, led to emergence of a new innovation ecosystem and positioned the case firm as the keystone firm.

8. FUTURE STEPS

The ecosystem studied as part of this licentiate thesis is a closed system where the primary goal is "value creation" (i.e., innovation ecosystem). Innovation ecosystems are closed networks where transactions occur amongst actors that participate in creating value (Jacobides *et al.*, 2018). As the ecosystem develops, new challenges arise related to appropriating this value. To move from "value creation" towards "value capture", all actors must collaborate and persevere for common standards for the technology (Brem *et al.*, 2016). In literature, the value creation ecosystem is addressed as an innovation ecosystem (Adner *et al.*, 2016; Gomes *et al.*, 2018; Oh *et al.*, 2016) and the value capture ecosystem as a business ecosystem (Adner, 2017; Moore, 1993). In an innovation ecosystem, the primary objective is to develop value in the form of a product or service. In a business ecosystem, actors are motivated by commercial prospect of the new product or service.

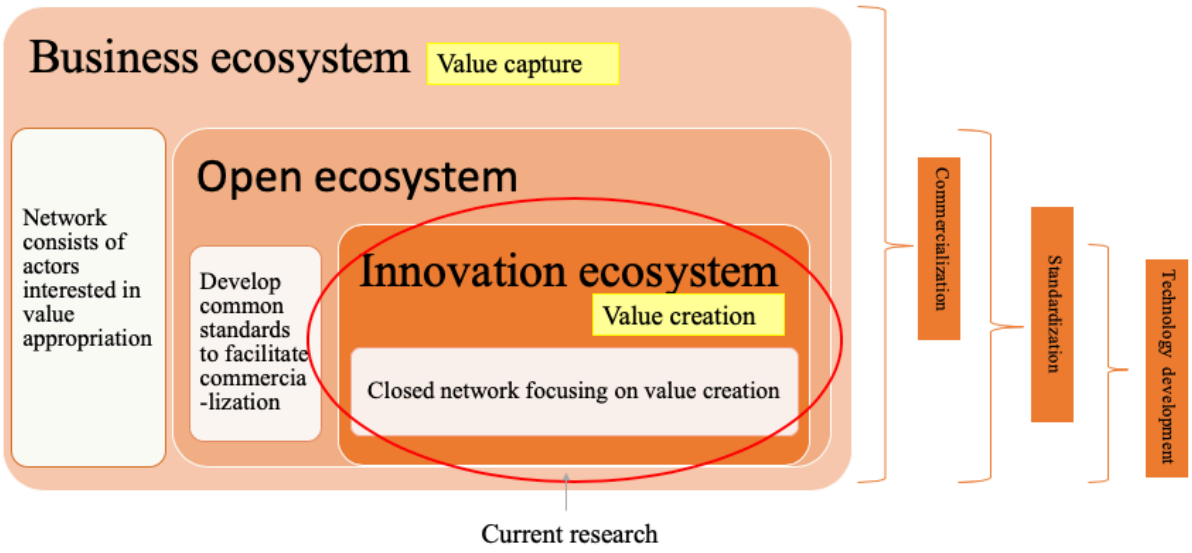

Figure 7 From value creation to value capture

This process of moving forward from an "innovation ecosystem" towards a "business ecosystem" necessitates a platform where all actors, from industry incumbents, to start-ups, to universities, can work together with the common goal of establishing standards for a new technology (see figure 7) (Gawer *et al.*, 2014; Rohrbeck *et al.*, 2009; Williamson *et al.*, 2012).

The plan for the second part of my PhD research is to better understand how an innovation ecosystem matures into a business ecosystem and the role of the keystone actor in facilitating this transformation, as outlined in Figure 8.

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