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Master's Programme in Industrial Engineering & Management

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Towards a dynamic capabilities view on ecosystem formation:

A case study on the emergence of an innovation ecosystem

Master's thesis

Helsinki, 28th December 2019

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Aalto University School of Science Master's program in Industrial Engineering & Management		ABSTRACT OF THE MASTER'S THESIS
Author: Ngoc Le-Östlin		
Title: Towards a dynamic capabilities view on ecosystem formation: A case study on the emergence of an innovation ecosystem		
Number of pages: 155	Date: 28.12.2019	Language: English
Major: Operations & Service management		Code: SCI3049
Supervisor: Professor Riitta Smeds		
Advisor: Doctoral Candidate Ulriikka Järvihaavisto		

Digitalization is a catalyser that drives rapid changes in industries. While bringing huge opportunities for business, digitalization outdated existing capabilities and working methods, thus, it brings threats to companies who cannot timely innovate themselves. In today's business landscape, no company has sufficient resources to develop digital innovation alone. Companies have to be able to attract, secure and combine a variety of new resources and competencies from other organizations to co-create new services on top of its technology platform. Currently, we see that *innovation ecosystems* are emerging to answer to this need.

Innovation ecosystems are inherently complex as they consist of multiple actors coming from different cultural, political, economical and knowledge backgrounds. Thus, developing innovation ecosystems can be very challenging. However, we have not been equipped with sufficient theoretical and practical knowledge to understand how a company can form an innovation ecosystem. Therefore, this thesis was set to establish a deeper understanding of the *factors and capabilities* that support the formation of an innovation ecosystem.

Through an extensive literature review of both fields - ecosystem and dynamic capabilities, this thesis established the first theoretical model that explains the development of an innovation ecosystem. This theoretical model was applied and developed iteratively in an in-depth case study of a European-based Intelligent Mine innovation ecosystem. This thesis was conducted using an exploratoratory, qualitative approach and followed an abductive research design. Data was collected through several open-ended interviews with ecosystem members, and analysed following Gioia methodology.

The results of this thesis shed light on: (1) the *key factors that trigger the formation* of an innovation ecosystem, (2) the *motivations of a hub company* for forming an innovation ecosystem, and (3) the *sensing and seizing mechanisms* that a hub company employed while forming its innovation ecosystem. Moreover, a conceptual model was developed after refining the initial theoretical with new empirical insights. This thesis contributes directly to the development of new theory on ecosystem formation and the new application of dynamic capabilities framework in ecosystem literature. It also provides useful suggestions for companies whose aspiration is to develop innovation ecosystems around their core technologies.

Keywords: innovation ecosystem, dynamic capabilities, interorganizational network, sensing, seizing, digitalization

ACKNOWLEDGEMENT

Writing this thesis has been quite an exciting journey. Thanks to this thesis, I learnt a lot about ecosystems, dynamic capabilities, and most importantly, I had a chance to work closely with a great supervisor and helpful colleagues in Simlab.

As this thesis concludes my Master's study chapter, it is a chance to look back on my journey at Aalto University. The past three years in Finland was the most challenging, yet important period of my life. All the mistakes, learning, friendship, love, and working experiences which I gained in the past three years defined who I am today. They will be cherished forever.

This thesis could not be completed without the support and guidance of many people. So to them, I am forever in debt.

First, I would like to thank my supervisor Riitta Smeds for arranging all the needed funding so I could have an ease of mind while conducting my research. Riitta's invaluable comments and suggestions have greatly improved my research and my writing. Her efforts to integrate me into the Finnish society and her advice on family and marriage matters will always be remembered.

Second, I would like to thank my instructor Ulriikka Järvihaavisto for getting valuable contacts for my research. Ulriikka's cheerful encouragement, suggestions and tips were very helpful for me while conducting my thesis.

Third, I want to express my gratitude to all company Interviewees who participated in my research interviews despite their busy working schedules. Without their participants, this thesis can no way be completed.

Finally, I would like to thank my parents, my husband Emil Östlin and my friends for their unconditional love. Thanks for being by my side and supporting me through all the ups and downs.

Ngoc Le-Östlin

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ABBREVIATIONS

AI	Artificial Intelligent
VRIN	Valuable, Rare, Inimitable and Non-substitutable

I. Introduction

This thesis studies the formation of an innovation ecosystem around a digital mining technology hub company. The main objective of the thesis is to understand what factors and capabilities support the formation of an innovation ecosystem. To achieve this objective, an initial theoretical framework is formed by connecting key concepts from the literature of ecosystems and dynamic capabilities together. Thereafter, the initial theoretical framework is tested in an exploratory qualitative case study of an emerging innovation ecosystem around the digital mining technologies. Following an abductive reasoning process, this thesis proceeds through several rounds of theoretical and empirical analyses.

In this thesis, the theoretical part firstly presents the key concepts of innovation ecosystems. Next, the concept and mechanisms of dynamic capabilities are presented along with complementing concepts of organizational resources. The empirical chapter provides understanding about the case context, and analyses based on in-depth interviews of the hub company managers and ecosystem actors.

The first chapter of this thesis presents my research motivation, literature gaps, research objectives and scope, the main research question, background of the ecosystem case and the thesis's overall structure.

1. Background & motivation

Digitalization is a catalyst that drives rapid changes in all industries. With the advancements in information technology and communication, nowadays, customers have better access to a wider range of products and services that are available right at their fingertips. Thus, due to the fact that customers have many options to choose from, firms need to constantly compete with others by innovating their businesses to catch up with the latest market trends and improve their technologies. The "total experience" that customers nowadays

demand calls for *"complex, integrated solutions rather than standardized products and services delivered in homogeneous volume"* (Williamson & Mayer, 2012). To meet such market demand, relying only on internal resources and competencies can no longer guarantee long-term, sustainable competitive advantages (Iansiti & Levien, 2004). Therefore, companies need to capitalize on the accumulative and collaborative power of business ecosystems around them to develop innovative solutions. In fact, Huxham and Vagen (2005,3) emphasize the power of collaboration in one sentence *"Almost anything is, in principle, possible through collaboration because you are not limited by your own resources and expertise"*.

Recently, we have witnessed success stories of companies such as Microsoft, Amazon, Walmart, Apple and Google creating enormous value to their end-customers by leveraging the accumulative power of collaboration in their innovation ecosystems. Such innovation ecosystems represent complex networks of multiple economic and non-economic actors interacting with each other through collaborative arrangements in which they integrate individual offerings into coherent, customer-facing solutions (Adner, 2006; Adner & Kapoor 2010). Enabled by the advancements of digital technologies, developing innovation ecosystems has become a strategic focus for companies' growth and renewal in various industries (Adner, 2006).

Since innovation ecosystems are highly complex inter-organizational networks (Jucevicus & Grumadaite, 2014), developing and growing them can be very challenging. In fact, the challenges of developing innovation ecosystems require firms to develop and leverage capabilities to grow and renew their ecosystems (Teece, 2007, 2017, 2018). Faced with various challenges coming from the fast-changing technology market and resource scarcity, *dynamic capabilities* (Teece, 2007, 2018) are increasingly important for firms who want to innovate by forming innovation ecosystems and platforms. In fact, firms possessing the capabilities to continuously sense, seize and transform themselves to realign with the ever-changing business landscape can better shape innovation (Teece, 2007). In the journey of adapting and innovating, firms "*purposefully create, extend, or modify their resource bases*" (Helfat et al., 2007) by

integrating complementing resources (Teece, 2007) to develop new solutions through innovation ecosystems. However, it remains unknown to us how firms dynamically extend their resource bases to successfully form innovation ecosystems. Therefore, this thesis is conducted to investigate the factors and capabilities that support organizations during the formation of innovation ecosystems. To explore the topic, this thesis establishes a bridge between two usually isolated literature streams - dynamic capabilities and ecosystem development - to create a multi-dimensional view of how companies engage in the development of innovation ecosystems. Through an extensive literature review, a framework explaining the formation process of innovation ecosystems through the lense of dynamic capabilities is synthesized. Thereafter, the framework is applied and fine-tuned through an explorative single case study of an emerging innovation ecosystem in the mining industry.

2. Literature & research gap

The term “ecosystem” has gained enormous interest from the research community over the past 20 years (Adner, 2017; Jacobides et al., 2018; Shipilov & Gawer, 2019). In fact, the total number of articles mentioning the term “ecosystem” in the seven mainstream journals rose from just 230 in the year 2000 to 4000 in the year 2018 (Shipilov & Gawer, 2019).

Despite the great effort in the existing ecosystem literature, the question about when and why ecosystems emerge has not received sufficient attention in the literature (Jacobides et al.,2018). Moreover, there are still many unanswered questions regarding how ecosystems are formed, governed and commercialized. Indeed, there is a huge gap in literature relating to dynamic capabilities required during the transformation of ecosystems from the emergence phase to the growth and renewal phase. For example, in the current competitive business setting, what kinds of capabilities enable firms to successfully create, develop, grow and renew their ecosystems over time? How do firms create sustainable value for their businesses while engaging in ecosystems? How do firms enter and exit ecosystems? How can firms identify and select

complementary resources? How do they transform acquired complementary resources into long-term competitive advantages? Given that we are living in a constantly changing business world, which capabilities help firms to facilitate goals alignment, reduce uncertainty and manage the complex ecosystem dynamics? These questions are important for both hub companies whose aspiration is to build ecosystems around their core technologies and also for complementors who provide complementing technologies to the hub.

Recent research has shed some light into possible ways to answer the questions above. Dynamic capabilities framework is suggested to be helpful in understanding the required capabilities for ecosystem development. Recent theoretical studies suggest some forms of dynamic capabilities that are essential in ecosystem development such as generative sensing (Teece, 2017, 2018), environmental scanning (Teece, 2017, 2018), innovation capability (Helfat & Raubitschek, 2018) and integrative capability (Helfat & Raubitschek, 2018). However, in practice, no empirical studies have been conducted to verify the existence of those capabilities at the ecosystem level. Therefore, more research is needed to shed light on the development and employment of dynamic capabilities in emerging markets and ecosystems.

3. Research objectives, scope & questions

The first theoretical objective of this research is to respond to the literature gap in the intersection between dynamic capabilities and ecosystems. Thus, my research seeks to establish a bridge between two usually isolated literature stream - dynamic capabilities and ecosystem development. As Amabile (1996) and Shipilov & Gawer (2019) highlight, creative insights are created in the intersection of multiple areas of knowledge. With the desire to connect the two literature streams together - dynamic capability and ecosystem development, I wish to generate creative insights which potentially help to illuminate academic discussions, so we could establish a holistic, multi-dimensional view on how hub companies engage in the development and growth of ecosystems.

The second theoretical objective of this thesis is to gain a deeper understanding of how a hub company forms an innovation ecosystem. Therefore, my research aims to explore the possible factors and capabilities that assist a hub company while forming an innovation ecosystem.

The practical objective of this thesis is to establish a guideline on how companies can successfully develop an innovation ecosystem in practice. While not aiming to generalize the findings of this thesis to other cases and contexts, the empirical findings of this thesis seek to serve the case company, and to act as references for other companies when they aim to improve the effectiveness of their ecosystem formation.

This thesis studies the formation of an innovation ecosystem around digital mining technologies. The innovation ecosystem that underwent I study is still going through its formation. Thus, this thesis was scoped within the emergence phase only. Moreover, due to the time constraint of this thesis, analyses were conducted with a focus on the hub company while forming its innovation ecosystem.

Therefore, taking my research objectives and research scope into consideration, the **main research question** of this thesis becomes: *How can a hub company support the formation of its emerging innovation ecosystem?*

4. Structure of the thesis

The thesis is organized in four main chapters: Chapter I - introduction to the research, Chapter II - theoretical background, Chapter III - empirical case study, Chapter IV - discussion, Chapter V - theoretical integration & conclusion, Chapter VI - evaluation and Chapter VII - implications.

In Chapter I, motivation of the study, literature gaps, research objectives, scope, main research question and the case context are highlighted.

Moreover, Chapter II presents a theoretical review of innovation ecosystems and dynamic capabilities. In the literature review of innovation ecosystems, key ecosystem concepts

and characteristics are studied. Next, the theoretical review of dynamic capabilities begins with some highlights on organizational resources, then continues with the introduction of dynamic capabilities concept and its sensing, seizing, and transforming mechanisms. At the end of the theoretical background chapter, reviewed literature is synthesized and presented in an initial theoretical framework.

In Chapter III, empirical research questions are presented at the beginning of the chapter. Following the empirical research questions, details of the innovation ecosystem case, along with data collection and analysis methods are explained. Subsequently, empirical findings are presented.

Chapter IV is dedicated to discuss the empirical findings. In Chapter V, the empirical findings are contrasted with the initial theoretical framework and reviewed literature. The overlappings and gaps between this thesis's findings and existing literature are highlighted. A refined framework is presented at the end of Chapter V.

Furthermore, Chapter VI discuss the quality and limitation of this research. Finally, Chapter VII suggests managerial implications, theoretical implications, and recommendations for future research.

II. Theoretical background

The literature review chapter forms a theoretical backbone for this study. This chapter reviews two literature streams that are often isolated from each other - ecosystems and dynamic capabilities. Supporting literature from interorganizational network theory, innovation management and organizational strategy are also utilized to provide diverse viewpoints to assist with the theory building nature of this research. Due to the vast amount of research has been conducted in these fields, only key findings which are relevant to the topic of research were selected to present in this chapter. By drawing insights from these literature streams, an initial understanding about how the concept of dynamic capabilities can be useful for ecosystem

formation is developed. At the end of the chapter, an initial theoretical framework is formulated based on the synthesis of the literature review.

1. Untangling the concept of innovation ecosystems

Ecosystem literature has a connection with network theory as both fields focus on explaining the phenomenon behind the complexity of inter-organization networks. In the following chapter, I will introduce an overview of ecosystem concepts and definitions. Literature of network theory, ecosystem and innovation management stream will be utilized in this chapter in order to bring out a lively picture of ecosystems in general.

1.1 Overview of the ecosystem concept

Research has shown a good effort in addressing what ecosystems are and how they can be developed (Iansiti and Levien, 2004; Javalgi et al.,2004; Nambisan & Sawhney, 2011; Adner, 2017; Jacobides et al., 2018). Overall, the research on ecosystems constitutes of three main literature streams: (1) business ecosystems which focus on the hub firm and its centrality, (2) innovation ecosystems which centers around technological advancement efforts and (3) platform ecosystems which pay great attention on the economical arrangement of complementing solutions around a core technology (Jacobides et al., 2018). Although each stream displays a different research focus, they suggest some common characteristics of ecosystems : (1) the symbiotic relationship between the hub and its complementors (Moore, 1993, 2006; Iansiti and Levien, 2004) (2) the modularity and complementarity of technologies, allowing ecosystems to emerge and grow (Jacobides et al., 2018, Shipilov & Gawer, 2019) and (3) co-evolution of members along ecosystem life-cycle (Iansiti and Levien, 2004).

To date, the most cited theory about ecosystem was originally proposed by Moore (1993, 1996, 1998). Moore introduces ecosystem in the business literature as *"An economic community supported by a foundation of interacting organizations and individuals – the organisms of the*

business world." (Moore, 1996: 26). In another attempt to clarify what this economic community called ecosystem consists of, Moore (1998) adds that business ecosystem is an *"extended system of mutually supportive organizations, communities of customers, suppliers, lead producers, and other stakeholders, financing, trade associations standard bodies, labor unions, governmental and quasi-governmental institutions, and other interested parties.*" (Moore, 1998: 168).

Various features from the business ecosystems can be related to the biological ecosystems, such as the complex structure of loosely interconnected actors, the shared fate between ecosystem members, and the roles played by each of them (Iansiti & Levien, 2004). Indeed, the analogy between the economic ecosystems and the biological ecosystems enriches our understanding about the interconnectedness of economical identities to a larger business environment (Anggraeni et.al, 2007). Due to the usefulness of this analogy, business researchers have extensively applied the biological ecosystem representation while seeking to explain the dynamics present in the complex network of inter-organizational relationships between business actors within and across industries (Adomavicius et.al, 2006; Anggraeni et. al, 2007). For instance, business ecosystems are similar to biological ecosystems in the sense that they form around interacting species which need to constantly respond to the dynamic environment (Iansiti & Levien, 2004). These species must constantly reconfigure and renew themselves to react to natural disturbances and the competitions among them. However, business ecosystems are different from natural ecosystems in a way that natural species do not have the conscious power of choosing which ecosystems they want to grow into, on the other hand, firms in business ecosystems can choose intentionally where they want to belong (Moore, 1996).

Moore (1996) states that business landscape should be viewed as a world consisting of business ecosystems, instead of "industries". Due to the enhanced technological power and the dramatic fall in the cost of information technology and communication, firms can better coordinate the dispersed capabilities and uncodified knowledge around the globe to form new business ecosystems (Williamson & Mayer, 2012). Many giant companies such as Apple, Uber,

Google, Facebook, Microsoft, Walmart, AirBnB have successfully adopted the business ecosystem mindset and mastered ecosystem business models. Small and mid-size firms, even independent freelancers are active partners in various ecosystems created initially by hub companies. For example, various app developers are contributing to the vibrant ecosystem around Facebook platform by actively producing new applications to Facebook end-users. Interestingly, Facebook community is not only opened for app developers, it is also a place where advertisers reach out to potential customers by producing more engaging, tailored content to the end-users.

1.2 Ecosystem roles

Every ecosystem consists of hub companies (or, in other name, keystone players) and complementors (or, in other name, niche players). While each player may have a different role in the ecosystem, their actions and behaviors affect the ecosystem's overall health. In this section, each of these ecosystem role will be discussed respectively.

First of all, the concept of a hub company can be better understood by relating it to keystone species in biological ecosystems. Keystone species are those whose presence have a paramount effect on other organisms within biological ecosystems. Through their behaviors and features, they benefit the ecosystem's overall health and its biodiversity (for example: honey bee is a keystone species. While gathering nectar from one flower to others, honey bees move pollen around, thus, helping the reproduction of plants). Removal of keystone species create dramatic cascading effects through the entire ecosystem, resulting in the decline of ecosystem health, loss of diversity, productivity, and eventually, extinction (Iansiti & Levien, 2004). It is interesting to note that, despite having lasting effects on the ecosystems, they are the least in count.

Sharing the same meaningful role as "keystone species" in biological ecosystems, the presence of hub companies is vital for the health and well-bring of business ecosystems (Iansiti & Levien, 2004). A hub company is a firm that provides a core offering or a core platform for

others to develop their complementing products/services on top of it (Gawer & Cusumano, 2008). Because the hub company provides the foundation for the development of complementing products/services, the removal of a hub company jeopardizes the existence of the whole ecosystem. Moreover, the hub company makes conscious choices on how the ecosystem operates. They *"set, and often enforces, the governance rules, determines timing, and often reaps the lion's share of gains after the ecosystem is aligned"* (Adner, 2017, 48). Through its actions, a hub company directly impacts the ecosystem productivity, robustness and niche creation (Iansiti & Levien, 2004). A hub company increases ecosystem robustness by constantly updating new technologies to improve the efficiency of the ecosystem as a whole (Iansiti & Levien, 2004). Moreover, it encourages niche creation by offering their technologies to a variety of third parties to produce new applications to the ecosystem (Iansiti & Levien, 2004).

Along the evolution of a business ecosystem lifecycle, a hub company needs to shift their actions and focus accordingly. For example, in the emerging phase, the hub companies carry the responsibility to make conscious choices to identify complementing capabilities, attract ecosystem members and design the ecosystem architecture so that value propositions are materialized (Moore, 1993; Teece, 2018). During the growth and renewal phases, hub companies work collaboratively with complementing actors (complementors) to constantly test, refine and expand their business ecosystems. There is a co-evolution in the roles and capabilities of both hub companies and their complementors so that improvement in the ecosystem offerings is introduced in a continuous manner, thus, enabling the ecosystem growth and renewal.

A hub company ensures its survival through collaborations with complementing partners (Iansiti & Levien, 2004, Teece, 2007, 2014). As customers in today's market prefer an ecosystem of integrated products and services instead of a stand-alone solution, various companies are faced with increasing pressure of having to innovate themselves by adding more advanced products into their offerings. When a company does not have all the necessary skills or financial

resources to produce innovative products by itself, it needs to rely on the strength and power of complementing partners. In fact, complementors are crucial for ecosystem's value creation (Iansiti & Levien, 2004). Complementors make up the majority of the ecosystem population, thus, their survival are critical to the ecosystem's overall health.

1.3. Concept & Characteristics of innovation ecosystems

As the result of a shifting paradigm from "invent-it-ourselves" attitude towards "invent-with-others", companies increasingly engage in complex innovation networks to create technically advanced solutions (Chesbrough, 2003). While expanding resources globally, firms do not limit themselves within a single industry (Moore, 1993; Iansiti and Levien, 2004; Adner, 2017; Jacobides et al., 2018). Instead, they form multidisciplinary innovation ecosystems consisting of a vast amount of diverse agents such as public organizations, companies, universities, entrepreneurs, investors, and policy makers etc. (Plowman et al., 2007; Johnson, 2009; Jucevicus et al., 2014; Jacobides et al., 2018).

innovation are the vehicle for firms' strategic growth and renewal. For decades, literature on systems of innovation has viewed innovation as the development of linear solutions (Jucevicius & Grumadaite, 2014). However, such linear structure fails at providing a completely functioning innovation system because it does not take into account the complex social dynamics of its interacting actors (Jucevicius & Grumadaite, 2014). Thus, there has been a gradual switch from "innovation systems" to "innovation ecosystems" to address such complex characteristics (Jucevicius & Grumadaite, 2014).

Durst & Poutanen (2013) view innovation as new ideas, improvements and solutions that are implemented with the goal of creating new values and enhancing firms' competitive advantages. Adner (2006, 98) points out that multiple firms choose to create innovation in *"collaborative arrangements through which firms combine their individual offerings into a*

coherent, customer-facing solution" The necessity for firms to engage in such arrangements is because innovative products and services require a complex integration of both codified and uncodified knowledge which are possessed by various firms, not a single identity alone (Durst & Poutanen, 2013). In innovation ecosystems, there are many interdependent actors who play major roles. They are *"economic agents and economic relations as well as non-economic parts such as technology, institutions, sociological interactions and culture"* (Mercan & Goktas, 2011, 102).

Innovation ecosystems are highly complex inter-organizational networks (Jucevicus & Grumadaite, 2014). Similar like any social ecosystems, innovation ecosystems consist of various cultural, economical, technological and political interactions (Jucevicus & Grumadaite, 2014). Innovation ecosystems are characterized by "*network ties, co-evolution, self-organization and disequilibrium*" (Jucevicus & Grumadaite, 2014). Various research highlight the dynamic nature of innovation ecosystems which is formed on the foundation of the interactions between a vast amount of diverse agents - public organizations, firms, universities, entrepreneurs, investors, and policy makers (Plowman et al., 2007; Johnson, 2009; Jucevicus et al., 2014). Each agent operates in a loosely coupled network where there are weak ties between them. Moreover, they are self-organized agents who operate with zero or minimum direct control from the hub firms (Chiles et al., 2004; De Toni et al., 2012). They interact with other members within the ecosystem and also, interact with the external business environment. Thus, in response to the changes in the external environment, there are spontaneous bottom-up interactions without a central control from the hub organization, causing a disequilibrium in the ecosystem (Jucevicus & Grumadaite, 2014). Thus, an innovation ecosystem is a highly complex adaptive system, meaning that, its nonlinear characteristics cannot be explained by a simple linear, input-output process.

2. Dynamic capabilities in ecosystem formation

In this chapter, a literature review on dynamic capabilities along with key concepts of organizational resources are presented. While keeping in mind that dynamic capabilities can exist in many forms ranging from managerial cognitive capabilities, ambidexterity, and entrepreneurial behaviors, I choose to focus the literature review of dynamic capabilities on the organizational practices that underlie in the microfoundations of dynamic capabilities.

2.1 Organizational resources

Resources are the underlying foundations of every business, because without them, no organization can operate and survive. Resources lie at the heart of organizations, in deed, they represent organizational strength. When resources are valuable, rare, inimitable and non-substitutable, they help companies to gain competitive advantages over their competitors (Barney, 1991)

Resources can be classified in two categories - intangible or tangible. While tangible resources are physical assets such as equipment or cash, intangible resources manifest in various invisible forms (Kantola, 2015). Some examples of intangible resources can be knowledge, know-how, personal network, organizational reputation, marketing brand, data, intellectual property rights and customer relationships (Hall, 1993; Eisenhardt & Schoonhoven, 1996).

Research in the field of organizational resources has shown diverging opinions about which organizational resource is more important. Some researchers argue that intangible resources are more critical because they offer the most potential for firms' long-term success (Barney, 1991; Hall, 1993). On the other hand, it has been suggested that the role of tangible resources on firms' success cannot be neglected (Schriber et al., 2015).

In fact, firms need to possess both tangible and intangible resources. Especially, in a world of increasing business competitions, the ones possessing better tangible and intangible resources have higher chances to survive. Since digitalization has completely transformed industries, the new wave of advanced technologies and know-how has outdated various organizational resources. Thus, firms must realize that simply possessing resources do not help them to succeed in today's business landscape. It's time for them to learn and develop new capabilities to upgrade their resource bases with valuable, rare, inimitable and non-substitutable resources.

With the rising cost of labor wages and the increasingly competitive market, firms need to find ways to innovate faster while cutting cost and reducing investment risks. Thus, by extending and modifying their resource bases, firms develop as well as enter innovation ecosystems around them. The promising resources that the ecosystem members possess can be seen as opportunities for an individual company to upgrade its resource base. It is interesting to note that, a company can attract more resources if it has strong social positions (for example: well-known brand and good reputation) (Eisenhardt & Schoonhoven, 1996). On the other hand, firms in vulnerable strategic positions (for example: having outdated skills or lack of financial resources) are more likely to enter *interorganizational innovation ecosystems* to gain extra *resources* (Eisenhardt & Schoonhoven, 1996).

2.2 Overview of dynamic capabilities

In this ever-changing business landscape, firms need to have *dynamic capabilities* to continuously align and realign with the changing business world so that they can constantly upgrade their existing resources. The abilities to *"purposefully create, extend, or modify the resource base of an organization"* is called dynamic capabilities (Helfat et al., 2007). Since the first time it was introduced, dynamic capabilities framework has strongly established itself as one of the most influential theoretical lenses in our contemporary strategic management

research. Dynamic capabilities framework has entered various management fields such as entrepreneurship, innovation management, marketing management, and human resource management (Schilke et al, 2018). However, as a result of a content analysis of 298 articles, Schilke et al. (2018) demonstrate that there is no conceptual convergence in the dynamic capabilities field.

Dynamic capabilities framework is an extension of the resource-based view (Teece, 1997, 2007; Helfat at al., 2007; Ambrosini & Bowman, 2009). While resource-based theory regards *resources* as the only things that matter for organizational success, dynamic capabilities view the *abilities to continuously acquire and deploy resources* to enable organizational reconfiguration over time are the most important (Teece, 2007). In line with Helfat et al. (2007), in this thesis, I use the term "resources" in its broad sense as valuable, rare, inimitable and non-substitutable assets (Barney, 1991). Such resources can be intangible or tangible. Various researchers view dynamic capabilities as a valuable framework to understand how firms can perform purposeful modifications of its resource base in response to its external environment (Teece, 1997, 2007; Helfat et al., 2007; Helfat & Winter, 2011). They are valuable capabilities that firms develop overtime throughout their organizational history (Teece, 1997). Thus, they are firm-specific and that's why they cannot be bought (Barreto 2010).

To differentiate dynamic capabilities from other types of organizational capabilities, it is important to note that there are two distinct sets of capabilities: ordinary capabilities and dynamic capabilities. However, there is a blurred line between ordinary and dynamic capabilities (Helfat & Winter, 2011).

Ordinary capabilities are those capabilities that support basic functions within an organization such as: administration, operations, and governance (Teece, 2014). Ordinary capabilities are performed in well-defined tasks and can be measured against organizational standards or best practices. Furthermore, ordinary capabilities are encapsulated in some combinations of: (1) repetitive organizational routines/processes, (2) skilled personnel, (3) equipment & facilities, and (4) administrative coordination (Teece, 2014). Moreover, efficiency

is at the central of ordinary capabilities. Such capabilities are argued to be easily imitated by competitors or easily bought from outside (Teece, 2014). In a nutshell, ordinary capabilities are best perceived as those that enable organizations to do the right things in firms' core operational functions.

On the other hand, dynamic capabilities are about doing the right things at the right time to enable *organizational evolutionary fit*, thus, dynamic capabilities have more to do with innovation. Strong dynamic capabilities allows companies to stay on top of the latest market development as well as institutional changes. Moreover, they enable firms to build and rebuild their internal and external resources to maintain competitive positions in the continually changing market. Many companies do not have sufficient internal resources (such as finance) to completely build new valuable resources for themselves. Thus, to extend their internal resources without taking huge risks, they choose to co-innovate with external partners to share and leverage external resources. By doing so, they can adapt and transform more quickly.

Essentially, in terms of resources, the core foundation of dynamic capabilities consist of three main building blocks: (1) *sensing* - the ability to identify and assess external resources (2) *seizing* - the ability to allocate internal resources to fully integrate external resources and (3) *transforming & renewing* - the ability to transform acquired resources into long-term commercial advantages (Teece, 2014). In fact, firms who better at scanning, seizing and transforming resources display a strong dynamic capabilities (Hannah & Eisenhardt, 2018; Teece, 2018).

Dynamic capabilities reside partly in the management team (Teece, 2014). It is important to note that good managers do not rely entirely on rigid processes - they act creatively and entrepreneurially without being constrained by routines (Teece, 2014). Unfortunately, to the best of my knowledge, such practices have not been widely researched. Thus, while not neglecting that managerial cognitive abilities play crucial roles in the development of dynamic capabilities, this thesis focuses more on the organizational practices that make up the underlying foundations of dynamic capabilities in ecosystem formation. In my

thesis, while adapting the view of Teece (2014) on dynamic capabilities' microfoundations (i.e. sensing, seizing, and transforming), I integrate literature of interorganizational networks to build a more suitable dynamic capabilities framework for ecosystem formation. In the following sections, I will explain the underlying foundations of sensing, seizing and transforming respectively.

2.3 Microfoundations of dynamic capabilities

2.3.1 Sensing mechanism

Sensing is a microfoundation of dynamic capabilities (Teece, 2007; 2014). According to Teece (2007), sensing is crucial for organization's evolution and survival. In literature, organizational sensing mechanism was researched actively in many fields, especially in organizational marketing (Baker et al., 1999, Agarwal et al., 2003). It's been argued that firms who perform sensing capability better and faster than the competitors have higher chances to succeed (Teece, 2014). To crystalize the diverse literature of sensing mechanism, two subsets of sensing need to be discussed: (1) market scanning, and (2) complementor scanning. It is important to note that, while the focus of market scanning is to stay updated with the changing market, complementor scanning relates to identifying capable complementors to co-innovate together.

Market scanning

Research on dynamic capabilities highlight market dynamism as a key driver for firms' evolution (Eisenhardt & Martin, 2000, D'Este, 2002; Mota & Castro, 2004). Various studies suggest that firms' abilities to address the environmental changes and align their resources to the changed market conditions is critical for firms' survival (Staber & Sydow, 2002; Alvarez & Merino, 2003). The ability to sense market changes and adapt to it quickly is hard to imitate, thus, it can be considered as a source for long-term competitive advantage (Barney, 1991).

While scanning in the markets, firms engage in a continuous process in which they learn deeply and evolve dynamically with the changing conditions (Akgun, Keskin & Byrne, 2012).

Teece (2007) highlights that sensing capabilities should be embedded in organizational practices. More specifically, such practices entail the following activities: (1) identifying target market segments and opportunities, (2) addressing unmet customers' demand, (3) monitoring technology changes, (4) conducting research related activities, (5) monitoring competitors' changes and (6) updating policy changes (Teece et al., 1997; Oktemgil & Greenley, 1997; Staber & Sydow, 2002; Tuominen et al., 2004, Teece, 2007).

Firms perform sensing activities by continuously searching and exploring both local and global markets to gather relevant market intelligence (Teece, 2007). While seeking to make sense of the acquired market intelligence, it requires an individual to leverage their existing knowledge to interpret information in whatever forms it appears - a presentation from a conference, a conversation from a networking event, a company visit or an industry report. Information must be filtered out from professional and social contacts to create hypotheses about the likely evolution of technologies, changes in the business environment and the potential market needs (Teece, 2017). Organizations with a strong sensing capability form processes or routines in which acquired information are disseminated thoroughly within the organization, and especially, within top-management team. Frequent discussions, and continuous hypotheses testing enable firms to frequently explore the changing market to make timely decisions.

Complementor scanning

In the increasingly competitive world, firms need to constantly innovate themselves. Thus, tapping into the external technological markets to enlarge their internal technological resources is a must. While extending their own knowledge base, firms engage in collaborations with interorganizational networks to leverage complementing resources to develop new products or solutions. The combination of complementing external resources and internal resources creates a synergy within an interorganizational network, thus producing greater value for innovation than any single firm could do alone. Complementing resources can be seen as co-specialized assets whose value are functions of their uses together with other assets (Teece,

2007). Indeed, there is a strong functional co-dependence between those assets or components.

While seeking for complementors to co-create new innovation solutions, firms form innovation ecosystems around them. Successful ecosystem formation begins with a careful selection of complementors (Sirmon et al., 2011). Teece (2007) suggests that pre-existing relationships, common industry origin or similar organizational characteristics create pathways for firms to enter into collaborative arrangements with external partners. An empirical study of a US-based R&D consortia found out that firms coming from similar industries often engage in innovation arrangements to co-create technological options for the future (Vonortas, 1997).

Firms often employ a regional strategy in which they identify resources within specific regions that can potentially give them the best access and support (Arregle et al., 2009). Close geographical proximity is an enabler for ecosystem formation as firms can spontaneously have face-to-face interactions, thus, increasing trust and strengthening social ties (Boschma, 2005). Furthermore, strong social proximity reduces the risks of opportunistic behaviors (Uzzi, 1997; Boschma, 2005). With regard to knowledge sharing, it can be easier to transfer tacit knowledge when they locate in a close distance with one another (Torre, 2008).

However, searching within local regions cannot guarantee to provide firms with the best complementors, especially when they are faced with an increasing talent scarcity and fierce competition for resources. Therefore, exploring international markets could provide a good source to identify complementors (Teece, 2007). Overcoming a narrow search horizon is extremely important for unlocking technological potentials of complementors (Teece, 2007). To do so, managers who engage in the technological search must be open-minded to prevent them from becoming their own prisoners of deeply ingrained assumptions and biased information (Henderson et al., 1994; Teece, 2007).

2.3.2 Seizing mechanism

Seizing is a subsequent process following the sensing of new resources such as commercial opportunities or technologies. Once new resources are sensed, they must be

addressed by rapid seizing mechanisms that are embedded in organizational leadership, architectural alignment, appropriability management and investment commitment. In seizing, it requires firms to leverage their own internal resources (such as human resources, financial resources) to fully capture external resources (such as complementing resources). Since the literature of dynamic capabilities on seizing mechanism focuses on managerial *cognitive abilities*, complementing literature of ecosystem and strategic alliances were used to enhance my understanding of the *organizational practices* being used to seize external resources. In the following sections, I will discuss the muli-dimensional facets of seizing through organizational visioning & leadership skills, architectural alignment, appropriability management and investment commitment respectively.

Visioning & leadership skills

Visioning capability of the hub company is critical while seizing external intangible resources (such as knowledge and know-how) (Spekman et all, 1998; Adner, 2017). Such capability is central for organizations to capture resources and most importantly, to realize value from the acquired resources (Spekman et al., 1998). First of all, a visioning skill is needed to *convince* external partners to share their resources. When the hub company formulates an *inclusive vision* for every member within the ecosystem, external partners are more likely to commit their resources because they can see potential benefits for participating in the ecosystem (Spekman et al., 1998). Once the ecosystem begins to take shape, managers must network within and across different organizational functions to secure sufficient financial and human resources to support the full realization of the new value brought by external resources.

Effective ecosystem management, especially during the ecosystem formation requires leadership skills. Studies show that managers having leadership skills and abilities to relate to others are more successful in managing interorganizational networks (Parker et al., 1996). Since each member entering the ecosystem might have different goals and different ways of working, problems arise when their expectations as well as actions are conflicting. If the ecosystem leader can facilitate a greater consistency between the members' goals and their expectations,

a higher likelihood that their actions will be convergent, which consequently increases the chance of generating positive innovation outputs (Adner, 2017). Thus, firms must employ practices to assess the members' level of motivations and goals, realize the possible gaps and then create conditions to close the gaps (whether through open communication, additional resource allocation or strategy revision) (Adner, 2017).

Ecosystem architectural alignment

To capture external tacit resources such as knowledge, skills and know-how, it is critical to have a supporting structure to enable easy integration of external resources. In fact, a focal value proposition cannot be materialized if there is no alignment structure between multilateral set of partners (Adner, 2017). Ecosystem alignment can be facilitated by setting up formal and informal interfaces in the interorganizational network.

Ecosystem leaders must define a basic architecture for the core innovation and invite members to build complementing components to make up this core innovation. A formal interface such as a flexible modular structure consisting of loose-coupled components can support knowledge integration (Akgun, Keskin & Byrne, 2012; Adner, 2017; Jacobides et al., 2018). The term modularity implies that the interorganizational network architecture is being decomposed into independently and loosely coupled units (Baldwin & Clark, 2000; Jacobides et al., 2018). Modularity can manifest at the physical level (for example, physical components arrangement) and data level (for example, digital system arrangement) (Richard & Devinney, 2005). Due to the weak linkages between the loosely coupled components, they allow each unit to have their own independent control, therefore, they can respond to changes quickly without affecting the other units (Beekun & Glick, 2001; Staber & Sydow, 2002). Moreover, one can flexibly modify a component without affecting the others, thus reducing unnecessary alteration costs (Richard & Devinney, 2005). Furthermore, the modular structure allows firms to test various combinations of components to improve the overall ecosystem design (Richard & Devinney, 2005). In general, modularized system consists of three elements: (1) the discrete functions that produce outputs based on given inputs, (2) the interface that sets standard

requirements for the flow of each component's inputs and outputs, and (3) the interactions taking place across component boundaries (Richard & Devinney, 2005).

While having a formal interface to guide the interaction flow is important, informal interfaces can be regarded as a "glue" to tie each loosely-coupled partner together. In interorganizational network collaborations, there is a positive relationship between collaborative interactions and efficiency as well as profitability (Lorange & Ross, 1993). Informal interfaces such as meetings are important to facilitate collaborative interactions. The frequency of meetings between members is a key indicator for creating alignment and facilitate knowledge exchange (Mothe & Quelin, 2001), especially during the emergence phase. Meetings are the forums for members to increase social ties and trust. Moreover, the intensity of social interactions between members contribute to the development of a common language, mutual strategic vision and knowledge base (Mothe & Quelin, 2001).

Management of appropriability

Ecosystem members have various concerns before joining an innovation ecosystem, including: (1) free-riding and opportunistic behaviors of other ecosystem members, (2) leaking of innovative technologies to competing companies/networks, (3) lack of clarity in tasks, and (4) uncertainty about ways to capture value created by the joint effort (Nambisan & Shawney, 2011). To remove those concerns and encourage members to contribute, the hub company should orchestrate innovation appropriability (Dhanaraj & Parkhe, 2006). Better orchestration of innovation appropriability results in more effective knowledge sharing and more cost-effective development of complementary products/services (Nambisan & Shawney, 2011).

One of the key enablers for knowledge sharing between firms is trust. In interorganizational networks, trust is essential for the formation of strategic partnerships between firms because it facilitates constructive dialogues (Johnson et al., 1996). Moreover, trust reduces the risks of partners' opportunistic behaviors (Ritala et al. , 2013). In innovation ecosystems, reciprocal trust stimulates openness and joint problem solving and reduce conflicts (Ritala et al., 2013). Thus, it increases the possibility of technological success. Trust can be

increased through cultural sensitivity, and organizational similarity. The abilities to acknowledge cultural differences, and adjust in new cultures increase the likelihood of successfully managing interorganizational relationships in international contexts (Dowling, 2008). Moreover, organizational similarities in terms of corporate values, culture, managerial styles and processes enable the development of trust (Johnson et al., 1996). A trust-worthy environment can be created and maintained by gradual, coherent and consistent effort over time. Constant open communication, maintaining personal relationships as well as coaching ecosystem members are intangible mechanisms that can be employed to build trust (Rita et al., 2013).

While intangible mechanism such as trust is undoubtedly important for ecosystem, tangible mechanisms such as contractual frameworks and intellectual property rights agreements can help firms remove their partners' fears for participating in the ecosystem. Contracts help align partners' expectations, intentions and incentives (Furlotti, 2007) under the uncertainty of the future partners' actions (Argyres and Mayer, 2007). Since interorganizational relationships are characterized by relational risks and performance risks (Furlotti, 2007), preventative mechanisms shall be employed. Relational risks are related to the likelihood of self-interest opportunistic behaviors (Mellewigt et al., 2012) and performance risks refer to the technological uncertainties that may arise from partners' competencies. Thus, contracts need to provide a mechanism to cope with those risks (Mellewigt et al., 2012). Clear definition of tasks, ownership and rights to use co-developed products/services must be discussed and mutually agreed. Moreover, addressing ecosystem members' concerns and motivations early on can help to improve the contract design, thus preventing future disputes and conflicts.

Managing investment commitment

An important element of seizing mechanism is to decide on whether or not one should make investments. Teece (2007) suggests that once opportunities are sensed, they must be addressed through organizational investment. The ability to make timely investment to realize potential opportunities is essential for organizations to stay ahead of the competition (Teece, 2007). Such investment might involve committing financial or human resources to develop a

certain set of technologies or new product features. Strategic decision making in investment is usually performed by top managers in organizations. Reports and written justifications are usually required by top managers to make investment decisions. However, bureaucratic organizational structures might slow down decision making, therefore, they do not support the development of innovation effectively (Teece, 2007). In fact, the existence of decision layers, rigid processes and routines hinders organizations in adopting disruptive innovation (Tushman & Henderson, 1986; Teece, 2007). Moreover, excessive risk aversion when making choices relating possible losses results in biased decisions that block innovation (Kahneman & Lovallo,1993). Investing in intangible assets (such as developing new technologies) without knowing a certain future payback is often a source for managerial excessive risk aversion (Teece, 2007). Such organizational challenges can be overcome if firms can create a working environment which encourages people to take risks. Moreover, having incentive structures for decision makers is also an organizational practice that reduces risk-averse behaviors (Teece, 2007).

In today's increasingly complex business ecosystems, firms face investment challenges outside of their own organizations as well. When firms enter interorganizational networks, they must coordinate with other members to commit their resources effectively. Due to the interdependencies between the work performed by each member in the ecosystem, it is critical to have mutual investment commitment to create positive innovation outputs jointly. Commitment can be measured by the size of human and financial resources as well as managerial responsibilities that members have during the daily activities of the ecosystem (Parkhe, 1993; Mothe & Quelin, 2001). In general, by showing strong commitment, ecosystem members signal determination to achieve mutual objectives, which in turn, indicating a desire for establishing long-term relationships with other members (Osborn & Baughn, 1990).

2.3.3 Transforming & renewing

After seizing essential resources, firms must fully transform acquired resources into long-term competitive advantages. Firms can do so by having appropriate business models.

Business models define firms' abilities to convert technological advantages into commercial advantages. While most existing business model frameworks focus on guiding firms to utilize their in-house resources to maximize their own profits, these frameworks are outdated when firms enter a sharing economy where common wealth should be preferred over a single firm's commercial objective. Thus, in the following sections, I aim to discuss why an ecosystem business model is needed and how it can be created. Moreover, due to the needs to constantly transforming while renewing organizations overtime, management of external and internal coherence is also highlighted.

Ecosystem business model design

The value of a new technology remains latent until and unless it is being commercialized with a right business model (Teece, 2007). A business model reflects the manner in which an organization delivers value to customers and make profits from the delivered value. To design a business model, organizations need to be able to answer these questions: (1) what are the intended value propositions? (2) Which technologies and features to be embedded in those propositions? (3) Which market segment to be entered? (4) How the revenue and cost structure can be designed to meet the customers' needs? (Chesbrough et al., 2002; Teece, 2007). It is important to note that, while existing business model frameworks often focus on how internal resources can be best utilized to generate economic value, they do not explain how a firm can leverage ecosystem resources to create greater value than what it could have done alone. Moreover, while the existing business model framework is useful to address how a single firm can capture value for itself, it is not beneficial to explain how a constellation of actors belonging to an innovation ecosystem can capture value together.

Thus, to generate values for the ecosystem as a whole, a business model must adopt an ecosystem view (Weiler et al., 2013; Adner, 2017). An empirical study of electrical vehicle innovation ecosystem in four countries United States, Japan, France and Norway shows that having an ecosystem view of value creation and capture is the key for successful commercialization of new innovation (Weiler et al., 2013). Since innovation ecosystem consists

of members whose fates are interconnected (Iansiti & Levien, 2004) , the focal firm designing the ecosystem business model must take partner firms' business models into consideration (Weiler et al., 2013; Adner, 2017). To do so, firms must make conscious choices to design a business model in a way that it makes a profit for the ecosystem as a whole, not just a single company. The empirical study of electrical vehicle ecosystems conducted by Weiler et al. (2013) gives an excellent example of how achieving an ecosystem view while designing business model can be useful. For example, an electrical vehicle ecosystem is a complex value network consisting of products and services supplied by electric car manufacturers, battery manufacturers, charging infrastructure developers, electricity producers, and information technology service suppliers. A business model for this electric vehicle ecosystem needs to take into account the commercialization of the whole integrated system instead of a single component in it (Weiler et al. ,2013). Another example can be: a business model of an airport needs to take into consideration how different members in the airport ecosystem such as luggage carriers, shop owners, airline agencies etc. can make their living. This example reflects the view that a focal firm can capture value for itself if its business model can create value for its stakeholders.

Along the evolution of the ecosystem lifecycle, firms must constantly adjust and improve its business model (Teece, 2007, 2014; Nambisan & Shawney, 2011). The capability to constantly modify and hone business models indeed lies at the heart of dynamic capabilities (Teece, 2007). Firms cannot rely on routinized or codified tasks to design and redesign business models. In fact, they must employ a large amount of tacit knowledge, creativity and experience (Teece, 2007). Top managers need to make informed guesses based on their own hypotheses of how customers and competitors will perceive and react. Along the journey of discovering the actual perception of the market towards certain products/services, managers must evaluate their business models through trials and errors. They also must collect fact-specific inquiries along their product/service lifecycle regarding: customers' needs, customers' budgets, supply

methods, complementing technologies, production costs, supply costs, and competitors' behaviors (Teece, 2007).

Business model experimentation is necessary for organizational renewal. A tool such as business model mapping helps firms to evaluate different business model alternatives (Chesbrough, 2010). Business model mapping analyses the underlying processes that make up the operation of a business model, thus, allowing companies to experiment by changing elements to formulate various business model options before committing real resources (Chesbrough, 2010). Following **Figure 1** displays a business model mapping canvas adapted from Chesbrough (2010).

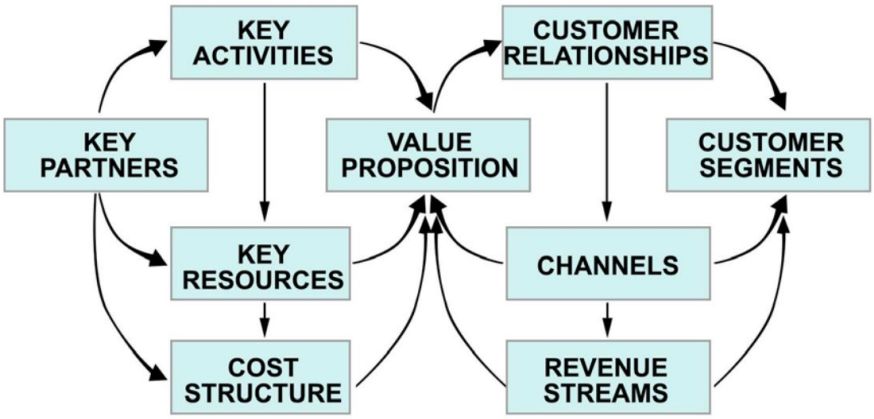

Figure 1 : Business model mapping framework (Adapted from Chesbrough, 2010)

While business model mapping is a good tool for experimenting with new business models, firms must remove the fear of failures, so that managers are more encouraged to start experimenting in real business settings. Moreover, firms must embrace fast experiment processes such as fast prototyping or lean methodologies to reduce experiment costs. Such methods emphasize more on conducting activities in the market to reveal hidden information, rather than heavy market research prior to the commercial activities (Saravasthy, 2009). With

the attitude of learning by doing, firms can capture new market information faster while developing market-fit solutions more efficiently.

Management of external and internal coherence

Firms operating in innovation ecosystems have the risk of becoming prisoners of their static visions of the market evolution (Bullinger, Auernhammer, & Gomeringer, 2004). The misalignment between the innovation ecosystem's internal goals and the external market context can diminish the value of the network outputs (Nambisan & Shawney, 2011). Thus, the hub firm plays a critical role to manage innovation coherence both internally and externally.

Changes in the technology and market environment create pressure for firms to re-align their innovation ecosystem architecture. The process of aligning an ecosystem's architecture towards the changing market is called *external innovation coherence* (Nambisan & Shawney, 2011). Following the adaptation of the market changes, firms need to restructure the coordinative interactions to maintain the ecosystem's efficiency and effectiveness. The process of firms aligning the internal interactions among ecosystem members is called *internal innovation coherence* (Nambisan & Shawney, 2011).

To maintain *external innovation coherence,* firms must continuously keep updates about changes in technologies, markets, competitors and suppliers. The market changes may obsolete existing technological components that are currently in use by the innovation ecosystem members. Moreover, when new technologies are introduced, new complementing knowledge might need to be integrated to enhance their innovation offerings to better fit the new competitive landscape (Teece, 2007). Thus, a redesign of ecosystem architecture is a must. To effectively influence ecosystem members' decisions on adapting themselves to the changing technical requirements, a hub company must employ two micro-processes such as: (1) information dissemination and (2) information interpretation and persuasion (Nambisan & Shawney, 2011). The ability to correctly interpret external technological changes and align members around those changes determines the continuing relevance of the ecosystem's

innovation outputs. Thus, firms must collect new information from the market, interpret them, disseminate information widely within its ecosystem and then, shape a vision of a promising future to persuade members to take actions (Nambisan & Shawney, 2011). An efficient dissemination of new knowledge aided with a common trust and a shared understanding can help reinforce the commitment of ecosystem members to adapt to the new market conditions.

Following the adaptation of the innovation architecture with the changing market conditions, firms are required to maintain an *internal innovation coherence* by reestablishing new coordinative interactions among ecosystem members (Nambisan & Shawney, 2011). Firms must redesign coordinative interactions of their ecosystem partners accordingly to ensure that they adapt their technologies to the changing market. In digital ecosystems, a modular structure offers a good architecture to manage interactions and knowledge flow. Such structure can be served as a foundation for activity synchronization during the innovation process (Richard & Devinney, 2005). Therefore, firms can employ modular structure to define and guide the newly established interactions of members in the ecosystem.

3. Theoretical synthesis

For companies facing increasing pressure in today's business landscape, engaging in innovation ecosystems can help them to innovate faster while lowering risks. Innovation ecosystems bring valuable resources to firms. Such resources can be intangible (such as specialized knowledge, know-how, and reputation) or tangible (such as physical equipment, plants and facilities). Firms can leverage their partners' resources to upgrade their existing resource base, thus improving their innovation power (Teece, 2007, 2014). As a result of the collectively strong resource base shared among ecosystem members, firms can produce much more advanced products/services than they could have done with their internal resources alone.

However, due to the dynamic and complex nature of innovation ecosystems, developing innovation ecosystems is a challenging task. Firms are faced with various difficulties, including:

(1) staying up-to-date with the changing market and technologies (2) finding competent partners who possess complementing expertise, (3) convincing partners to join the ecosystem (3) creating an ecosystem structure which enables partners to share their knowledge (4) aligning partners' interests, goals, working methods and commitment, (5) designing a business model that benefits every member within the ecosystem, and (6) constantly realigning the ecosystem with the ever-changing market. Such difficulties can be addressed by various organizational practices that lie within three microfoundations of dynamic capabilities: *sensing, seizing and transforming/renewing* (Teece, 2007, 2014).

One of the main objectives of **sensing activities** is to help firms *scan the market* for latest technological trends, new customer requirements and competitors actions. On the other hand, firms *tap into the external technological market to identify competent partners* to co-create new innovative solutions with. Firms perform scanning actions across their local and international markets in various channels such as: conferences, company visits, networking events etc. Interestingly, preexisting relationships, common industry origin or similar organizational characteristics can create pathways for firms to enter collaborative arrangements with external partners who bring complementing resources. To perform scanning activities effectively, managers must overcome their own biased assumptions and go beyond their narrow search horizon.

Once new resources are sensed, they must be addressed by rapid **seizing activities**. Such seizing activities are embedded in *organizational visioning & leadership skills, architectural alignment, appropriability management and investment commitment.*

First of all, the ability to create an *inclusive vision* is needed to convince external partners to commit their resources in interorganizational collaborations. When partners see potential benefits for themselves in the ecosystem vision, they are more likely to participate (Spekman et al., 1998). Moreover, effective ecosystem management requires *leadership skills*. When a hub company or an ecosystem leader has the ability to relate to others, there is a higher possibility to successfully manage interorganizational networks (Parker et al., 1996).

Moreover, ecosystem leaders must assess the members' goals and motivations, realize possible gaps and create conditions to close the gaps. Closing the motivational gaps can be done through additional resource allocation and strategy revision (Adner, 2017).

Furthermore, external partners cannot contribute their resources if there is no ready architecture for them to do so. Firms can create such *architecture* and facilitate *alignment* by setting up both formal and informal interfaces. A formal interface such as flexible modular structure allows easy integration of external tacit resources such as knowledge and know-how. Such loosely-coupled units can be modified without affecting the other components, thus, reducing the technological risks and unnecessary alteration costs (Richard & Devinney, 2005). While a formal interface can guide the interactions between ecosystem members, an informal interface such as frequent meetings can be seen as "glue" among the members. Frequent meetings increase social interactions between members, thus creating the foundation for a common language and mutual vision (Mothe & Quelin, 2001).

Management of appropriability is crucial for removing partners' concerns prior to joining an ecosystem. Because external partners may have fears relating to potential opportunistic behaviors of other ecosystem members, they are unlikely to share their specialized knowledge if there is no trust. A trust-worthy environment can be enabled by cultural sensitivity (Dowling, 2008) and organizational similarities (Johnson et al., 1996). Trust can be created through constant, gradual efforts of open communication, relationship maintenance and ecosystem members coaching (Rita et al., 2013). In addition to the intangible mechanism such as trust, tangible mechanisms such as contractual frameworks can facilitate stable partnerships. Moreover, contracts help to align members' expectations and intentions while reducing relational risks and performance risks (Furlotti, 2007).

After seizing essential resources, firms must employ practices to fully **transform** acquired resources into long-term competitive advantages. Firms can do so by having appropriate *business models.* Since innovation ecosystems consist of members whose fates are interconnected (Iansiti & Levien, 2004) , the focal firm designing the ecosystem business model

must take partner firms' business models into consideration (Weiler et al., 2013; Adner, 2017). A business model must be constantly adjusted and redefined along the ecosystem lifecycle. Since business model design requires a large amount of tacit knowledge and experiences, firms cannot rely on codified or routined process (Teece, 2007). They must encourage managers to overcome their fear of failures and risk-aversion attitude to experiment with new business models. Business model mapping canvas (Chesbrough, 2010), fast opportunity prototyping and lean methodologies (Saravasthy, 2009) are useful for business model experimentation.

Lastly, firms must constantly align and realign their ecosystems with the changing environment. **External innovation coherence** can be created when firms align their ecosystem members with the new technological changes. To maintain external innovation coherence firms must: (1) constantly update market changes, (2) interpret those changes, (3) disseminate information about changes within the ecosystem and (4), persuade members to take actions to better fit with market changes. Adapting an ecosystem with *external market changes* must be followed by maintaining a structure *within* the ecosystem to create **internal innovation coherence***.* Internal innovation coherence can be established by redesign members' tasks and interactions. To do so, firms can employ a modular architecture to define and guide knowledge flows and interactive actions of ecosystem members.

By integrating key literature findings, an initial theoretical framework is synthesized as in **Figure 3.** In this theoretical framework, the development of an innovation ecosystem is presented through the lense of dynamic capabilities. The theoretical framework assists our understanding on how a hub company facilitates the formation and growth of an innovation ecosystem under the influences of market dynamics. Placing at the center of the theoretical framework are the organizations' motivations for participating in innovation ecosystems: modifying their existing resources bases by leveraging ecosystem resources. Those resources can be either tangible resources (such as physical equipment and facilities) or intangible resources (such as data, intellectual property, and know-how). While forming and developing ecosystems, firms employ various mechanisms - sensing, seizing, transforming and renewing -

which are the underlying microfoundation of dynamic capabilities. Such mechanisms need to be performed in a continuous manner so that firms can align their ecosystems with market changes.

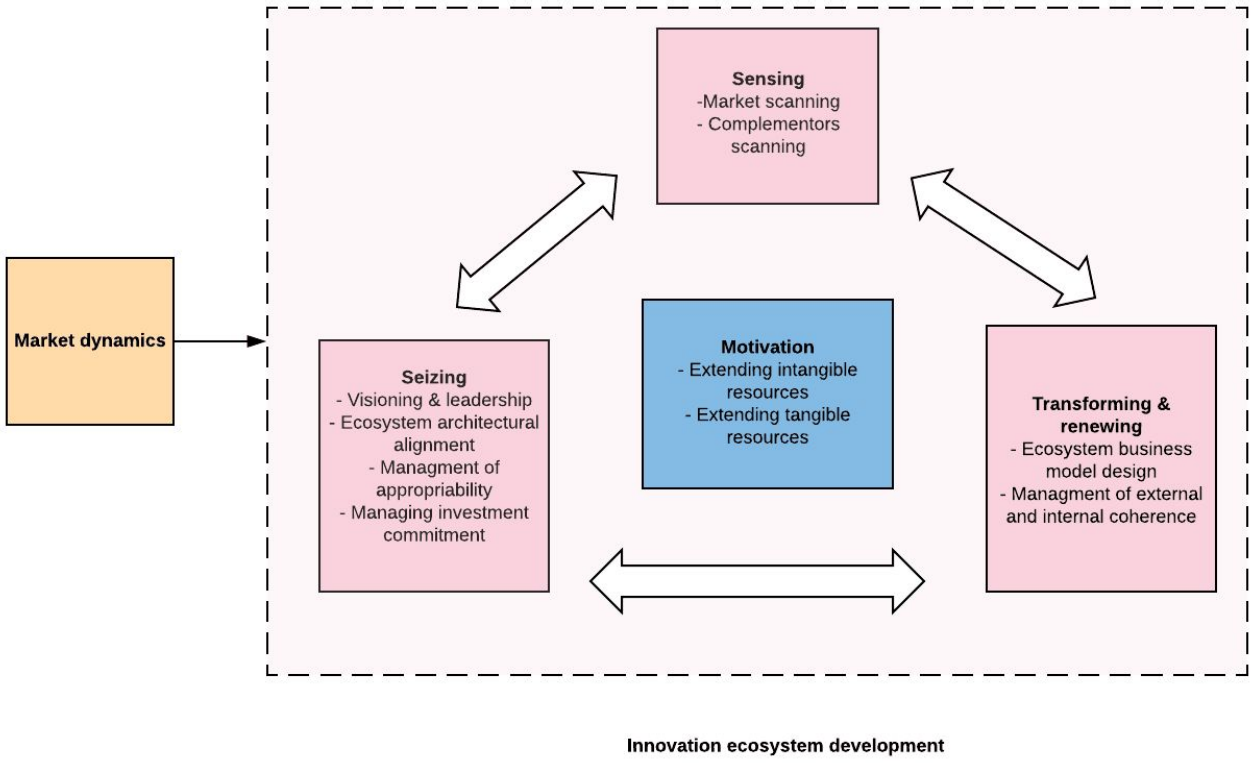

Figure 2: Theoretical framework

III. Empirical case study

1. Empirical research questions

In order to fully answer the research question of the thesis, empirical research is conducted to answer the following empirical research questions (ERQ) in more detail:

ERQ 1: *What triggers the need for developing an innovation ecosystem?*

ERQ 2: *Which resources is a hub company looking for in the emerging ecosystem?*

ERQ 3: *How does a hub company use its dynamic capabilities to enlarge its resource base?*

These questions are approached through an in-depth case study of an emerging innovation ecosystem. The first empirical research question aims to explore the key factors that triggered the formation of the case innovation ecosystem. Next, with a central focus on resources, the second empirical research question focuses on understanding the hub company's motivations behind the formation of its innovation ecosystem. Lastly, the third question aims to shed light on the capabilities that help the hub company to form the innovation ecosystem.

2. Case context & descriptions

2.1. Case selection & background

Saunders et al. (2009) stress that a research case needs to be particularly informative and it should best assist the exploration of possible answers for the research questions. Keeping in mind the interest in exploring the formation of emerging innovation ecosystems, an European-based innovation ecosystem which was going through its formation was selected as the research case.

In the beginning of 2019, a high-tech company focusing on mining equipment & solutions (Hub Company A) initiated the formation of an innovation ecosystem to co-create advanced digital solutions for the mining industry. During the emergence phase, the Hub Company A invited 12 international partners including business and academic organizations from 7 countries to join. To support the innovation ecosystem in researching and developing new technologies for the mines, the Hub Company A and its partners were applying for financial support from European Union during the time of this study. The innovation ecosystem was already approved by European Union to advance from the first funding application phase to the second phase. Due to the geographical challenges, mostly, online meetings were conducted between the Hub Company A and the ecosystem members. However, in July 2019, a two-day, face-to-face ecosystem meeting was conducted by the Hub Company A in Finland, with the presence of Interviewees from all ecosystem members.

At the time of this study, the innovation ecosystem was in its emergence phase. The selection of the initial partners was already done by the hub company. The funding application and project planning were on-going. In this study, the author of this master's thesis worked as a part of an academic research team completely independent from the Hub Company A.

In the following, **Table 1** illustrates the set of initial partners who joined the ecosystem during the emergence phase, along with their organizational size and ecosystem roles.

No.	Company code	Company overview	Location of headquarter	Total employees (2019)	Ecosystem role
1	Hub Company A	An engineering group focused on machining solutions, mining & rock technology and materials technology	EU country	42,000	Hub
2	Complementor B	A global corporation providing computer, IT and technology solutions	Non-EU country	350,600	Complementor

3	Complementor C	A multinational organization focused in telecommunications, IT and consumer electronics	EU country	103,083	Complementor
4	Complementor D	A company providing advanced hardware and software technologies for measuring and reporting ore grade and ore characteristics	Non-EU country	70	Complementor
5	Complementor E	A startup company providing AI solutions for industries and enterprises	EU country	25	Complementor
6	Customer Complementor F	An international mining corporation focus in exploration, acquisition, development, mining and processing of precious metal properties.	Non-EU country	388,000	Customer & Complementor
7	Complementor G	A startup providing optical sensor systems for non-contact chemical analysis	EU country	5-15	Complementor
8	Complementor H	A project management consulting company	EU country	50	Complementor
9	Complementor K	An AI company providing simulation for autonomous system	EU country	5-10	Complementor
10	Complementor L	A multi-disciplinary university focusing on engineering and technologies.	EU country	5000-10,000	Complementor
11	Complementor M	A university focusing on engineering and technologies.	EU country	5,200	Complementor
12	Complementor N	A university focusing on engineering and technologies.	EU country	1000-5000	Complementor

Table 1 - The ecosystem members in the emergence phase

2.2 Context of the emerging innovation ecosystem

The research case is an emerging innovation ecosystem around intelligent mining solutions. The **Intelligent Mine innovation ecosystem** was initiated by the **Hub Company A** - a large Nordic high-tech engineering group having extensive experiences in selling heavy equipment to underground mining customers. With an organizational strategy focused in digitalization, the Hub Company A aims to transform itself from working mainly as a traditional original equipment manufacturer (OEM) to providing more data-related solutions to the underground mining customers. Realizing that it does not have all the expertise and financial resources to fully develop digital solutions to tackle all the technical challenges in underground mines, Hub Company A formed an innovation ecosystem in order to develop innovative digital mining solutions faster and at lower costs.

At the beginning of the innovation ecosystem, **Hub Company A** formed a strategic alliance of twelve international partners with the goal of developing a complex platform which integrates various advanced solutions to tackle challenging issues in the mines. To support the research and development activities of the Intelligent Mine, the Hub Company A and its initial ecosystem members (**Table 1**) applied for public funding from European Union's Horizon 2020 programme. The ecosystem possessed a closed nature during the emerging phase as only a limited amount of partners and experts were selected to join the ecosystem. Although the alliance started with a closed nature, there is a potential that it will grow into a business ecosystem in the future. In the open-ended interviews with Hub Company's managers and ecosystem members, **6 out of 12 members** mention a believe that the current alliance will certainly grow into an innovation ecosystem in the near future.

2.3. Roles of ecosystem members

There are twelve international partners including business and academic organizations that participate in the EU project for the emergence of the Intelligent Mine innovation ecosystem. Although their capabilities and expertise could be developed and grown separately from each other in different contexts, in this case, they are all critical for the ecosystem's success. The failure in creating and delivering one component might lead to the whole ecosystem's failure. Like a biological ecosystem - the health, existence, and actions of an individual affect and are affected by other individuals within the Intelligent Mine innovation ecosystem. In fact, a symbiotic relationship exists between the technology providers, the hub company, the academic partners, and the funding organization.

Each partner in the emerging innovation ecosystem has a unique expertise which complements the others. For example, while the hub company provides a thorough understanding of the technical challenges in the mining industry, other partners provides sensor technology, AI algorithm, data analytics, and 5G connectivity to develop an integrated solution to tackle the addressed challenges.

Twelve members of the innovation ecosystem are organized and operated as modularized work packages in the EU project proposal - rock flow, energy flow, air flow, water flow, artificial intelligence, data analytics, 5G connectivity, sustainability assessment and ecosystem coordination. While the hub company and the management consultant company co-share the overall responsibilities of managing the ecosystem, each work-package has its own leaders taking care of the activities at the work package-level. These work package leaders were nominated by the ecosystem members.

Each work package focuses on an important aspect which needs to be improved in the mine. The rock flow work package aims to reduce mineral waste and improve mineral tracking by using advanced sensor technologies. The energy work package, air work package and water work package focus on the improvement of energy, air and water consumption respectively.

The artificial intelligent work package utilizes all the inputs from other work packages to develop an algorithm for process optimization, operational prediction and generate inputs for autonomous vehicles. The data analytics package assists the artificial intelligent package to utilize transmitted data around the mines. Moreover, the 5G connectivity package aims to develop a reliable wifi network for the mines, thus enabling real-time data transmission underground. Furthermore, the objective of sustainability assessment package is to develop key performance indicators that can track sustainability level of developed mining technologies.

Figure 3 illustrates an overview of the Intelligent Mine innovation ecosystem and its work packages.

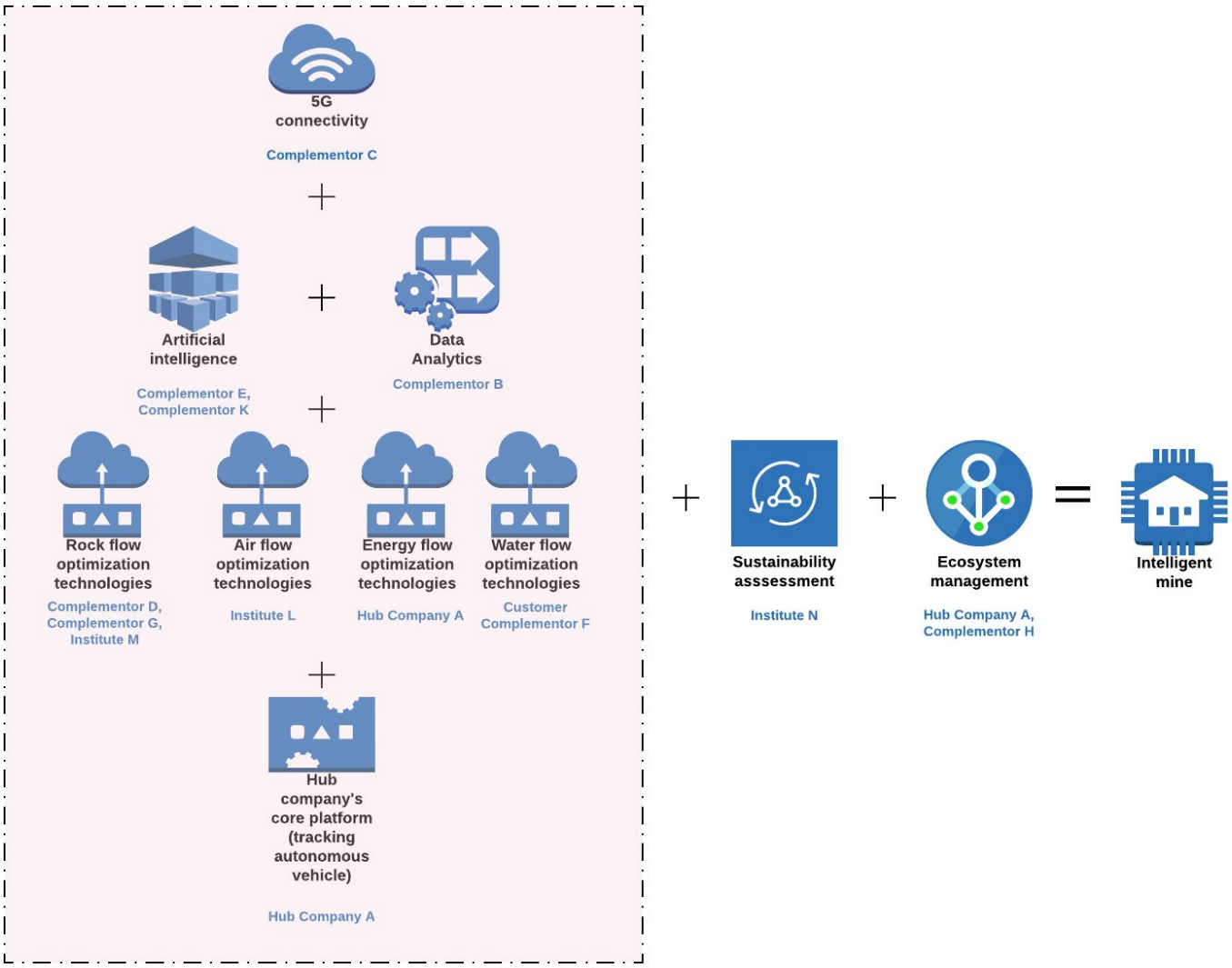

Figure 3: Overview of the case ecosystem structure

3. Research methodology

In this chapter, the methodological choices of this research is described. First, the choices of research design and research process are explained. Next, details on the selection of the case data as well as data collection and analysis method are elaborated.

3.1 Research design

To further contribute to the nascent theory of the application of dynamic capabilities to ecosystems development, an exploratory approach was chosen for my research. Yin (2009) highlights that an exploratory approach is suitable for research focusing on answering the questions of "how" and "why" - which are exactly the nature of my research. Furthermore, Yin (2009) suggests that a case study is an appropriate strategy especially for answering such "how" and "why" question. To explore the contextual conditions of the case in parallel with investigating the interconnectedness between various elements, a qualitative approach was selected.

To best leverage the power of both theoretical insights and empirical data, the abductive research approach has been chosen for my research. The abductive research approach is described in another word as "systematic combining approach" (Dubois & Gadde, 2002). Systematic combining approach is useful when researchers' objective is to discover new variables and relationships, leading to the development of new concepts (Dubois & Gadde, 2002). Moreover, systematic combining is especially beneficial for theory development because the continuous movements between the theoretical framework, empirical fieldwork and case analysis helps researchers develop theories and propositions that closely fit with reality (Dubois & Gadde, 2002). Dubois & Gadde (2002) state that this kind of movement is critical because theory cannot be understood with the absence of empirical knowledge and vice versa. Therefore, to generate insights with novelty and utility, informed theory building and theory testing were carried out hand-in-hand in my research.

Furthermore, my research is built on a single case study. Various researchers argue that case studies are useful for theory development since they allow in-depth studies of empirical phenomena in their contexts (Dubois & Gadde, 2002; Yin, 2009). Yin (2009) states that case studies have been a popular method in many scientific disciplines, such as management, psychology, sociology, history, political science, education etc. However, one of the most

well-known criticisms towards case study is the generalization of the findings. Despite this criticism, Weick (1979, 37) states that case studies are "better tools than first imagined" and then, he suggested researchers to *"try harder to make interpretations specific to situations"*. Dubois & Gadde (2002) further state that the interactive links between the phenomenon and its context can be better understood through in-depth case studies. Dubois & Gadde (2002), argue that researchers should not choose the quantity of cases over quality. Because "*researching a greater number of cases, with the same resources, means more breadth, but not depth*" (Easton, 1995, 382). Moreover, Dubois & Gadde (2002) state that when the research problem is to explore the interdependencies between various variables in a complex context, an in-depth single case study is preferred over a multiple case study. Thus, to understand how dynamic capabilities were applied by the hub company in the complex settings of an emerging innovation ecosystem, an in-depth single case study was chosen for my research.

3.2 Research process

Following the systematic combining approach, I conducted several iterative rounds between theoretical review and empirical data analysis to create an in-depth understanding about the practical phenomenon under my study (Dubois & Gadde, 2002). **Figure 4** illustrates the systematic combining approach in the light of Dubois & Gadde (2012).

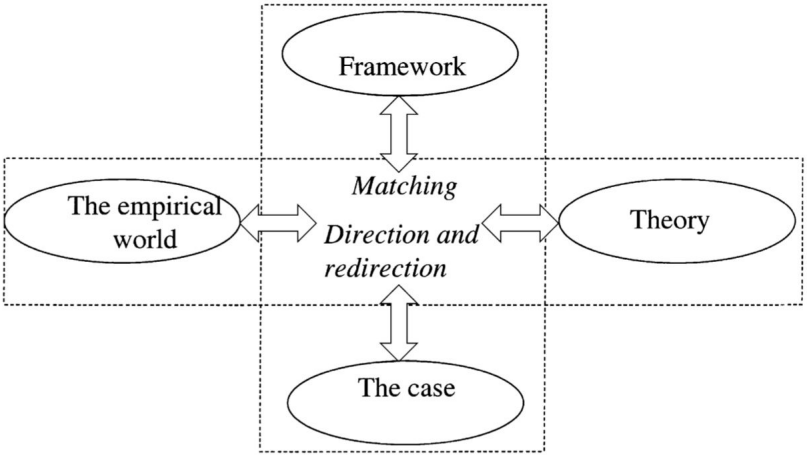

Figure 4: Systematic combining research process (Dubois & Gadde, 2002)

As the first step in the research process, an initial literature review was conducted. Yin (2009) points out that it is highly recommended to develop an understanding of what is being studied prior to making the first field contacts. Gioia, Corley & Hamilton (2012) added that organizational studies requires a discovery of relevant concepts to further guide the creation and validation of organizational constructs. However, to prevent researchers from being too "blind" to the existing theories, one should look at the theories at the general level while allowing a level of "semi-ignorance" to unimportant issues which are out of the research scopes and objectives (Gioia, Corley & Hamilton, 2012). Thus, in my research, I conducted an initial literature review to understand essential concepts of emerging innovation ecosystems, and dynamic capabilities. Complementing theories from organizational network, innovation management and strategic alliance were used from time to time to enhance my understanding of the subject. I conducted several searches on Google Scholar with keywords such as "dynamic capabilities", "innovation", "innovation ecosystems", "dynamic innovation capabilities", "innovation management", "closed innovation", "open innovation", "dynamic", " capabilities", "alliances", "formation", "ecosystem formation", " emerging ecosystem", "managerial

capabilities", "ecosystem review", "dynamic capabilities review". My searches resulted in 139 articles in total. Collected articles were then uploaded in Atlas.ti. Abstracts and findings of each article were analysed and coded in Atlas.ti. Following the theoretical coding process, only articles somehow related to dynamic capabilities in interorganizational networks, alliances or ecosystems were selected. After removing irrelevant articles, I was left with 98 articles.

As the result of the initial literature review, I gained a preliminary understanding of how dynamic capabilities and innovation ecosystem formation could be related. An ***initial literature review*** was written on three components of dynamic capabilities - adaptive, absorptive and innovative capabilities. Based on my preliminary understanding drawn from the initial literature review, I designed the main research question, empirical research questions and the initial interview guide. An ***initial theoretical framework*** was designed to reflect my initial theoretical understanding.

Next, the interview guideline and interview questions were discussed with two other researchers. In the ***initial interview guideline (appendix 1),*** open-ended questions regarding the context and background of the innovation ecosystem case were designed. Moreover, open-ended questions of how ecosystem members in the emerging ecosystem adapt to market changes, absorb new knowledge from the ecosystems and innovate themselves to meet new market requirements were designed. The ***first four interviews*** were conducted with this initial guideline. Each interview was recorded, transcribed and triangulated with other researchers accordingly.

The first round of data analysis was conducted after the completion of the first four interviews. The reason for conducting data analysis at that time was to respond promptly to the freshly collected data while allowing to adjust the research direction before proceeding with the next round of interviews. Analyses of the collected data were conducted following the systematic coding guideline established by Gioia, Corley & Hamilton (2012). The first order codes were generated from the interviews, then being grouped into higher level codes. Furthermore, to generate the most accurate synthesis of both the theoretical world and the

empirical world, Dubois & Gadde (2012) suggest to test the empirical evidence against the initial theoretical understanding and vice versa. Following Dubois & Gadde's advice, we revisited the literature to primarily see how well the initial collected literature could explain the empirical data. The comparisons between literature and generated codes were conducted iteratively to see the overlappings and gaps between the theoretical world and the empirical world. While comparing the empirical data and initially collected literature, we realized that the initial theoretical framework did not fit the empirical data very well. Thus, following this realization, we decided to change our research direction to what the empirical data revealed to us. As a result, a ***new research direction*** was set to understand: (1) the triggers for the hub company to form an innovation ecosystem, (2) the resources that the hub company was looking for through the emerging ecosystem and (3) the capabilities that the hub company employed to identify, capture and transform resources. Following the changed research direction, we *modified our interview guidelines, and research questions* ***(appendix 2)***. This time, the research questions were designed at a more general level rather than focusing too deeply on the adaptive, absorptive and innovative aspects of dynamic capabilities. This newly established interview guideline was then used for the next round of data collection (**9 more interviews**)

In the second round of data collection, repeated procedures like in the first round were conducted. Further instillations of data were performed, which gave me the ability to generate more open codes. First-order open codes generated in the second round were then added into the existing open codes from the previous round. Whenever necessary, I generated new categories (2nd order themes) for open codes which did not fit to any previous categories.

In the last phase of the study, after completing the generation of the highest level codes, a final round of literature review was performed. The purpose of literature review this time was to see if any existing theory could support the discovered phenomenon. In this study, for the purpose of new theory discovery, a balance between knowing and not knowing the full length of literature was maintained. While contrasting the empirical findings with the reviewed literature, the initial theoretical framework was tested against empirical findings which gave

rise to a refined framework. This refined framework provides new concepts and understanding of ecosystem formation. **Figure 5** illustrates my research process further.

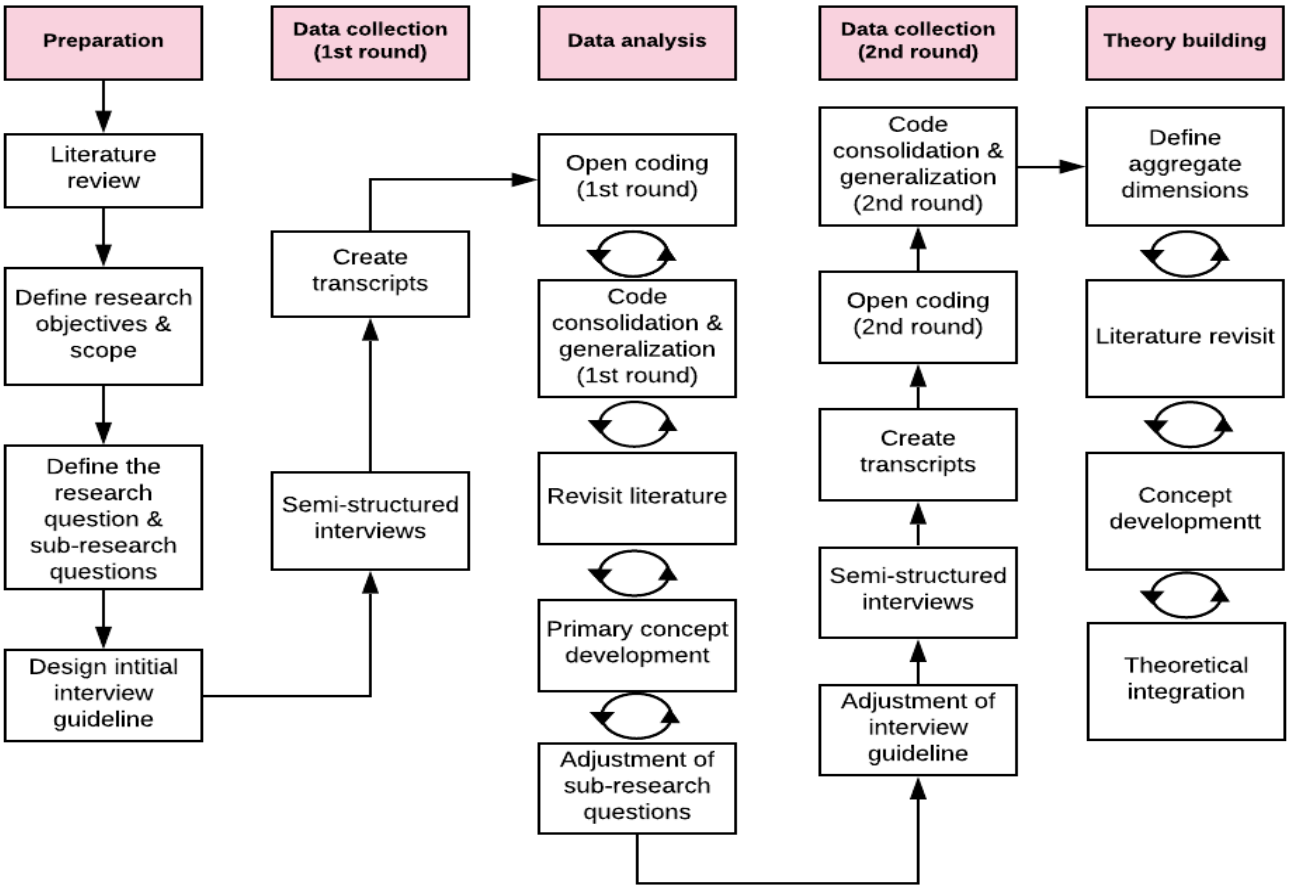

Figure 5: Research process (adapted from Dubois & Gadde, 2002 and Gioia, Corley & Hamilton, 2012)

3.3. Data collection & analysis

Saunders et al. (2009) suggest that a purposive sampling technique shall be employed in case studies, especially when a relatively small samples could be collected from the case. Since the formation of the ecosystem involved small amount of members, invitations for participating in research interviews were sent to all members. Out of 12 organizations participating in the emerging innovation ecosystem, 12 Interviewees from 9 organizations agreed to participate in

the research interviews. More specifically, 2 interviews were taken with hub company's top-managers who directly participated in the ecosystem formation. Moreover, there were 8 interviews with top managers of industrial partners and 2 interviews with Interviewees of a university participating in the ecosystem. The following **Table 2** describes the participants took part in the research interviews.

No.	Company & industry	Informant's code	Job title	Industry experiences	Interview duration
1	Hub A (mining)	A1	Head of technology sourcing and new product development	25 years	92 minutes
2		A2	Director of Research and Technology Development	18 years	62 minutes
3	Complementor B (IT)	B1	Project Manager	12 years	83 minutes
4	Complementor C (telecommunication)	C1	Director of Application Program and Digital Automation	14 years	83 minutes
5	Complementor D (sensor technology)	D1	Chief Technology Executives	23 years	99 minutes
6	Complementor E (AI)	E1	Head of AI Control	9 years	86 minutes
7		E2	Chief Operating Officer	18 years	89 minutes
8	Complementor G (gold & copper mining)	G1	Chief Executive Officer	28 years	101 minutes
9	Complementor H (innovation management consulting)	H1	Director of Manufacturing and Energy team	20 years	82 minutes
10	Complementor K (AI simulation)	K1	Chief Executive Officer	21 years	76 minutes
11	Institute M (research institute)	M1	Doctoral Candidate, Geoscience & Engineering	5-10 years	61 minutes
12		M2	Professors, Head of resource engineering section	27 years	64 minutes

Table 2: List of participants taking part in the research interviews

The primary data was collected through semi-structured interviews which were conducted with ecosystem members. The initial set of interview questions were designed with

an open-ended nature. Open-ended questions were applied so that interviewees had the full freedom to explain and elaborate on their lived and on-going experiences with ecosystem formation. To make sure that the interview questions were easy to understand, I discussed the questions with other researchers to further simplify complex questions, and eliminate redundant questions. Additionally, there was a deliberate use of terms and concepts which were familiar with the interviewees instead of our academic language. For example, while interviewing, we actively used the word “project consortium” and “EU program call” instead of “innovation ecosystem” because our interviewees were more familiar with those concepts in their ecosystem context.

Even though a long set of interview questions was developed to support a full coverage of areas to be explored, our interview guide was applied in such a way that the application of broad interview themes was preferred over the detailed interview questions. The detailed interview questions were only used as follow-ups to interviewees’ responses, whenever necessary. During the interviews, new questions often emerged based on the revealed information, thus allowing us to explore the empirical world to a great extent.

As our research proceeded, the interview questions and its interview guide were being developed iteratively, following the redirection of our sub-research questions. The interviews were carried out both in face-to-face meetings and via online communication tools such as Google Hangout. In most interviews, at least 2 researchers were present to bring up relevant questions following the flow and revelation of new information. Two researchers were in complementing roles with one another - while one researcher took notes and acted as a relatively active listener during the interviews, the other ones were actively asking questions. From time to time, researchers interchanged their roles, thus, allowing us to follow the conversation with interviewees by asking relevant questions. All participants were informed about the anonymity of their answers, thus, making them more comfortable in providing honest opinions to our questions. Interviews were recorded and transcribed word by word. The

transcriptions of interviews were reviewed and triangulated with other researchers to make sure that no essential information was missed.

In a case study, the diversity of data sources allows researchers to gain a broader view of the case context, thus, enabling them to generate more accurate and convincing conclusions (Yin, 1994). Following Yin's recommendation, multiple sources of data were used in my research. Even though the qualitative data collected from interviews with ecosystem participants was the major source of data, to best understand the contextual conditions of the external environment which might play a critical role in the ecosystem formation, complementing data from European Union's Horizon 2020 program, industry reports and published annual reports of various companies involved in the ecosystem were collected and analysed. Additionally, meeting notes, and informal discussions with the participants of the ecosystem acted as valuable secondary data sources. In total, **978 minutes of interview data** and **300 pages of textual data** were collected from interviews and other reports.

3.4 Data Analysis

The unit of analysis was the emerging innovation ecosystem. To enhance the quality of the research, data analysis was conducted in parallel with data collection. In the analysis, the "Gioia method" was employed in order to bring qualitative rigor to new theory development and grounded theory articulation (Gioia, Corley & Hamilton, 2013).

Following the Gioia method, all interviews were first transcribed and triangulated together with other researchers. Next, important information from the transcripts were being labeled line-by-line as the first-order codes. As the goal of this research is not theory testing, first-order codes were generated in a bottom-up manner and completely isolated from any reference to literature. It is worth to note that the first-order codes were simply reflecting the exact terms and wordings used by the informants without attempting to fit them under any categories. Thereafter, first-order codes possessing similar characteristics were being consolidated step-by-step into second-order theoretical themes. While grouping first-order

codes into higher categories, literature was revisited to see if emerging concepts could offer an explanation to the empirical phenomenon. Lastly, second-order theoretical themes were further grouped into higher level concepts. These aggregate dimensions display a data structure that provides excellent visual aids to data analysis process which is seen as a critical element to demonstrate qualitative rigor (Gioia, Corley & Hamilton, 2013). Corbin & Strauss (2008) further stress that the core concepts represented in higher-level themes should be adequately generic to embrace the relationships and characteristics of the lower-level themes. Thus, in this study, the labels for each second-order codes and aggregate dimensions were chosen in a fashion that they explain the behavior of the interviewees in a meaningful way. The following figure outlines an example of my coding procedure (**Figure 6)**.

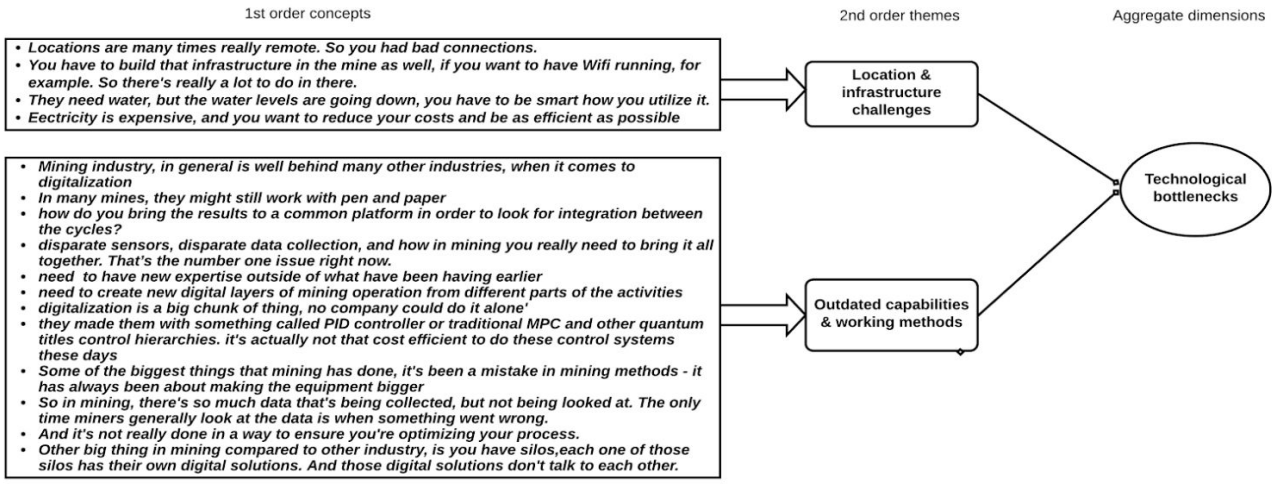

Figure 6: An example of coding structure

Two rounds of data analysis were performed. While the codes in the first round were generated freely, to reach saturation, the generation of codes in the second round was performed with the guidance of the first-round codes. Open codes taken from the second analysis round were added in the code book along with the first-round codes. It is important to note that code generation was performed in an iterative manner.

IV. Findings

In this chapter, the main findings from my data analysis are presented. The main objective of this research is to understand why the hub company forms an innovation ecosystem and what kind of capabilities helped it in the formation process. In the first section, factors that triggered the development of the researched emerging innovation ecosystem are highlighted. In the next section, motivations of the hub company for forming an innovation ecosystem are discussed through the lense of organizational resources. Next, capabilities that the hub company employed while forming its innovation ecosystem are explained through the lense of dynamic capabilities.

1. Triggers of the innovation ecosystem's formation

The first empirical research question aims to understand the factors that trigger the development of the studied innovation ecosystem. In **Figure 7**, a representation of my analysis following Gioia method is shown. Codes at the first-order level were generated freely from the interviews. Consequently, first-order codes were grouped to form the second-order theoretical themes. Finally, second-order theoretical themes were grouped into higher level theoretical concepts which offers explanations of the phenomenon in a conceptually meaningful way.

In **Figure 7**, a representation of my analysis following Gioia's methodology is shown. It is important to note that, since the formation of the studied innovation ecosystem was initiated by the hub company, the following analysis will focus on the triggers affecting the hub company, not the complementors. In the following subchapters, the findings will be presented in more detail along with participants' ´quotes that supported the findings.

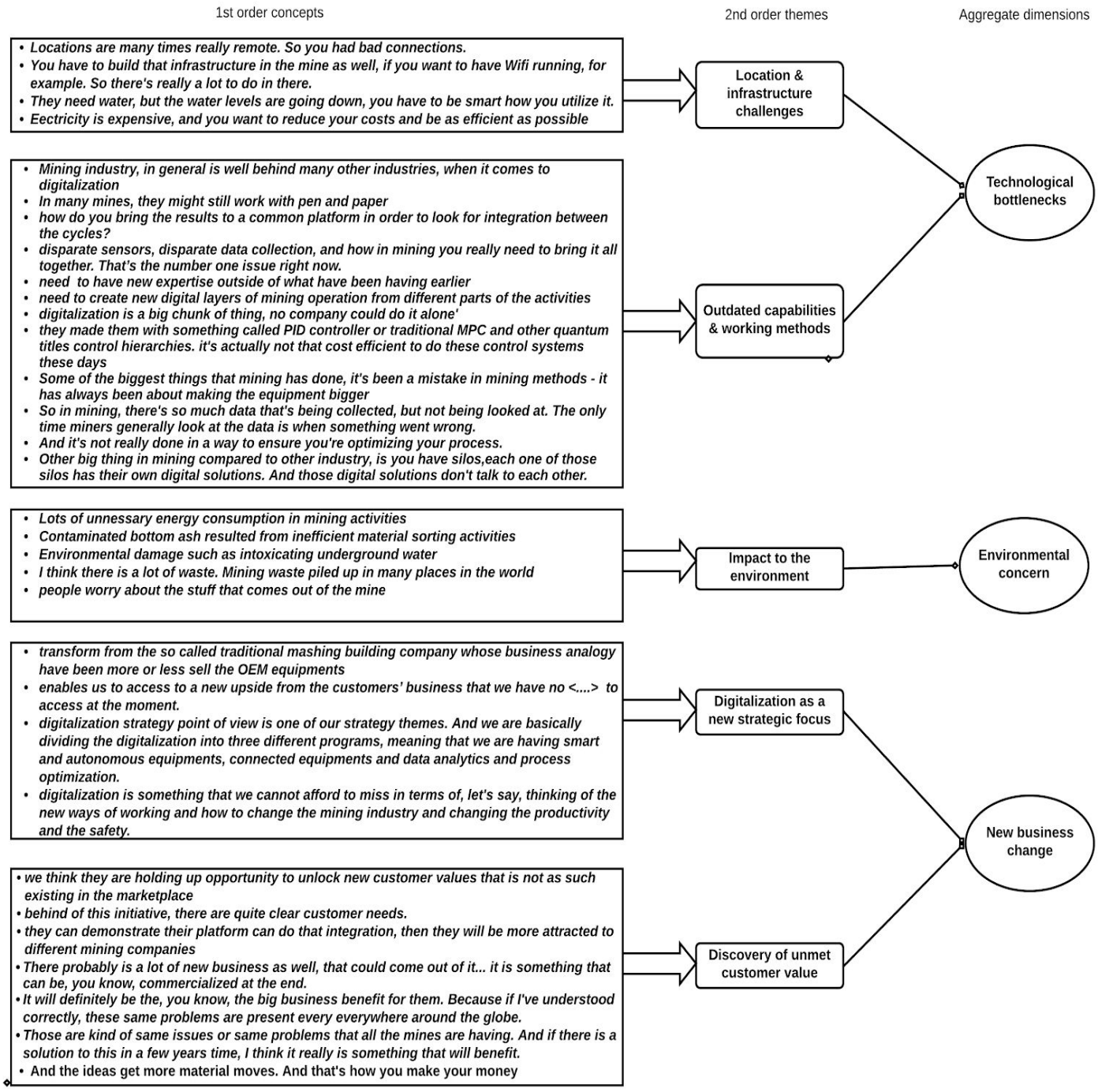

Figure 7: Analyses of triggering factors affecting the formation of the innovation ecosystem

1.1 Technological bottlenecks

Technological bottlenecks exist at the global industry level. At the industry level, infrastructure challenges in the underground mining industry have remained unsolved for decades. Despite the advancements of technologies, no mining company has been able to solve these issues completely. Moreover, mining companies have outdated working methods. All these challenges appear at the global industry level. They are so complex that a single mining technology company cannot solve them alone.

1.1.1 Location & infrastructure challenges

The underground mining industry has been reportedly having various technical issues in the availability and optimization of minerals, energy, air, water and internet connection due to its remote conditions. These issues have been summarized very well by **Interviewee B1** - a project manager of Complementor B - a global corporation providing computer, IT and technology solutions for various industries, including mining industry:

> *B1 "...the locations are many times really remote. So you had bad connections. And of course, you have to build that infrastructure in the mine as well, if you want to have Wifi running."*

Interviewee B1 highlighted the challenges that come with the remote locations of the mine. Far from residential areas, most mines suffer from the underdevelopment of telecommunication infrastructure. **The project manager B1** continues addressing other problems in the underground mines as the following:

> *B1 "...these same problems present everywhere around the globe. They need water, but the water levels are going down, you have to be smart how you utilize it. And electricity is expensive, and you want to reduce your costs and be as efficient as possible. And yes, they want to mine smart, so they don't want to have waste. They want to get the best mineral. "*

1.1.2 Outdated capabilities and working methods

A Interviewee from the hub company and four complementors highlighted that working methods in the mines are outdated. Moreover, while transforming from a traditional industry with outdated practices and technologies to a more modern mine where advanced technologies are connected and utilized, internal resources and capabilities of a single company alone are not sufficient.

Project manager B1 stated a view that mining industry is lagging far behind many other industries in terms of digitalization. Pen-and-paper based working practices still exist in many mines despite the level of digitalization in other industries.

> *B1 "I think, as I'm understood this, you know, mining industry, in general is well behind many other industries, when it comes to digitalization for example. In many mines, they might still work with pen and paper down in the mine where they, you know, recording what they are producing during one shift..."*

Chief Technology Officer D1 provided his overall view about the "common mistakes" of mining companies: making equipment bigger instead of smarter. He also highlighted that there are disconnections of data in the mine, thus hindering an efficient mining operation. Furthermore, data in the mine is underutilized which represents a common issue across mines over the planet.

> *D1"Yeah, some of the biggest things that mining has done, it's been a mistake in mining methods - it has always been about making the equipment bigger….At best, we look at 1 to 2% of the data that we collect, at best. So in mining, there's so much data that's being collected, but not being looked at. The only time miners generally look at the data is when something went wrong. Yeah. It's not done proactively. And it's not really done in a way to ensure you're optimizing your process. And then the other big thing in mining compared to other industry, is you have silos. ...And what is a real problem in mining is that each one of those silos has their own digital solutions. And those digital solutions*

don't talk to each other. And so there's a lot of inefficiency as you hand over from silo to silo..."

From the process control point of view, **Head of AI control E1** stated that the mines have been using very outdated control regime which do not provide cost efficiency.

E1 "So they made them with something called PID controller or traditional MPC and other quantum title control hierarchies. And this is something where we see that we can cut actually quite a lot of engineering time, make them able to automate much more machines and even these kinds of more rare machines where it's actually not that cost efficient to do these control systems these days."

E1 "They have many, many mechanical systems, electrical mechanical systems are hydraulic systems that need some sort of automation or control regime but tuning, building this is actually quite slow"

Due to the lack of coherent operational data in the mine, according to **Chief Executive Officer K1**, a representation of existing operational model in the mine is lacking.

K1 "But for example, digital mine is a good example of where you can see, but the digitally visualizing digital things is actually quite important for human beings because a lot of these digital ecosystems have no physical representation"

Head of technology sourcing and new product development A1 emphasized that the hub company is currently lacking various capabilities related to digitalization**.** Thus, it could be understood that digitalization has revealed a need for the hub company to create new fields of expertise that have not needed before. Especially, with the goal to build a more transparent digital mine where all flows and assets are interconnected, different parts and components need to be integrated from the outside.

A1 "The digitalization, it has been basically saying that, from the partners and the network point of view, we have been in need to create a whole new, let's say, field of expertise outside that we have not been basically having earlier. "

A1 "There are three companies that we have been starting the discussion very recently,

*but again, in a new area, for example, artificial intelligence***"**

1.2 Environmental concerns

Interviewed participants shared the concern that a lot of waste is produced by inefficient mining activities. Such inefficiency represents a technical bottleneck that mining industry must find solutions for. For example, **Chief Executive Officer G1 of a sensor technology startup** highlighted the unnecessary waste in energy and chemical consumption in mining activities.

> *G1 "I was amazed how much energy is used in mining worldwide...to get the ore out in transportation, in crushing, and chemistry. And that's a huge amount and a lot is wasted..."*

Furthermore, **Chief Executive Officer G1** continues to highlight the increasing concern about the environmental impacts that mining activities cause. These increasing concerns put pressure on mining companies to rethink their working approaches and rebuild new technologies as well as methods to reduce waste.

> *G1 "They try to get a little bit of energy out of their own waste. But in the end, they still will end up with what is called bottom ash. And in bottom ash you could get out the iron and a lot of the metal parts but then you are still left with a sort of contaminated stuff."*
>
> *G1 "That is incredible and that many people get really worried about you know, what is happening underground and can we get little earthquakes? Or, what is happening to the price of my house...."*
>
> *G1 "But if it's something else to worry, I think there is a lot of waste. Mining waste piled up in many places in the world and probably you don't really want to know it's probably a lot of toxic. "*
>
> *G1 "If people worry about the stuff that comes out of the mine. And you could show them that you can measure it."*

1.3 New business changes

1.3.1 Digital ecosystem as a new business focus

Digitalization is a change agent in many industries and the mining industry is not an exception. Keeping digitalization at the centre of the company strategy, **Hub company A** puts digitalization as its focus strategic area. In line with this strategic direction, the hub company prioritizes research and development effort towards digitalizing key aspects of mining industry such as autonomous equipment, interconnected devices and process optimization. Moreover, the hub company wants to start building new solutions to increase mining efficiency, productivity, safety and eventually, transforming the mining industry. The top managers at the hub company have been initiating global research & development initiatives to create new digital capabilities.

Head of technology sourcing and new product development A1 highlighted the hub's digitalization strategy as follows:

> *A1 "Yes. So, as no surprise, digitalization is a big change agent in business today and we are not an exception. So, from the digitalization strategy point of view, digitalization by <...> is one of our strategy themes. And we are basically dividing the digitalization into three different programs, meaning that we are having smart and autonomous equipment, connected equipment and data analytics and process optimization. So, those are the themes on which we are performing the digitalization research and technology development."*
>
> *A1 "Obviously on the high level, we've created a digital strategy 10 years back. ...And then there is a wide variety of new technologies that can enable us to evolve the target of these things. "*

Moreover, the hub company also has a ***digital ecosystem strategy*** in their business. This is confirmed by **Interviewee A2 - Director of Research & Technology development of the Hub Company:**

A2 "We have different types of ecosystems exercises with public funding organizations as well, of course, and we have had this kind of programs like Rock Factory in the past. Now we have a self-tuning mine on-going. But in parallel, we want to run this Intelligent Mine. So we have a strategy and the focus area. So we wanted to create this kind of consortium ecosystem type of project around our strategy, of course."

A2 "I think it's helping and boosting our activity in this area where we are going now. Our strategy has always been ecosystems that are supporting and helping and putting more structure to our work...."

Digitalization is a strategic transition within the hub company. From a company originally selling underground mining equipment such as drillers, loaders, rock cutting tools, rock drilling machine, the hub company has started to develop and sell autonomous equipment for around a decade. For the past years, seeing how digitalization has enabled data-related business with higher profitability, the hub company has developed a new service unit with a whole new focus on data. **Director of research and development A2** stated as follows:

A2 "...I would say that the past five years the data has been showing much stronger role in the business. And the past two to three years, I would say that we are selling the data products as well....We can see already that the digitalization is gaining value, but that we have been working very strongly already, many tens of years. In automation, digitalization, of course, that has been developed a lot since past year. So it has been helping us to hit the market with a better solution.."

Moreover, while keeping digitalization as a strategic focus, the hub company is trying to transform its traditional business as an Original Equipment Manufacturing provider to a digital company who can offer solutions to optimize different parts of the underground mines. **Interviewee K1 - CEO of an AI startup** noted:

K1 "I mean, I have some experience with, you can call this digitalization right? Hub Company A is a pure hardware company that is entering the world of digital."

The transition from a company providing hardware to software has also been acknowledged by the **Head of technology sourcing and new product development A1** as below:

> *A1 "And obviously, the target is to transform us from the so called traditional mashing building company whose business analogy have been more or less to sell the OEM equipment, and then offer the parts and services over the lifetime. So, then change that into a new offering content, which enables us to access to a new upside from the customers' business that we have no access at the moment."*

1.3.2 Discovery of unmet customer value

There are various technical bottlenecks that exist as unresolved questions for every mining company all around the world. These bottlenecks can represent a huge business potential. **One interviewee from the hub company and two complementors confirmed this view**. **Interviewee D1 - CEO of a sensor technology company** highlights that if the hub company could improve their previously developed platform by integrating new modules into it such as air flow, energy flow, water flow, rock flow, the newly developed platform could be very attractive for many mining customers.

> *D1 "So I think, they have the platform, we have all these other solutions integrated and they can demonstrate their platform can do that integration, then they will be more attracted to different mining companies."*

Project manager B1 of a global corporation providing technology solutions speculated that due to the scale of challenges existing in the mining industry, solving these challenges could lead to new business. Due to the global scale of the technical bottlenecks in the mining industry, building up solutions to tackle those bottlenecks could mean long-term business benefits.

> *B1 "So in that sense, I feel that yes, there probably is a lot of new business as well. That could come out of it. But I think especially for Hub Company A, it is something that can be, you know, commercialized at the end. It will definitely be the, you know, the big business benefit for them. "*

B1 "So I think those are kind of the same issues or the same problems that all mines are having. And if there is a solution to this in a few years time, I think it really is something that will benefit."

Seeing the technical bottlenecks as unmet customer value and a market gap, **Head of technology sourcing and new product development A1** stated that they are building Intelligent Mine ecosystem as a solution to fulfill such gaps. He stated as below:

D1 "We have designed, or made the design of the program. And that design is based on the identified new customer values. "

A1 "And the value drivers for customers, if we were first considering what if we could do this and that. And then we were finding from our point of view, the right drivers - that if we address these defined drivers, or if we can target towards, if we can move toward these to set goals...So behind of this initiative, there are quite clear customer needs. And thought benefits - what we could produce if we could do this than that. "

Furthermore, **Interviewee A1** also stated that fulfilling such market gaps require a huge effort and a wide set of expertise that must come from outside of the hub company's in-house research department. For example, because the hub has been only focused on developing mining machineries, the other capabilities such as artificial intelligence, data analytics or 5G wifi network must come from external members.

A1 "I think from Hub company A's perspective, we develop the vision based on where we see a gap with the customers, what the customers are asking for, and what we can actually provide. There is a gap and the gap they can't fill in the run...And I don't think any individual company, a mining company would deal with that either. So unique, lots of different expertise."

1.4 Summary of findings

There are three main factors that triggered the hub company to form the Intelligent Mine ecosystem: technical bottlenecks existing in the mining industry, rising environmental concerns and business change.

First, the highlighted technical bottlenecks are those components that hinder the growth, efficiency and operation of the mining industry as a whole. These bottlenecks do not exist within a single mine alone, but they exist in every mine at the global level. Such bottlenecks are the results of various challenging conditions that belong to the nature of the underground mining industry itself. For example, most mines are located far in the rural areas which are far away from the residential areas. Unfortunately, in remote areas, telecommunication infrastructure almost do not exist. Additionally, to perform mining activities, companies need to go deeper underground to extract minerals. However, the deeper as they go underground, the more resources scarcity they face (such as lacking of wifi connectivity, water and energy and air ventilation). Those bottlenecks have been existed in the mining industry for decades, however, they still remain as problems to every mining company. Technologies have not yet developed to a level that could solve all of these existing issues at once. Thus, those bottlenecks represent the biggest problems in the market of mining technologies that need to be solved. Due to the level of complexity and difficulties of technical problems, not a single company could have all the resources to solve them alone. Therefore, they need to collaborate with others to find solutions to such problems.

Second, there are a rising environmental concerns from citizens and public organizations. Those concerns include mineral wastes, negative impacts on underground water, CO2 release, degrading property value and landslide. These concerns have been putting lots of pressure on mining companies. As a result of that, mining companies need to start researching for new methods to perform mining activities more efficiently, which can result in the reduction of environmental impacts.

Third, there are changes in the hub company's business direction. These changes are the results of two main reasons: the realization of unmet customer value and the business focus on digital ecosystems. Recognizing that the existing bottlenecks represent unmet customer value which hold great business potential, the hub company decided to change its strategic direction. The hub company wants to transform itself from a traditional Original Equipment Manufacturer to a digital technology company which can offer advanced solutions to its mining customers. However, because of its currently insufficient capabilities, the hub company formed a digital ecosystem strategy. This digital ecosystem strategy focuses on shaping an innovation ecosystem around key digital mining technologies that the hub company want to develop.

2. Motivations for forming an innovation ecosystem

In this section, motivations of the hub company for forming the Intelligent Mine innovation ecosystem are explored from the data. In **Figure 8,** a representation of my analysis following Gioia method is shown.

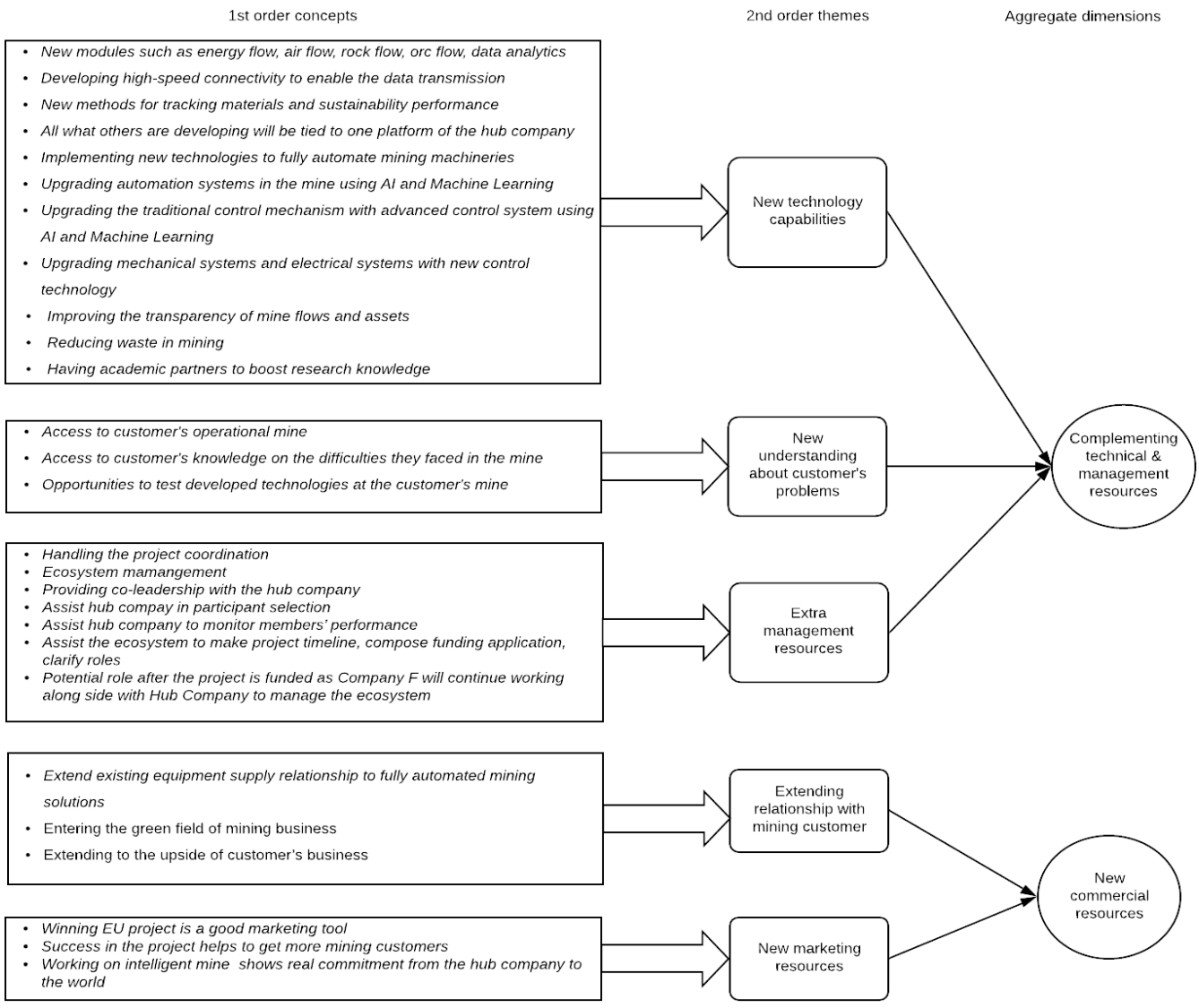

Figure 8: Analysis of hub company's motivations for forming ecosystem

2.1 Complementing technical and management resources

2.1.1. New technological capabilities

As mentioned earlier in subchapter 1.1, the mining industry has suffered from various challenges for decades. With a deep understanding of the challenges presented in the industry,

the hub company is looking to build new technical capabilities to solve the existing issues in the industry by forming its Intelligent Mine innovation ecosystem. To identify the capabilities that the hub company is planning to develop, questions concerning the overall objectives of the ecosystem were asked in 12 interviews with Interviewees of the hub company and complementors.

To highlight the overarching, high-level capability that the hub company wants to develop from the emerging innovation ecosystem, **Head of technology sourcing and new product development A1** stated:

> *A1 "So our target and vision is, for the starting point, to transform mining process, let's say closer to a factory process, like from serious of backward type of tasks towards the automated and continued process, that really enables the autonomous and telecommuting operation, and digitalization plays a big, big role in that one....Our offering on which we are building, the further transparency of different mine flows and assets and can really create the digital layer of mining operations from different parts of the activity."*

Moreover, **Interviewee A1** continues to address the high-level technical capability of the ecosystem. He sees that the "end-product" of the ecosystem is a total improvement of key flows in the underground mine - which are air flow, rock flow, energy flow, and water flow.

> A1 "....*And there are the key flows in the mine. So <you will> I can actually say, then you have the energy flow, you have the air flow, you have the rock flow, mining is all about to manage these flows*."

Interviewee A2 - Director of Research and Technology Development stated that the *hub company is looking to extend its autonomous vehicle tracking platform with new technical modules.* Due to the hub company's limited resources, the new technical modules which are energy flow, air flow, rock flow, and data analytics need to be developed by other partners. When the new technical modules are developed, they will be integrated in the hub company A's

existing autonomous vehicle tracking platform. This platform will serve the hub company A's vision to fully digitalize the mines.

> *A2 "Basically, we discussed in the meeting that one of goals with all will be ending and tied at the system and platform board, it will be hub company A's solution. So all what others are developing will be tied to our hub company A's platform "*

It is important to note that no company, including the hub company, can build up the fully automated mine alone. It is certainly evidenced in the following statement by the **Interviewee A1** - **Head of technology sourcing and new product development and interviewee C1 - Director of digital automation:**

> *A1 "Because digitalization is the big chunk of things, that I don't believe there is one company who can or we don't generally speaking, we don't believe that there is one super company who can manage all of that. Instead, it will be a group of different companies joining, they offering content together...."*
>
> *C1 "It's not enough Hub Company A and us, we need...there are some analytics players, smaller players and then the real mine and, you know, that alone, it won't work. Ofcourse what is interesting then there is Complementor B. So there are a few of these big ones like us and Complementor B, and then I think two universities and then the one real mine".*

In **Table 3**, a summary of complementing technical capabilities of complementors is shown.

Company code	Capability	Quotes
Complementor B	**Technical capability** Providing new analytical module to the Hub Company A's existing platform - Providing KPI tracking feature so that one can track real-time operational data - Machine performance	**Interviewee B1** *"We have developed a new module to the Hub Company A's platform. So, the platform itself is having different modules already, which have been developed by Hub Company A or by their other partners, previously, but Complementor B has developed the analytics, which is now a new module, which is part of the platform. And then within that module, what we do is we can follow the operations in near real time, what is happening on the ground in the mine. So we can track with different KPIs through dashboard, what*

	breakdown prediction	*we have developed, how the production is going, if they are meeting the targets that have been set to the crew. And then the other part of the solution is that we are able to predict breakdowns for the equipment because it's really expensive, if a machine breaks down during the operations in the tunnel...."*
Complementor C	**Technical capability** - Provide 5G telecommunication technologies to enable fast and efficient data transferring and receiving - Enabling the communication of underground devices, equipment and platform	**Interviewee C1** *"We are the connectivity... In that project, ...first of all the connectivity, meaning that the how do we wirelessly get the needed data? If there are the sensors, how do we wirelessly get it, and then potentially, some video data analytics, and then this whole, the whole automated guided vehicles. That's their remote control and things like that where again, the wireless connectivity is so key. "*
Complementor D	**Technical capability**: - Providing sensors who measure real-time rock movement in the underground. - Generating data of material movement to be integrated to hub company A's platform	**Interviewee D1** *"So what we're doing is we're putting sensors, right at the point that you're actually mining the orc, right at the active states. And actually measuring the quality in the ore at that point, and then making decisions on what that is orc or whether it's waste**...**But we're doing now they're saying now we can give you a real time measurement and make better decisions at a much smaller size of ore*." **Interviewee D1** "*And what we do is a sensor sit on top of the buckets. And as the ore fills the bucket, they measure the grade of copper, in real time. So this is the first time that anybody's ever done that in real-time. Our plan with hub company A is to take that same type of system, but now put it underground, on hub company A's buckets**."***
Complementor E	**Technical capability:** - Provide optimization algorithm, industrial prediction, control technology and machine learning solutions for autonomous mining machineries. - Providing industrial prediction and control technology	**Interviewee E1** *"The first thing that we offered them was this industrial prediction and control technology that we were researching for two years."* **Interviewee E1** *"...And we help them to come up with a really nice machine learning solution that actually can do decisions on board automatically so that they can work on one obstacle. "* **Interviewee E2** *"...And our role is to be...we have rather general technology that can be used, basically, for any of those. So instead of having our own one work package, we will kind of be delivering technology to all the other work packages, or at least the ones that happen to be a good fit for us."*

Complementor F	**Technical capability:** - Participating in the water flow package to optimize water consumption in the underground mine - Potential end-customer of the Innovation Mine ecosystem	**Interviewee K1** *"Yes. Especially to Complementor F, they were there to do this contribution, water flow"*
Complementor G	**Technical capability:** - Chemical sensing provider: Developing sensors to detect identify useful materials - Developing material source tracking technology	**Interviewee G1** *"For the proposal, we are one of the,you could say, technology providers. So, one of the things that is needed in this project is chemical sensing."* **Interviewee G1** *" And if we can, that can be useful, then you can later on detect that somewhere in the process, you have a lot of material and you could even say okay, half of it came from that area down in the mine and the other half came from another area."*
Complementor K	**Technical capability:** - Provide technologies to physically represent digital things in the mine - Provide a map for tracking vehicle underground	**Interviewee K1** *"...AI is artificial intelligence is an emerging needs, but they also have a need for visualization. I mean, to validate. I mean, visual it was, was about mobility and mobile vehicles. But for example, digital mine is a good example of where you can see, but the digitally visualizing digital things is actually quite important for human beings because a lot of these digital ecosystems have no physical representation. And it's very difficult for people to see what it means physically. So the visual aspect wasn't the initial idea of showing what must be fixed. It was more like training machines and regulating machines. But now we come to realize that actually making it visible as an added value to the stakeholders."*
Institute L	**Leadership capability:** - Leading the air flow work package **Technical capability:** - Provide methodologies for optimize for air flow underground	**Interviewee M1** *"Institute L, they will do the airflow work package, they do participate in that."* **Interviewee M2** *"Institute L has mining machinery group which is very much a multidisciplinary group. So they look at mining machinery, but they also look at aspects like ventilation and air flow. And so their expertise in that group within this project is going to be applied on the air flow part."* **Interviewee M2** *"And also knew Institute L leading the group...They are working at the air flow work package*."
Institute M	**Leadership capability:** - Leading the rock flow work package **Technical capability:** - Implementation of sensor technology for material tracking	**Interviewee M1** " *In that project, I will be working on the technical aspect of the implementation of use of sensor technology, for material tracking, that's will be basically on the use of like, fused data from different sense of technology, to track material to track mineral, at different potential <....> throughout the mine."* **Interviewee M1** "*Material characterization, it's the main application. When we say material characterization, in our*

		case is mineral characterization in mining operations."
Institute N	**Technical capability:** - Assessment of the sustainability of developed technologies and methodologies	**Interviewee M1** *"Institute N, they work on the dissemination, dissemination aspect of the project. And also they do participate in the assessment of sustainability of the technologies by setting different key performance indicator to access the improved or the added value of the project approach from the already existing concept. So they do basically assess the sustainability of technology and methodology which will be used in the project. So that involves all the work package. But they would take the lead to set the criteria and assess it against the achieved results. And they are the criteria or the key performance indicators, based on key performance indicators."* **Interviewee M1** "*And Institute N, their contribution is mainly based on this sustainability assessment and dissemination of the project outputs. So that's how they will contribute here.*"

Table 3: Complementors' skills in the innovation ecosystem

2.1.2. New understanding of customer's problems

It is interesting to note that in the initial set of ecosystem members, there is a presence of a potential customer for the Intelligent Mine innovation ecosystem - Customer Complementor F. Customer Complementor F has been a long-term customer of hub company A. For the research and development activities of the innovation ecosystem, Customer Complementor F agreed to open up their commercial mine so that ecosystem members can perform testing at the real operational conditions. Having access to a real mine brings enormous benefits to the hub company and complementors because they can fine-tune their technologies to fit with the real mining conditions. Moreover, it is also beneficial for Customer Complementor F because there will be lower barriers to commercialize innovative technologies at the mines operated by Customer Complementor F. **Interviewee D1 - Chief Executive Officer of Complementor D** stated this view as follows:

> *D1 "The commercial mine provides a real test environment. So it is the mine that would love to have solutions to the things to the project. So it's an underground mine, it is a gold mine. And they were willing to provide access to the underground environment for us to collect samples, for instance, to the measurements, and to test certain ideas...This Customer Complementor F mine is an operational mine. So you have a lot of real*

constraints, real world constraints in terms of, where you can go, how you can do it, it had to fit in with the operation itself. And it's got issues with things like noises, machinery makes noise. It's a real environment...I think in a role in the project, we will use the test mine in <....> as a facility sort of control facility, and then use the test mine from Customer Complementor F, the real mine from Customer Complementor F to find out some of these ideas, what are the problems in the real environment that could affect to the ideas in this project. And also Customer Complementor F ultimately provide possible end users for any product or group of products come out of this project. They provide a customer, an end user..."

The view of Interviewee D1 was shared by Interviewee M1 - a resource engineering specialist from Institute M:

D1 "Actually, it will be for example, the use cases to test like that's like real mine operational mine. So, if we get them as a partner in the consortium, and of course, that can be the use case for this project concept to show that like the added value of using the technology that developed methodology….for it could be because it will have definitely economic impact environmental and social impact as a project when i <...>, we will get like a direct company or the user who can be beneficial from the output of the project."

2.1.3. Extra management resources

There is a presence of an innovation management consulting Complementor H in the Intelligent Mine ecosystem. The consulting company was invited by the hub company to coordinate and co-manage the ecosystem activities. Although Complementor H does not contribute technical resources to the ecosystem, **four participants** noted that *Complementor H's management expertise is very critical to the ecosystem.* **Interviewee A2 - Head of technology sourcing and new product development** stated the main reason why they needed Complementor H in the ecosystem in the first place in the following quote:

A2 " Because we need to be there a lot of activities involving different parties and what

*we have been promised that they need to follow up if everybody's following the plan was that they have been promised to do and then align the message and the reporting part as well, so that, it's really that we are doing exactly what we have been promising, but also that our ecosystem is efficient**.** They need to boost and run it. I think more or less, they are the facilitator still. "*

According to the above quote from **Interviewee A2,** *due to a large amount of coordinative work to be done, they needed the expertise of Complementor H to manage the ecosystem efficiently.* As per **Interviewee A2**, *Complementor H performed regular followup and monitoring of ecosystem members' performance.* Additionally, they boosted the efficiency in the ecosystem and facilitated various tasks in the ecosystem.

Interviewee M1 - **a resource engineering specialist** expressed her appreciation towards the management work performed by Complementor H. She further highlighted various project management tasks that the Complementor H has performed. For example, in the below quotes, she noted that Complementor H provided its expertise since day one to coordinate ecosystem activities.

*M1 "Yes, they did a very good job in coordinating and monitoring all this proposal writing process and like, initiating each partner to give their input on their speciality. But they do frame it in a very good way that everything is very clear for each partner. They were actively involved with from day one and managing the time very well**.** So we do believe that they did a very good job. And I do hope that this project will be successful."*

M1 "... they did plan the time very well, because the submission for application stage proposal was not like...we had not much time from the approval of first phase proposal to second phase proposal. So what they did is they did plan each contribution from their partner with deadline... they do their best to help on the contribution as well. And they did check the general flow of the proposal as well is because when every partner contribute only its own path, then there might be some open spaces. It is like, which may not create like a flow for the proposal. So they were making sure that everything's like

consistent, everything is like, logical and practically, which can be implemented practically. So they did set deadlines, and they were following the deadline but like, they were also contributing, and answering each part of questions as well, because like, there were so many open questions at the beginning of the proposal writing, but every partner were raising this open question, but these Complementor H people do their best to answer the questions. Maybe like they arrange a meeting to discuss it with other partners so that the other partners can get answers from other partners."

Interviewee M2 - an expert in rock flow technologies from Institute M added that Complementor H orchestrated administrative tasks such as setting timeline, meeting coordination, giving feedback and advice for deliverables.

M2 "They have been composing the proposal and doing the coordination of contributions so they were actually the one set the deadline for different stages, proposal compilation, they arrange meetings, telephone meetings, which will not hold very well attended, not all partners really joined. They provided a mechanism for feedback and providing mechanism for advice and for deliverables what we had to be at a certain time, which the proposal had to be at a certain time."

Interviewee H1 - Director of Manufacturing and Energy team expressed how he perceived his role in the ecosystem - *he stated that his role could be seens as "watering and putting nutrient" to the ecosystem.* He further added that sometimes his role was more than just coordinative tasks, he also participated in helping the ecosystem members to clarify their concepts. He also participated in business case analysis whenever required.

H1 "Let's see what is our role in the ecosystem. Our role is like watering, or putting some nutrients there. Or so if there is a need for that type of let's say, for example, writing a proposal or helping to put the concept together or getting the funding. Yes, definitely. We are more than happy to be there. Sometimes we also work as part of the project, we doing some part of the maybe some tasks or business case analysis or something. So then we are in a way we are partners as well. So it depends."

Moreover, because Complementor H has a strong expertise in applying for public funding programs, *the hub company relied on Complementor H's expertise to select partners to form a strong ecosystem to match the requirements of the public funding organization*. **Director of Research and Technology Development - A2** shared this view:

> *A2 "Complementor H was helping in that sense that they know as a track record for the public funding organization that what is needed, that will be the most likely the application will be accepted. So definitely helped our thinking in that sense**.**..."*
>
> *A2 "...We were discussing with Complementor H because their role is to get the acceptance for the program. And then we collected this kind of table that, which type of roles we have been needing and <...> University. So I think that was a starting point for that we were considering which type of competence and knowledge we need**.**"*

Director of Manufacturing and Energy team - H1 further noted that they will contribute to the coordination work of the ecosystem after the funding is granted.

> *H1 "Well, that is the goal that, you know, when it will be funded, then that we would be then working with the ecosystem. And doing some coordination management work. We call those as orchestrating the project."*

Director of Research and Technology Development - A2 confirmed his belief that Complementor H will continue its management role if the ecosystem continues developing further.

> *A2 "They will do that when we will get the green light from the EU, they will do that as well a bit. But basically, they are more or less, we are paying a certain amount of money that they will run the show and know when we need to report and collect all the information and like that. It is the bit same role like universities or research centers are running the EU projects as well. So because there's a lot of also industrial partners, we try to make this as easy as possible for every partner, ecosystem partner. "*

2.2 New commercial resource

2.2.1 Extending relationships with mining customers

One of the interesting things about this ecosystem is that the hub company invited one of its existing customers - Customer Complementor F - to join the innovation ecosystem. Traditionally, the hub company has been supplying heavy underground mining equipment to the Customer Complementor F. But for Intelligent Mine ecosystem, Customer Complementor F is both an end-customer and also a complementor. **Director of Research and Technology Development - A2** stated that having an end-customer participating in the ecosystem is very valuable for business. Because the end-customer will have first-hand experience in using and testing the developed technologies from the ecosystem, it is likely that they can become the first customer of the ecosystem.

> *A2 "I would say that the digitalization in our company and the role of automation, so the really big opportunity to make a growth for the companies in that area, and it's very, very big. It's really, really big focus for us. Intelligent Mine, as the size of the project, of course it is EU project, it's not the biggest one that we are doing. But I would say that these kind of EU project, this is what how to measure that. It's not just the financial benefits or anything like that, I would see that the value is in the consortium itself. We have our ecosystem partners there, we have a customer, and I saw that, via that I see it is a really valuable project."*

2.2.2. New marketing resource

Director of Research and Technology Development - A2 believed that there is tremendous marketing value for the hub company by taking part in ecosystem initiative funded by European Union. According to A2, by showing that the hub company is leading a group of serious actors who come together under the funding of European Union, their future partners and customers

will be convinced about the hub company's capability and commitment in developing innovative solutions.

> *A2 "...it will give us a set of marketing values. When you get this kind of EU and you have a consortium together and driving this kind of consortium, I think is that it's a good way to show others in the industry that we are seriously working with Intelligent Mine, not just talking and showing the bullet points."*
>
> *A2 " I think it's also strategically important to show the industry that we have this EU project and this is one way to solve it. So we are really putting effort for this. So it's also a marketing tool for us as well. So it's a marketing tool. It's a technology tool. It's a <fancy?> of tools so I see a lot of opportunities and value."*

Moreover, **Director of Research and Technology Development - A2** and **M2 - a resource engineering specialist** believed that the ecosystem's end-product will definitely attracts mining customers.

> *A2 "And the reason is that you can <receive>, safety, productivity, reliability, sustainability, we have these solutions, which, of course, important for us as values as a company. But as far as well, of course, the customer point of view, we have a very strong digitalization strategy, and Intelligent Mine is part of that. And we have already solutions for the Intelligent Mine. But I will say that we need to, we need to make the future solution as well."*
>
> *M2 "So I think, Hub company A has the platform, we have all these other solutions integrated and they can demonstrate their platform can do that integration, then they will be more attracted to different mining companies."*

2.3 Summary of findings

Chapter IV.2 addresses the key resources that the hub company is looking for in the emerging ecosystem. Complementing technical, managerial and commercial resources were found to be the major resources that the hub company seeked for.

Complementing technical resources are the technological knowledge and expertise that the complementors contribute to the joint ecosystem's development effort. As identified through my findings, despite having decades of working experience in the mining industry, the hub company did not possess all the required technological skills as they enter the digital age. With an ambitious vision of having a coherent solution that can solve all existing bottlenecks in the mining industry, they needed complementing skills from experts outside of their in-house R&D department to build their visionary solution. Thus, specialized expertise from complementors were the utmost important resources that the hub company looked for.

The emerging ecosystem also gives opportunities for the hub company to deeply understand the customer's problems and their expectations. By inviting a customer in jointly defining problems to solve, the hub company seeked to gain extraordinary knowledge for improving the technological fitness of their upcoming innovation. Moreover, since there was a tight collaboration between the hub company and a customer in the emerging ecosystem, it could be seen as a commercial resource which strengthened the business relationship between the hub company and the end customer, thus opening up future business possibilities. Furthermore, the end product was perceived as a vehicle for the hub company to enter a new side of the markets - the greener and more sustainable market.

Furthermore, the emerging innovation ecosystem along with its potential public funding provide marketing resources for the hub company. By showing the real commitment and capability in driving a truly advanced digital mine ecosystem, the hub company could increase its reputation with mining customers, opening doors to more future business possibilities in the digital mining industry.

Moreover, while sharing the leadership tasks by having complementors assisting in the overall management of the ecosystem, the hub company looked for extra managerial resources to manage the ecosystem effectively. All in all, the emerging ecosystem adds extra resources which the hub company is lacking, thus, helping the hub company transformed its resource base, making it more advanced in terms of technical, economical and managerial aspects.

3. Dynamic capability mechanism

In the following chapters, findings of the capabilities and practices employed by the hub company to form the Intelligent Mine innovation ecosystem are discussed.

3.1 Resource sensing

In **Figure 9** below, a representation of the analyses is shown. Detailed explanations of each aggregate dimensions along with 2nd order themes will be discussed in each sub chapter.

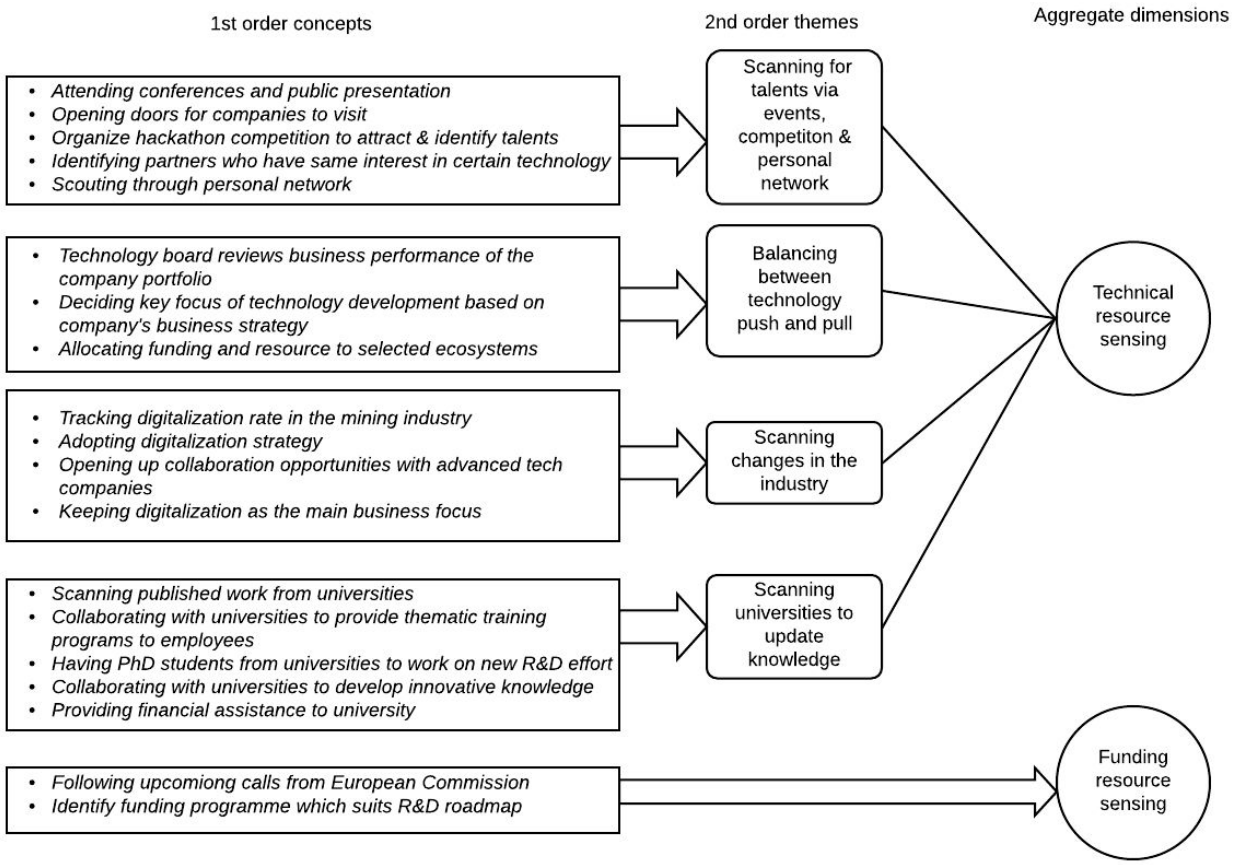

Figure 9: Analysis of sensing activities

3.1.1 Technical resource sensing

The hub company engaged in a series of sensing activities to find complementing technical resources. While the hub company attend events to identify complementing partners, complementors use those events to make their technologies and skills visible to the hub company. Such sensing activity can only be successful when both the hub company and complementors actively engaged in it.

i. Scanning for talents through events, competitions & personal network

Through my analysis, it appears that the hub company performed various sensing activities to explore the external world of knowledge. It is interesting to note that the exploration journey of the hub company cannot be completed without the participation of complementors. Complementors also need to perform sensing activities to make themselves visible to the hub company. Complementors' sensing activities are done by participating in international conferences, giving presentations and other networking events. Through those events, the hub company creates contacts and learns from the complementors's knowledge. In the following quotes, **Director of Application Program and Digital Automation C1** stated that her company had established first contacts with the hub company via a thematic conference.

> *C1 "But it started in a robot conference in <...>, one of my team members was there maybe last year summer and got the contact with hub company A and that's how it went."*

Chief Operating Officer E2 - also highlighted a robotics event where they presented their AI technology got the attention of a representative from the hub company A. Most importantly, there was a common interest in this certain type of AI technology from both the hub company and complementor E.

> *E2 "I think the way it went is that they had originally heard Harri talking about AI and robotics in a robotics event at <...> . And then they had some research that was relevant.*

So they contacted us, or we contacted them"

Head of AI control E1 shared a similar view with E2:

E1 "That's actually through scouting, so I think we've been giving talks, especially our CEO, has been giving talks, talks in various forums about AI in general and what Complementor E does. And then I visited, I think it was a European robotics forum, which happened to be in <...> , two years ago, and there were <...> from hub company A and he mentioned that he also saw my CEO's presentation before..."

Other than attending events to attract and identify talents, the hub company A also organized thematic hackathons to address new technologies for their core business - rock technology. The result of the hackathons helped the hub company to identify capable partners - for example, Complementor G - who is now providing innovative sensor technology to help the hub company improves underground rock flow. A fruitful working relationship between the hub company and Complementor G started after the Complementor G won the hackathon. **Interviewee A1 - Head of technology sourcing and new product development, Interviewee M2 - a rock technology specialist and Chief Executive Officer G1 -** shared their memories about the rockathon event:

*A1 "We treated that to fit with the hub company A's environment so we organized a Rockathon. So it was kind of an open innovation competition, aiming to find technologies to identify rock characteristics and the Complementor G at the time participated and they won the competition. So we created the project with them. And we started to work with them. So for example, with Complementor G***,** *we have been working for about a year."*

K2 "Two partners were already there because one of the partners in the work package already worked with the hub company. And I was also involved in a Hackathon, they invited teams, people to present their ideas. And I was part of a Dutch small company, I was part of a team and we won that Hackathon. So that's why hub company A approached me and approached this other Dutch company Complementor G to

participate in this proposal."

G1 "It's like a hackathon. But in this case, it was about measuring what's inside the piece of rock from the mine. And we were selected to be in the final in <...>, which five or six other companies I think, and finally we also won the competition."

G1 "Because we won the Rockathon on. So we got this. We didn't get anything. We got the honor but we got the intention from hub company to start an R&D project with us"

G1 "It's already great to do and then you and then you win. And this was the start of my relation with hub company and later on also with Interviewee A1, and other people"

Furthermore, the hub company A opened its door for company visits. In such company visits, the hub company learns new technologies and their potential use cases. **Chief Executive Officer E2** informed that they visited the hub company to give a presentation of their core technology.

E2 "And then I and <...> went to visit them at Tampere and showed them what we have done in reinforcement learning and control stuff."

Chief Executive Officer K1 also shared a similar experience with Interviewee E2. He also visited the hub company to present his company's technical capabilities and proof of concepts. From such visits, common technical interests were sparkled between hub company and complementors which built pathways for the complementors to enter into the emerging ecosystem.

K1 "I think we had a first call probably, then we visited them. And when we initially talked about our prime target, which was a simulation for the purpose of improving autonomous vehicles. When we had a proof of concept product on that topic, and to basically build a very simple say test environment for them to experience and to get a better understanding of what we could do. And then we actually started to discuss when we started to see more opportunities in kind of technology and the solution and then the scope of discussion expanded to do what we would now being called this intelligent mine. I guess on that side, we also have a lot of work on the origin of that topic, but the initial discussion on on basically vehicle training and vehicle validation then. Basically, we

expand it to discussion to a wider topic, which you can call the digital mine which is not just vehicles, but to have an overall ecosystem of a mine and validating different type of next."

Personal network was also a common channel to scan for partnering opportunity. According to **Chief Executive Officer K1,** through a mutual referee from his personal network, he established contacts with the hub company.

K1 "Obviously got in touch with a couple of hub company A people from my personal network with my previous company, talking about maps and positioning. And then we basically had some discussions and then also brought up this."

Moreover, **Head of AI Control E1** suggested that the hub company scanned for complementing expertise within its geographical proximity. *According to E1, he felt that his company's deep research capabilities, which lead to its visibility in its local proximity, made his company noticeable for the hub company.* Moreover, *he believed that his company was the only AI company who could do such deep research within the geographical proximity of the hub company.*

E1 "Oh, one of the things is of course proximity, and that we are actually a company, so also a small, medium sized enterprise that's, so it's our competitors would be maybe some research groups in Montreal, or then you have like huge companies like Google DeepMind, or something like this. And they're probably would be talking about much bigger, bigger projects. So it's harder to get like started. And then from the like, of course, there are like me and startups on AI, but quite a few of them actually do their own deep research, like hardcore research and present their results in the, in the international conferences, which is, of course, a mind blowing for me, because I'm trying to do like the commercialization. But that's how they see us being - we can provide like the real research based stuff on several levels of what is out there, what can be done and what's coming next. But rather than then applying something that is just off the shelf in some open source library of it, what is kind of a textbook example. So that's our key

differentiator, and we happen to be close to see them. So it's easy to talk."

Indeed, **Interviewee A1 -** Head of technology sourcing and new product development from the hub company A **shared the same view with E1**. He stated that the *hub company has been continuously scanning the market and following the development of different companies. Their visibility in terms of knowledge in the technological areas that are relevant to the hub company is the most important element.*

> *A1 "We have been, of course, we are continuously scanning the markets and following the development of different companies. And we've tried to, it's kind of a having a radar market to understand who is doing what in the area that is, in our interest areas. And I think, the selection was based on the visibility to the markets that we created. And based on the knowledge of the companies that we have been identifying, <...>, in this defined field of use or in the area."*

Moreover, the *hub company shared parts of its responsibility for finding complementors through a partnership with the management consulting company H*. *Complementor H helped the hub company to find some ecosystem members to increase the technical strength of the ecosystem*. Complementor H ensured that there was a balanced mix of having both large and small companies, both economic organizations and academic ones to enhance the chances that the emerging ecosystem get funding from the public organization. This view was supported by **H1 - Director of Manufacturing & Energy team.**

> *H1 "The goal is to have, first of all, that you bring the needed competence. So that it's really a world class or European, based on the Europe. And then, and if it's not found in Europe, then of course, you look outside the. In this case, there were some companies ,for example, from Canada, which were then invited. So the purpose is to first is to ensure that there's the best quality that are needed, and then is to show that the partners will complement each other well. The areas they will be a good balance of partners contribute the results that are needed.... "*

ii.. Balancing between technology push and pull

The hub company has a technology and business review board taking part in deciding the technologies that the hub company will pursue. This board consists of R&D directors and vice presidents who meet four times per year to review the performance of its business portfolio. The technology board meeting is a key forum where the hub company reviews the performance of existing research & technology portfolio, identifies customers' needs, plans the company's future business plan and aligns key activities to match with the plan. From those meetings, the hub company decides on the level of technology push and pull which will eventually shape the company R&D plan. **Head of technology sourcing and new product development A1** highlighted the critical role of the technology board as follows:

> *A1 "There are R&D directors, that product line, VP, who are driving and responsible of the P&L. So what do they want from the technology content going forward, in order to commercialize new functions that are good for the customer? So that is an ongoing dialogue, and then that then expanding the network a lot."*
>
> *A1 "We have something called technology and the business review boards, who are where we are calling the key stakeholders from the divisions for one day meeting four times a year. There we are reviewing all the portfolio of activities that we are doing and driving internally and with our network partners. And this is really the basic key decision making forum where our businesses getting the transparency of their results and the work that we are actively doing, and how does that align to the future business plan. So that's one kind of a key forum that directs and aligns the activities, and obviously, then there is a project planning. And, obviously, there's got to be a balance, technology push and pull."*

Moreover, the technology board of directors plays a critical role in managing the hub company's ecosystem. For example, *the board evaluates the network of ecosystem members, their competencies, distributes resources to the projects with those partners accordingly.*

Director of Research and Technology Development A2 reflected on the role of the board in the following quotes:

> *A2 "We have, with my management team, we have, we have full transparency for portfolio management, and ecosystem partners, the partners' information so that's the key. That's important for them that we are following that part."*
>
> *A2 "Our research & technology portfolio, which is supporting our strategy and goals. And then, of course, the ecosystem via that."*
>
> *A2 "All the right partners, their competencies, how spending is divided between the research and the industrial partners, also how internally we get the resources, and it's like running a business and technology organization but this ecosystem is giving, I would say, a bit more detailed reporting and transparency for the work what the other people are doing."*

iii. Scanning changes in the industry

It is noticeable that the hub company has been able to keep track of the most prominent technological trends happening in the mining industry - the digitalization movement of most aspects underground. According to **Head of technology sourcing and new product development A1** , *digitalization has enabled new ways of working, thinking and operating in the mine.* Thus, *to match with the rate of change in the industry, Interviewee A1 felt that digitalization is something that hub company A cannot miss.*

> *A1 "For sure they are supporting and they see equally that digitalization is something that we cannot afford to miss in terms of, let's say, thinking of the new ways of working and how to change the mining industry and changing the productivity and safety. So top management is, pushing, heavy pushing heavily initiatives worldwide and create a new capability for sure. So, there is no question about that."*

Director of Research and Technology Development A2 gave a remark about the impact of digitalization at the industry level. Such impacts forced the company to adopt digitalization widely to deliver strong IT-enabled solutions to the customers.

> *A2 "I think the industry is going to that direction itself already that I would say that in the past many, many people think that the mining industry is a bit boring and old fashion industry, but I have to say honestly, that <....> is leading at the moment, many, many industries via digitalization. And the reason is that you can <....>, safety, productivity, reliability, sustainability, we have these solutions, which, of course, important for us as values as a company. But as far as well, of course, the customer point of view, we have a very strong digitalization strategy, and Intelligent Mine is part of that. "*
>
> *A2 "I would say that the digitalization in our company and the role of automation, so the really big opportunity to make a growth for the companies in that area**,** and it's a really big focus for us"*

Furthermore, **Head of technology sourcing and new product development A1** noted that *while having to develop software for sometime, hub company needs to integrate new expertise that are not within their in-house capabilities or within their traditional network of partners*. As a consequence, the hub company needs to open up their networks and collaborate with new partners to develop new products to fit the customers' demand. For example, in the following quote, **Head of technology sourcing and new product development A1** stated that they needed to collaborate with companies from outside of mining industry such as visualization company, AI company or data analytic company.

> *A1 "We have a long history of doing software. But not in the extent what we see is required by digitalization here. So we need new types of skills that we don't really have in our network. So, this has been grown our network quite a lot. Because we are now working with the topics and with the type of companies that earlier which simply did not have the need to work with. And for example, we are working with companies that come from the gaming industry. So when we are building custom, let's say, capabilities to*

visualize operations, or simulate work cycle, we've never really had a need to, to work with these kind of companies who have been, for example, making computer games. But now they one of a sudden they become very much relevant. This has been creating a new field of expertise that is now needed. Say same thing that data analytics, artificial intelligence company, everything about the environment of sensing, for example, we are now developing equipment for the restricted area automation to work on area restricted autonomy. So a lot of new technologies, and a lot of new capabilities to make that happen. We need to have a different companies who are specialized in image recognition, for example, or creating a library of picture libraries, or we need to onboard companies who have let's say, good models to teach the neural networks, via the libraries. And that's nothing really part of the machine building traditionally in the past, where now it becomes very available"

During an interview, **Chief Executive Officer D1** left an interesting note about the hub company A. According to D1, *it seems like no other companies in the industry is as "aggressive" as the hub company when it comes to developing digital solutions for the mines, which could be translated as* ***strong dynamic capabilities*** *at an industry level*:

D1 "So I think, hub company A has the platform, we have all these other solutions integrated and they can demonstrate their platform can do that integration, then they will be more attracted to different mining companies. I don't think anybody else is really doing it as aggressively right now as they are."

iv. Scanning university to get updated about new technology

Three participants highlighted the important role of universities in developing in-depth knowledge for industries. **Head of technology sourcing and new product development A1 and Director of Research and Technology Development A2** r*egarded universities as a center of new knowledge.* They believe that universities and academic partners can bring tremendous value to industrial companies like hub company A because of two main reasons. **First of all**, universities

can challenge the existing work practices, thus boosting the technological evolution in the industry. **Director of Research and Technology Development A2** addressed this reason as follows:

> *A2 "The reasons for that is that because we see that there is always a lot of value of universities and academic partners to challenge all the big industries and keep a different view than the industrial partners. And, that's critical. And of course, we also hope that the ecosystem, we will find long-term relationships with these universities and going to get more work to be done also in the future with those. "*

Second, *universities educate many experts who can provide in-depth knowledge in the field*. To get access to those knowledge, hub company A has been working with doctoral students on contemporary topics to produce new capabilities for the company.

> *A2 "Sometime, also that. But I mean, it's also some, we are also , let's say, conducting a lot of <....> but also, for example, with one university partner that we are having at the moment, seven doctoral school students working for us, and some of the topics are structured in a way that they are actually producing for us in depth knowledge of the new capabilities."*

The hub company also provided financial assistance to universities for their educational programs. Moreover, they also partnered with universities to produce training programs to their employees, thus equipping them with better knowledge. This was noted by **M2 - a rock technology specialist - who is also a professor of Institute M:**

> *M2 "We got involved with hub company A through an education program here at Institute K, a master program, an international master program. So originally, we had industrial consortiums provided scholarship money, and hub company A was part of that consortium. So that how I was introduced to hub company A. And then after that, hub company A had a training program for the employees what they called Mining Academy program..And they asked me to put together the exploration course....So I got <...> through that, and then they with some ideas for thesis projects, master's thesis projects*

and we had some students are now working with hub company A."

To identify relevant universities to partner with, the hub company scans the published work from universities to address experts who work with technologies related to their focus area. After identifying relevant people, they will then be invited to collaborate with the hub company. **Director of Research and Technology Development A2** described this scanning process as follows:

> *A2 "And we have been working with the staff of universities, we are scanning the universities with what they have been publishing and what type of work they are doing. So strategically, basically, we were looking for that if there are valuable universities who are working around the intelligent mine, we would we would like to get them on board and of course, how they strategically be to the whole system. But we didn't have any of these kind of past beliefs that we need to have academic partners and that and that. We knew it already some universities, which are, I would say the leading universities in this area, and it was important for our ecosystem that they will be leading universities are also that. Because there are leading companies, we wanted to lead in universities and academic partners as well."*

3.1.2 Funding resource sensing

The hub company is *continuously scanning upcoming calls from funding organizations such as European Commission to stay updated*. It is important to highlight that *the hub company made go/no-go decisions to decide which funding was worth applying*. At first, they analysed if the funding is suitable with their key focus areas. Then, if there was a match between the nature of the funding and the hub company's R&D road map, they proceeded to apply for the funding. **Head of technology sourcing and new product development A1** reflected on this funding process as follow:

> *A1 "First, we are following what are the upcoming calls from public funding organizations. And this digital mine initiative was of course a good match with our*

thinking and we thought that this is the right <basically > call to participate. Because it is having attraction, a lot of traction with a key focus area that we would be working anyway. So that was kind of we foresaw that as a way to boost our current activities, if it we should get funding from that party. So it was quite natural."

3.1.3 Summary of findings

According to my findings, the hub companies scanned for technological and funding resources in various channels. The most common channels for sensing technical resources include thematic hackathons, conferences, networking events, university-industry partnerships, company visits and personal networks. Interestingly, the case company has a technology board that overlooks the development and economic performances of their key technological areas. They also make decisions to shape the technological trajectories of the company according to the organizational business plan. Thus, their decision affects how the hub company scans for new technologies in the market. Moreover, following the digitalization movement in the mining industry, the hub company aligned its organizational strategy with the industry's digitalization rate, thus, defining the key focus of the companies when scanning for digital partners in the market. Furthermore, the hub company followed the upcoming public funding programmes which are relevant to their key focus areas. It is important to note that, while the hub company is scanning the market, the complementors also engage in similar scanning activities to make themselves visible to the hub company. Moreover, there was an interplay between the sensing activity from the hub company and the sensing activity from the complementors.

3.2 Resource seizing

In the following **Figure 10** , an overview of the findings from the interviews is shown. The findings will be discussed in details in the following sub chapters.

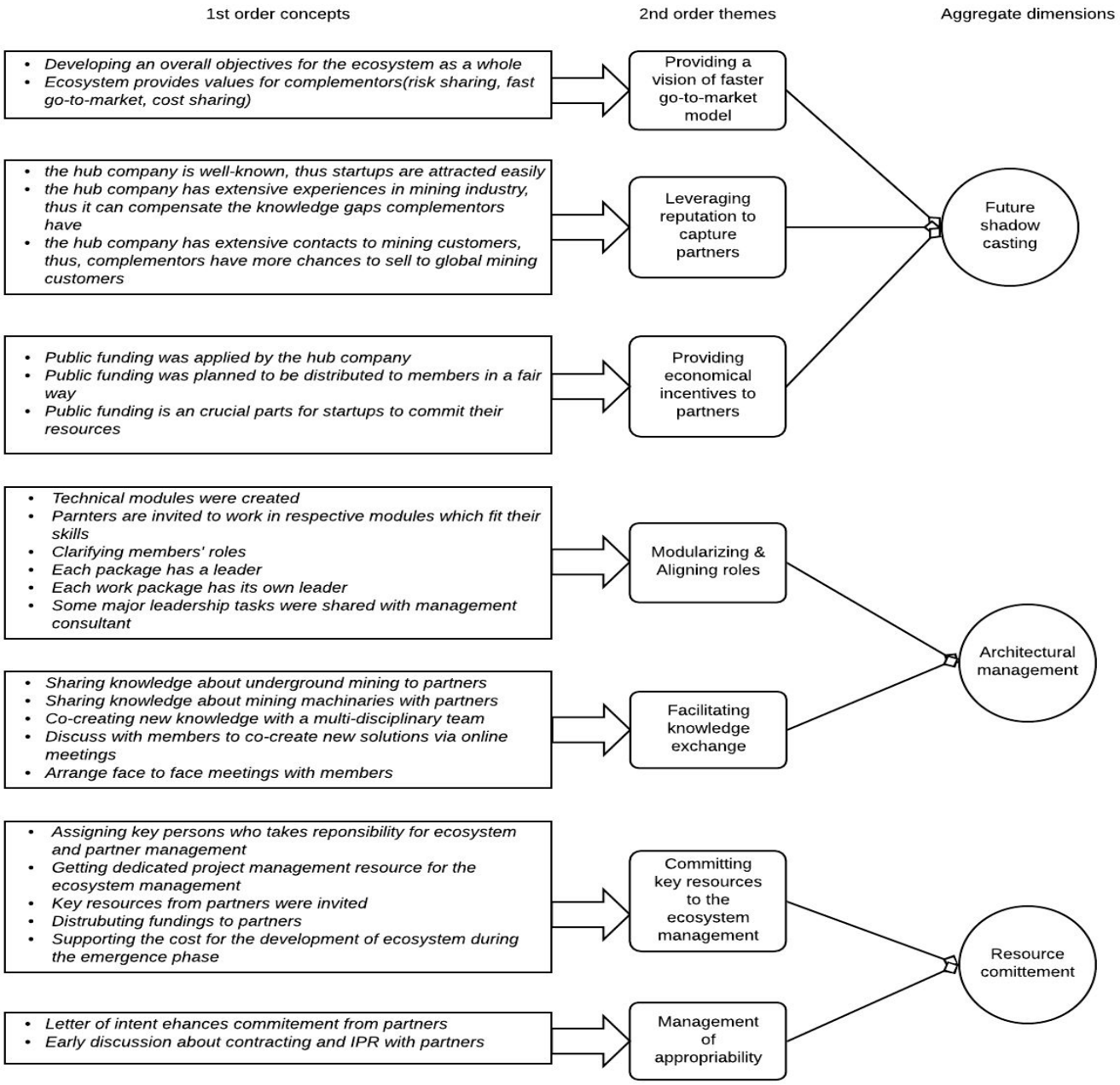

Figure 10: Analysis of seizing activities

3.2.1 Future shadow casting

i. Leveraging reputation to capture partners

In my analysis, it is shown that the hub company has leveraged its existing social resources which are reputation and industry experience to influence complementors's perception. My analysis shows that most complementors were convinced to join the ecosystem influenced by their positive perception of the hub company's reputation. **Four complementors** *highlighted perceived future benefits from the collaboration with the hub company in the emerging innovation ecosystem.*

One of the most commonly stated reasons for complementors to be convinced to join the emerging innovation ecosystem is *the underlying benefit of working with large companies like the hub company***. Head of AI control from Complemetor E1, Chief Executive Officer D1 and Chief Executive Officer I1** stated that startups usually face tremendous difficulties when they want to initiate a working relationship with large companies. *When the hub company A approached startup complementors, it is often perceived by startups that there are possibilities to significantly improve their businesses by the collaborations with the hub company*. In the following quote, **Head of AI control E1** stated the most common challenges for startups is to enter business relationships with large customers:

> *E1 "As we see it, so for a startup, it's, of course, very hard to talk with really large customers, because they have all the support they need and kind of - you have to have enough muscle to talk with them."*

Chief Executive Officer D1 also **shared a similar view with Head of AI control E1** in a sense that a barrier for his business comes from the company size and limited resources. *E1 further stated that having to partner with large companies like the hub company is a "big thing" because he believed that the hub company can provide tremendously valuable technical knowledge in the context of mining industry which the startup E1 is currently lacking.*

D1 "But I think, you know, we're a small company. So for us, because of our size and a lot of technical people. I think it's about making a solution work well. That's a big thing for us and having the support of a company like <...>, or like hub company A even in mining, it's a company like tech. So we tend to partner with somebody who will be a good partner we interact with, we're not necessarily trying to expand throughout the whole world right away. We're trying to do it in a very partnership-centric kind of way."

Complementing previous viewpoints of the **Head of AI control E1 and Chief Executive Officer D1**, **Chief Executive Officer K1** stated that the hub company did not have to put much effort to convince him to join the ecosystem. He values the collaborations with the hub company because without this collaboration, his company would have a hard time accessing data in the mines. The access to data is valuable for complementor K to improve its technologies. Moreover, the connection with the hub company helped complementor K to pitch themselves better to the next customers.

K1 "You know, when you are a startup, you are ready to go with any customer to some extent though. So, I cannot say that they had to convince us a lot. ...Typically, to use Artificial Intelligent needs a lot of data. And it may be obvious if you have a car because it's quite easy to record data, but it's actually not that easy for for example, in mines to record data because you know, there's not so much data about mines. So, it was our starting point.."

K1"...Mining is a niche market, you can argue. There's not so many say information. But mines, typically it is private and not very visible public data. There's no data at all of the mines. So it's actually one of the industries where there's a need for mapping things. But there is no real solutions for it. "

This view is similar to the **Director of Research and Technology Development A2.** *He felt that the reputation of the hub company is an influencing factor when it comes to capturing complementing resources from outside*.

A2 "They know that we are specially in that digitalization area - we are the OEM who is

leading this in the market. So more or less, I have to say that they would like to join with us that we didn't really need to ask too much "would you would you like to jump on?".It would like natural that they would join with us. And we have the best consortium, the best guys together. And that's the thing."

The experiences and knowledge that the hub company possesses in the mining industry seem to benefit it a lot when it comes to capturing complementing resources for the ecosystem. The technical experiences that the hub company possesses is perceived by complementors as an indicator for faster innovation development and faster go-to-market entry. In a sense*, the technical knowledge from the hub company complements the ecosystem members to develop new knowledge for themselves.* This view was shared by **Chief Executive Officer D1** and **M1 - a resource engineering expert** in the following quotes:

D1 "And again, that comes to why we interact with hub company. Because hub company A has, as a good view of mining, they have a lot of experience in mining. If we went alone to do this without a mining company, it may be a little bit more difficult...But having hub company A is there to make that go a lot faster. So when we choose our R&D, rather deal with the hub company A, we look at what both of us bring to the table to make sure that can move pretty quickly. If there's going to be any gaps in there, that could be a problem for us in terms of R&D."

D1 "I think the experience is a big part. I think, you know, take the movement of equipment, the movement of orc, they've already got the hub company's platform. So they already have a lot of people in their organization who understands mining closely...They know how to drill holes, they know how to put screens up and bolts a man and everything, but they may not understand the extraction process from the face, taking it out of the mine, even downstream processing. Hub Company A understands that better, and therefore can understand how to generate value. So I think they have a pretty unique position here for underground mines."

M1 "Yes, I do believe that they will play a very critical role, they are very well advanced in terms of machinery and this mining equipment. And they do have extensive experience of the electric flow, which they will directly contribute. And they are a very big company, who has expanded experience. So I do believe that they will do the coordination and the technical contribution and in a very good way. "

ii. Providing economical incentives to partners

Public funding was a critical element that helped the hub company to persuade complementors to join the ecosystem. The hub company has taken a major role in applying for the ecosystem's funding, and also made a plan for distributing the funding in a fair way to the complementors. **Director of Research and Technology Development A2** noted that the initial plan of who is getting what and the tasks they need to perform according to the allocated funding were somewhat agreed between the members.

A2 *"Okay, so you have the approval of this funding, that is they would get already"*

A2 "Yes, we have raised the issue of who is getting what? How much they need to work by themselves."

For small startups, funding was an integral part of their growth. During the interviews with startup complementors, *three startup Interviewees stated that the "shadow" of gaining funding for the development of new technologies and boosting R&D activities* is the central element that made them commit their resources in the ecosystem. This view was shared by **Chief Executive Officer G1, Chief Operating Officer E2, and a rock technology professor M2.**

G1 "But for startups like us, I think I have to admit that the money the funding is probably the number one reason."

G1 "I think for us, we're probably for most starters, the main motivation is money.

Very simple because once you get it done, so we now have, we were just granted what is called an SME instrument phase 1 grant, took us a long time so you get 50,000 euro. Just like that almost so it's not easy to get funding from European Union. It's never been easy

but once the money is there it's easy money and a long term financial backbone let's call it that way because for years that's almost eternity if you were started."

E2 "And, of course, we did the math, and there's funding available coming our way. Well, public funding is an integral part of being a technology startup, you need to consider those options. So either it supported our R&D plans, and it provides us with possible funding for that same R&D so many good things for us."

M2 "And I think part of it is also opportunistic, they see perhaps a vehicle for developing technology with the sponsorship for the development of the technology."

iii. Providing a strategic vision to the ecosystem members

From my analysis, it is visible that *a compelling vision of the future benefits for everyone within the ecosystem was created by the hub company. Most importantly, the hub company's vision was widely shared by complementors*. To the hub company, the Intelligent Mine ecosystem is a vehicle to enter a more sustainable mining business - which is providing digital solutions to enable greener and more profitable operations for their mining customers. This strategic transition marks a transformation of the hub company from strongly focusing on the hardware business to providing more technically advanced software to mining customers. *Two representatives from the hub company and four representatives of complementing partners* stated that the ecosystem brings a vision of an easy access to the underground mining market where the hub company already occupies a large market share.

From the interviews with ecosystem members, it could be understood that *the hub company communicated and shared the strategic vision widely to members*. The widespread ecosystem vision was evidenced from the interviews as *every complementors were stating a somewhat similar vision to what the Interviewees from the hub company addressed.* The hub company Interviewees believed that *a clear strategic plan of the Intelligent Mine assisted the complementors to understand the hub company's vision better, thus it was easier to convince them to join the ecosystem***.** This view was stated by **Director of Research and Technology**

Development A2.

> *A2 "And many of our ecosystem partners said that we are driving that. We are not just trying to apply something because we want to get EU funding, it is because we want to do something because they see that hub company is not doing this because of the fun. We are seriously considering how we can make an Intelligent Mine and develop this kind of <...> research things with our partners, how we defined and I think that generally I would say that the thing has been that when the strategy and the plan have been clear, it has been much easier to talk with the ecosystem partners and it has been quite easy for them to understand what we are trying to do."*

It is important to note that, *the hub company's ability to create an **inclusive vision** for the whole ecosystem, not just for its own business, is important for persuading complementors*. To make complementors commit their resources to the ecosystem, *the ecosystem vision should include future business possibilities for complementors as well*. **This view was supported by interviewees from hub company and the complementors**. For example, **Director of Research and Technology Development A2** noted that, their ecosystem initiative brings plenty of business value and opportunities for everyone. In his view, the vision of *a certain pay-back time is a critical driver that helped the hub company to convince complementors to provide knowledge and resources to the ecosystem's joined development effort.*

> *A2 "I think that the value of both parties comes basically that way that we see both that there are plenty of opportunities. And even in the field of, I would say, business to academic work point of view as a business opportunity. But if there's a room, for example, as a university example, the Complementor B as an example that Complementor B can create value for us and our business, we know what to do with their knowledge and help. At the same time that value with Complementor B creating, they will get the value for their own business. So that's why I think it helps the situation and that way, it should be always so that for all parties who are involving or investing in their own knowledge resources, and that means that there needs to be a pay-back time*

*at someday. That's pay-back time. If there is no pay-back time, I think that no party would be seriously participating more or less***,** *and trying to get the funding or be like a passenger in the car."*

A2 "Yeah, we discussed and I think no one wants to be out of the Intelligent Mine, the digital mine of the future which we are creating now. Everybody wants to be in. And I think we will have much more opportunities for everyone that we can see today."

In a similar opinion as A2, **Head of technology sourcing and new product development A1** believed that *taking part in the ecosystem is a great vehicle for complementors to penetrate the market. Because complementors can integrate their solutions in the ecosystem's final offering, it is easier for them to enter new markets and new customer segments.*

A1 "But for example, the Complementor G would have, hopefully, they could have spend their lifetime of trying to sell the analysis equipment to the mine, but if they are part of the platform, what together is by far, by far stronger than the individual technology offering or the solution or system or component, so they can penetrate the market via the platform, by far more efficiently than what they could do alone. So encouragement comes from the meaningful content and the purposes"

The view from the hub company's Interviewee A1 and A2 were shared by the complementors. As **Interviewee M1 - a resource technology expert** stated, she *was completely impressed by the concept and vision of the ecosystem created by the hub company*.

M1 "But what I can tell, again, is like the concept of ecosystem is very impressive for us. And this very good idea <...> I think that would be quite interesting."

Chief Technology Executives D1 highlighted that *the decision to join the hub company in the ecosystem comes from his believe that there is a possibility for expanding his company to the underground mining industry.* He felt that *the connection with the hub company is a very beneficial for growing his company's business in the underground mining market.* Furthermore, he highlighted that the hub company's resources such as equipment and experience in the underground mining business are valuable resources which the complementor D is currently

lacking. In general, for those reasons, D1 believed that hub company A is and will be a strong partner to collaborate with.

> *D1 "So the main reason that we engaged is that hub company A is an OEM, they have a lot of experience. They have equipment. And they have a platform that does needs this additional measurement that I was mentioning. So we have not taken our solution underground yet. We've only been on the surface. So the hub company who has about a third of the market for underground equipment, maybe 40%. So it's a big proportion. "*
>
> *D1 "Having a strong partner to work with going forward. So after we do this, we get into one or two mines, and we grow from there. Project execution and those softer things, hub company A will be able to bring to us. We're a small company, we haven't developed all those skill sets yet. I think that's another big thing. And then ultimately, exposure to a lot of different underground mines. Yeah, sure, I've got my contacts. But I know hub company A has many more contacts. So they will be able to help us move a lot faster in underground operations..."*

In a similar vein, **Director of Application Program and Digital Automation C1** envisioned a possibility for *growing businesses in mining industry if they are able to partner with the hub company and its ecosystem members*. **Interviewee C1** believed that there is a *higher possibility for selling their digital automation assets and bringing connectivity to more mining customers if they are a part of a mining consortium.*

> *C1 "...I see there an opportunity to sell our digital automation assets you know, and get that that domain and along with it, it's not easy. It's far better to go with the consortium that that really is from the mining industry and we bring connectivity, you know, offering."*

Chief Executive Officer E1 also stated that he could foresee potential values that come from the technological vision of the ecosystem as well as the potential customers that are existed within the ecosystem.

E1 "For us, it is easy to say that it's big enough. And sort of, they are really interesting potential customers in the consortium and of course the technological side of it."

3.2.2 Architectural design

i. Creating modularized components & assigning roles

There is a common view between ecosystem members that the hub company has clearly taken a leading role in defining the ecosystem vision, the ecosystem architecture and members' roles. First of all, the hub company built a vision of a digital mine which could fully automate and optimize different aspects such as autonomous equipment, energy flow, air flow, rock flow. This *vision was a central guidance for the company to design the structure of necessary components and the actions that need to be developed by complementors.* **This view was stated by 3 interviewees - Head of technology sourcing and new product development A1, Director of Research and Technology Development A2 and the rock technology professor M2.** The hub company's head of technology sourcing and new product development A1 and Director of Research and Technology Development A2 describes how the architecture of the project was created to support its big picture in the following quotes:

A1 "I think the coordination on the big picture that we are still driving towards the targets that we set for us. It is to coordinate the initiatives like I said, if, in this call, like it is expressed the technology readiness level is <.....> quite low <...>. So, it is, for example, technology reach in certain blocks are made, and we need to reiterate <...> and do alternative planning, we need to coordinate that in the way that these activities are supporting the big picture."

A1 "Yes. I said, we basically created the architecture and the framework for this entire initiative. And then it defines what we want, what were the default key focus points. For example, we could say that rock flow is one of the work packages. "

A2 "We are of course not alone here. Like it's a kind of ecosystem type of initiative. So each of the company are having their own work packages that are interlinked into the big picture."

The professor in rock technology M2 shared the same view as Interviewee A1 and A2:

M2 "What hub company does is it provides the technical framework or the overall ambition. Because they might, they have a commercial interest here in a product, in an integrated overview of the mine that's ultimately what this project is trying to do. And so they have an overview of what the end product they would like to see as a commercial product for them….they knew very well the different components that need to be enhanced or it to be developed, need to be included, and they knew very well which components are particularly important."

Six complementors stated that *the vision of the hub company enabled them to create mining specific components which will be integrated afterwards in the final coherent solution for mining customers.* For example, **Chief Executive Officer D1** shared this view:

D1 "Ok, so even though Complementor B might bring a bit of a platform thinking, they won't be able to bring it to a mining context. We have two companies on board - Complementor E and I forgot the other one. They're into artificial intelligence. Yeah. So they may know what to do with artificial intelligence, but it'll be hub company that will say, look, here's how it's important to mining. Okay, so by doing that, hub company will be able to develop these kinds of mining specific solutions which they want to integrate into the platform, and then sell on two different miners."

Chief Executive Officer D1 further noted that *the vision of the hub company was a central guidance for them to design the ecosystem architecture.* He further observed that there is a *balance in the ecosystem architecture as a sufficient amount of complementing partners were brought in the ecosystem.*

D1 "Yeah, I think it's pretty clear that hub company had a vision, they knew all the missing pieces might be on the flow <sheet?>, they looked around in the world about

who could fill some of those gaps. They probably haven't done everything. But they've kept it to a size that would be good enough to actually execute the project. So if you have too many people, it would probably would be way too difficult to manage. So I think they reached the balance here, the right types of people were bring in, in order to get this amount of success for this particular project. "

Moreover, the *hub company created a modularized structure which enabled an easier knowledge integration within the ecosystem members*. *Members were organized and operated around modularized work packages - for example, orc material flow, energy flow, air flow, water flow, coordination, and integration work package.* Each work package had a leader who was nominated by the ecosystem members. While the hub company and the management consultant company H co-shared the general leader role, *there are work package leaders who took care of the management of the activities, progress, and work quality of members at the package level*. **Rock technology professor M2** shared his insight about the work package leaders:

M2 "The project development was managed by hub company.They are the coordinator, they are leader of the work packages on coordination management. Then within the work package, they form a steering committee onboard and that has work package leaders in it. And then leaders feedback to the individual consortium members. And I think the plan is that every six months or every year to have a consortium meeting with all the different participants in consortium together. And more together group meetings with work package leaders and coordinators."

Furthermore, to enable active contribution from members, *the hub company created meaningful roles to its members*. **Head of technology sourcing and new product development A1** stated that such **meaningful roles** were created because partners were able to share the vision and have the ability to realize the roles assigned to them.

A1 "I believe the basis is to create meaningful goal and the meaningful, like, what I was explaining that we are orchestrating a framework for this initiative. And then we were

looking for partners who would have a role to play in that one, and they could contribute to identify the interest from the part of the bigger picture."

Ii. Aligning members

More often than not, misalignment and differences in opinion created conflicts between the ecosystem members. Thus, it was very important to have a leader to resolve conflicts and maintain the alignment between members. This view was shared by **Chief Executive Officer K1** as below:

K1 " I think there needs to be always a leader to many things. I don't personally believe in, no. But things happen with no pure equality. Everybody has an opinions over consensus, especially when you build new things, ambitious things, there needs to be thought leadership. I don't mean a leader in terms of detail management or micromanagement. But in terms of vision, in terms of, again, thought leadership - what are we trying to do."

Moreover, **Director of Manufacturing and Energy team H1** also performed tasks to facilitate the alignment between ecosystem members and the overall objectives of the ecosystem. Interviewee H1 stated as follows:

H1 "Well, one important aspect is to put together work packages and work packages describing different tasks that need to be done in the project. So, that is something that we can help check that, you know, they have objectives that they want to get this and this done. And then we kind of check "Well, how do you have tasks, which are aligned to establish that?" Or then in the proposal, we described the excellence of the concept. So we also make sure that all sides of that concept is kind of addressed or looked upon, so that it's not like there's something very relevant is missing, which not make very well..It would look somehow illogical for the evaluator that "hey, you talk about this, but you don't say anything about this?" How do you think this happens? So that's, we check that. And then we make that question to the concept owners or who created it that "have you

thought of that?". So we kind of see, and sometimes we suggest ideas, and "how about this?" but basically the companies, they should bring their own kind of insights and expertise."

iii. Facilitating knowledge exchange

The coordination of knowledge exchange was seen as an important task in the ecosystem. Although the structural modularization of technical components was an enabler for complementors to "plug in" their knowledge, the complexity of the end-visioned products required a smooth knowledge integration within and across each technical module.

First of all, the hub company appeared to have an instrumental role in shaping the knowledge-sharing environment in the ecosystem. Their technical knowledge and vision were a central element and a foundation for the complementors to build new solutions upon. **According to Project manager B1, Chief Executive Officer D1, and Chief Executive Officer K1**, the *hub company took a leading role in sharing the knowledge of "what should be done and for what purpose"*. However, the *complementors also took an active role in exchanging their knowledge with the hub company to further clarify their tasks*. This view was supported widely by complementors B1, K1, and D1.

B1 " In that sense, sometimes it's more than client is having the business knowledge and then Complementor B is bringing the technical knowledge but in here, Hub company is really bringing also the technical knowledge that own business knowledge so it's been a bit different, how it can be, how it normally is. "

K1 "Hub Company is kind of leading the things, I think we have been contributing to do their thinking and to their strategy with providing our understanding of things, what could be done, and for what purpose. "

D1 "So as a lot of integration that goes on, that doesn't happen overnight. And hub company with all the other equipment they have underground. They have autonomous drills are working on, autonomous <....> are working on, they understand the importance

of having that communication network. And we will be adding into that. ”

My findings shows that knowledge was exchanged within and across the boundaries between the work packages. *Knowledge was disseminated, combined and transformed at the work-package and at the ecosystem level*. **At the work package level**, *members discussed with the package leaders and among themselves to combine individual knowledge into new knowledge.* **Rock technology professor M2 and resource engineering specialist M1** stated that work package leader took a crucial role of leading and designing work package. Furthermore, they highlighted that ecosystem members contributed their knowledge while interacting with others and with the work-package leaders.

M2 “So you have partners within the work package who can contribute but the work package leaders should have an overview of the general goal of the work package. So for our work package, we spent some time, we put together the work package, and then we send it to our partners for contributions, and I mean, good contributions. And then we included those, and then in the end, it was a work package, we assume the responsibility for compiling the work package and we assume the responsibility for leading it. And I think it is similar in other work package. “

M1 “Generally, there was like, of course, each company has its own main speciality in that aspect is very clear from the start, who's doing what, but why do you implement and achieve the objective, for example, our work package, there are so many integrated things which are to be... should be done together with our partners, for that the partners who are involved in the work package, discussed about it. ...we do have the framework, but when it comes to the actual implementation, there should be a discussion to make it more easier this way to make it more...how do you could... easy or more feasible in terms of implementation.”

M2 “Yes, we work together with Complementor D and Complementor G, they are specialists into technologies ...So of course, we work in the same work package, we focus on material characterization, we use somehow different technology. But when it comes

to data integration, of course, it will be a joint effort to fuse the data and characterize the material under investigation."

According to **resource engineering specialist M1,** *the main reason for members to exchange knowledge is because of the interdependency of data generated*. Since the data inputs need to be coordinated smoothly, members need to work together to figure out ways to transfer information. Moreover, they further discussed their roles, responsibilities and planning the implementation tasks.

M1 "We need to integrate. So there's a data exchange in between collaboration in between, of course, we need to find a way that's how we use like, similar platform in terms of exchanging information. So yeah, we need to work together."

At the ecosystem level, there is *multilateral knowledge interactions across the boundary of work-packages*. Such interactions helped to integrate knowledge from each package into a collective whole. As stated by complementors, *interactions with other members are crucial as new knowledge cannot be developed purely from a single complementor.* For example, **resource engineering specialist M1** stated that although she is a leader of the rock flow package which works mainly with material tracking technology, she often has to work with **Complementor B and C who are key members of different working packages**.

*M1 " Because like, for example**,** if you check out how and what the package which mainly focus on rock flow, there are companies bigger companies like Complementor C, for example, Complementor B, who will contribute for our work package, so during our face to face meeting in Finland, we have tried to point out and discuss their role clearly. And we know it by now we know that, of course, who is doing that and which companies contribute in what way."*

Moreover, all members seems to interact with the hub company to exchange knowledge. While the hub company provides valuable knowledge in mining to complementors, the complementors also provide their expertise into the discussion with the hub company, thus, further helping the hub company to clarify its vision to better fit everyone in the ecosystem.

Interviewee H1 - Director of Manufacturing and Energy team noted as below:

> *H1 "I think the others they had the vision by themselves....but all became more in detail described during the collaborative process, where also the partner could kind of bring their expertise, interviews there as well."*

3.2.3 Resource commitment

To fully integrate resources into the operational structure of the ecosystem, the hub company had to assign some key resources. Dedicated resources such as funding and key personnel were purposefully allocated to support the formation of innovation activities of the ecosystem.

i. Committing key resources to the ecosystem management

My findings shows that dedicated human resources were allocated from the hub company to take part in the ecosystem.

The hub company assigned their Head of technology sourcing and new product development to personally overlook the development and management of the ecosystem. This dedicated ecosystem manager was an active agent in building the ecosystem architecture. This view was described by the **Director of research and technology development A2**:

> *A2 "Basically, M. is the captain of the show and running the show, and I have appointed him to be the hub company's Interviewee to run the show. So because he's reporting for me, so it's quite natural thing. So I'm always delegating things. I'm not doing too much myself. That's my role."*

The hub company also allocated people from finance department and other key resources to the ecosystem. This view was shared by **Director of Research and Technology Development A2** and **Director of Application Program and Digital Automation C1**:

> *A2 " M. is there, or some other key persons and other Sandvik persons from finance or so on. So we are doing that by ourselves."*

C1 "A handful of people giving their time. But it's still in our scale, it's not the small one. But then Hub Company would double more than we are. Complementor B puts quite a lot and the smaller put, of course, less but it's like it's already enough for me to have a headache that how do we really resource it, but then we also pull our <...> research along the process. So we have more people that can report."

More than just human resources, the hub company has also allocated financial investments into the development of the ecosystem. For example, they have hired the management consultant company H to handle the daily administration tasks as well as manage the work progress of the ecosystem members. The hub company has funded the whole ecosystem preparation phase, according to **Director of Application Program and Digital Automation C1:**

C1 "But I think that I see hub company as a glue and hub company also funded this preparation phase. So they take it so seriously."

Moreover, they also organized a two-day face to face meeting with ecosystem members at their company with their own cost. The face to face meeting was a social forum for partners to interact, increase trust, commitment and knowledge sharing.

ii. Management of appropriability

During the emergence phase of the ecosystem, heavy contracting was not implemented. **Chief Executive Officer K1** stated that

K1 "Uh, well, with hub company A, we have an ongoing relationship. So before this, we were already kind of having a customer supplier relationship. With all the companies in the ecosystem now, we don't have a contract in place."

However, *a light version of a contract - a letter of intent - was signed between ecosystem members.* On the letter of intent, ecosystem members showed their interest in working in the ecosystem as well as the commitment to contribute necessary resources to the ecosystem. Such letters of intent, however, do not present much legal effect. This view was supported by **Director of Manufacturing and Energy team H1 and rock technology professor M2:**

H1 " There is this kind of a letter of intent that you kind of show your interest that you want to participate in this. That type of agreement has been made, which is a common procedure when you start working. And kind of show that yes, it's not, I guess it's not legally binding, but it shows your willingness that there is some way of engages you to that you want to work together with this part to get this established."

M2 "We signed a letter of intent to participate in the project, you have to sign the consortium ground agreement and that is explicit in most agreements. So once you signed that, you've committed to obeying those rules. And that's the legal commitment. So at the moment, we haven't seen any reason for conflict, or competition."

M2 "Well, the contracts are binding. Essentially the description of work, and the deliverables that have specified, you agreed to do them. And they also say that you have the resources necessary to do it. So you can't just take the money and give it to another company and say "do it for me" and submit results so that's definitely the European Union can take money back or stop the project, cancel the project."

According to **Director of Manufacturing and Energy team H1**, the letter of intent had a strong effect in keeping complementors committed to the project. Because it needed the whole organization to stay committed, signing the letter of intent displayed a careful consideration of the organization for joining the ecosystem.

H1 " I think it's, it's complementing this, this psychological agreement that you have with just written emails and talking them and so on it, I think it complements that somehow. Because usually you need to get commitment from your organization higher from you to get a signature for that. So it makes also visible in that your own organization say "hey, we're doing that". It's not just your own wish or your own hobby that you would like to participate in that. It makes it more official."

When being asked, **Director of Manufacturing and Energy team H1 and Chief Executive Officer K1** believed that a heavy contract right at the beginning of the emergence phase was unnecessary because they were still waiting for the funding decision for the ecosystem. It was

enough to have only the letter of intent at the beginning because both H1 and I1 could see real commitment in actions of complementors.

H1 "No I don't think so. Then when it gets funding, then there is this grant agreement that you do meet with EU, and then partners will do some more agreements. I think that, so far, I think it's been enough."

H1 " Well, I mean, I mean, this letter of intent, I think that is enough. So because it shows your indication. Yes. So you want to work towards that. And because there's no, let's say, everybody's so far they doing you know, there's they're spending their own money there, that the funding this course the time they use a travel from their own pockets. So, of course, that's one indication of commitment."

K1 "Look, there's one thing which is very clear. When you're a small company, you can sign any contract, but you're able to enforce that. You know, contract doesn't give you confidentiality. Well, on paper, yes. But in fact, it's not. So it's important. Usually, it's more important for big companies than for small companies. You know, of course, contractual agreements are part of the activities and you need to do them. But again, they don't provide much coverage. When you don't have a means to enforce it if you need to. So, yeah, no, I don't think that's super important to be playing that track."

K1 "Yeah, I mean, it's stressed. It's also a feeling of having similar and goals stuff of things, right? What we call the same thing. I think, for me, this is more important than any paper."

4.3.2.4 Summary of findings

To fully transform identified resources into difficult-to-imitate capabilities, the hub firm performed a series of actions that reveal mechanisms to fully capture and integrate those resources in the ecosystem. According to my analysis, future shadow casting is the foremost factor that enables an effective capture of complementing resources. Under the influence of a compelling vision of the hub company, and the hub company's well-known social resources (such as reputation and experience), complementors were convinced to commit their resources

in the emerging ecosystem. Moreover, it is important to note that even when the complementors were convinced to join the ecosystem, they would not be able to do so if there was no ready structure for them to join. According to my analysis, the modularized structure was one of the elements that allows an easy integration of complementors' resources into the ecosystem. Moreover, the hub company also aligned complementors' roles to remove conflicts and misunderstandings. It is interesting to note that, the hub company was assisted by some complementors in leading the ecosystem. Some management tasks were performed by complementor H who assisted the hub company at the ecosystem-level and some other leading tasks at the work-package level were performed by academic complementors such as Institute L, M,N. The hub company also purposefully allocated needed resources such as funding and key personnel to the ecosystem development activities, which created a trust-worthy environment in the ecosystem. This trust-worthy environment further encouraged complementors to commit their human resources and monetary resources into the ecosystem. Furthermore, the hub company facilitated knowledge sharing through frequent meetings between members to disseminate complementors' knowledge within the ecosystem, thus, enabling the development of joint innovation. Shared knowledge between hub company and complementors is indeed a valuable vehicle for the ecosystem to create innovative technologies that will be hard-to-imitate by competitors.

V. Theoretical integration & Conclusion

This chapter evaluates the empirical findings in light of the reviewed theory, thus, providing answers to the empirical research questions. Three empirical research questions were formulated in chapter III as the followings:

ERQ 1: What triggers the need for developing an innovation ecosystem?

ERQ 2: Which resources is a hub company looking for in the emerging ecosystem?

ERQ 3: How does a hub company use its dynamic capabilities to enlarge its resource base?

By answering the above empirical research questions, the conclusion to my main research question is reached. While contrasting the empirical findings with the reviewed theory, overlappings and gaps between theory and reality are highlighted.

1. Triggers of the innovation ecosystem formation

In this subchapter, the answer to ER1 is discussed. According to my findings, three key drivers that triggered the formation of the innovation ecosystem were identified. They are industry-level technological bottlenecks, industry-level environmental concerns, and internal business changes.

Industry-level technological bottlenecks

One of the key findings of my research is the pivotal role of industry-wide technological bottlenecks to the strategic formation of the innovation ecosystem case. These technological bottlenecks are challenges caused by the remote condition of most underground mines. Moreover, the empirical case highlights that technical bottlenecks also include outdated capabilities and working methods. These issues are extremely challenging for underground mines around the globe as they hinder the growth and operation of the mines. There is not a single company that could develop solutions to all of these bottlenecks alone.

In literature, bottlenecks are defined as critical components that are necessary to the functioning of the whole system, but they do not exist at all, are very limited in nature, or exist but have poor performance (Adner, 2012; Baldwin, 2015). Bottlenecks are traditionally used by scholars to understand the "direction and pace of technological change and capturing value in large, complex technical systems" (Baldwin, 2015, 6). To the best of my knowledge, in ecosystem literature, industry-level technological bottlenecks have not been identified as contextual conditions that give rise to the formation of innovation ecosystems.

While comparing my empirical findings to theory, it is surprising that **technological bottlenecks have not been identified by extent research** as the contextual conditions that trigger the formation of innovation ecosystems. Though ecosystem literature does not highlight technological bottlenecks explicitly as antecedents to the formation of innovation ecosystems, however, recent researches have used the concept of bottlenecks to suggest how firms can compete by using bottleneck strategy. As explained in these researches, firms create value through advanced technologies that resolve technological bottlenecks - they control it and maneuver from solving one bottleneck to others (Jacobides and Tae, 2015; Hannah et al., 2018). To stay competitive, firms need to identify the bottlenecks quickly, then build necessary resources to better benefit or not to suffer from the bottlenecks (Hannah & Eisenhardt, 2018; Teece, 2018). However, my case research results show that companies cannot always solve the bottlenecks alone. Rather, like in the studied case, they need help from external partners to be able to build innovative solutions to tackle bottlenecks as quickly as possible. This notion implies that **bottlenecks are the reasons for the formation of innovation ecosystems** in which firms collaborate with other partners to gather cumulative power for new products/solutions development - just like in the Intelligent Mine ecosystem case.

Some more interesting similarities between theory and empirical findings were found. In the empirical world, this thesis addresses the existence of a reputed company who took a leading role in forming the Intelligent Mine ecosystem in order to create more value to the market. On the other hand, in the theoretical world, the existence of "kingpins" whose have

superior market capitalization and superior technical capability were highlighted as those can create substantial value by tackling market bottlenecks (Jacobides and Tae, 2015). Value creation by developing solutions towards bottlenecks was also highlighted in a recent research by Hannah et al. (2018). The researches of Jacobides et al. (2015) and Hannah et al. (2018) highlight two elements: (1) the existence of a company who acknowledges the impact of bottlenecks at the industry level and (2) the organizational thrive to solve those bottlenecks by collaborating and/or competing with complementors. My findings are in line with these theoretical suggestions in two ways: It confirms (1) the critical role of a technically strong company whose in-depth knowledge was the foundation of the ecosystem 's formation, and (2) the necessity of collaboration between the hub company and complementors in order to develop solutions to tackle the addressed bottlenecks. However, while previous research by Jacobides et al. (2015) and Hannah et al. (2018) seem to emphasize the value of competition over collaboration, **the case study conducted in this thesis suggests a dominant role of collaboration instead of competition during the emergence phase of the innovation ecosystem**. Nevertheless, previous research of Jacobides et al. (2015) and Hannah et al. (2018) confirm my finding that *an innovation ecosystem is formed as a response developed by companies who acknowledge the need to co-innovate with complementing partners to the technological bottlenecks in the market*.

Industry-level environmental concerns

The empirical findings suggest that environmental concerns regarding mining activities are rising from citizens and governments, thus, putting high pressure in underground mining companies. Due to the nature of underground mining activities, influences on the environment are inevitable. However, mining companies need to find new solutions to reduce their environmental impacts as much as possible. Thus, changing in ways of working and learning how to optimize operational activities can help mining companies to greatly reduce their environmental footprints. While most mining companies have strongly focused on technology instead of sustainability, they need to reach out to experts who are outside of their in-house

R&D department to gain new knowledge on the physical environment. The need to gain new expertise to tackle challenging sustainability-related issues leads to the formation of the innovation ecosystem case. Existing ecosystem literature has not addressed the link between external factors such as environmental concerns to the formation of an innovation ecosystem. Thus, *this work suggests a new contextual factor that triggers innovation ecosystem formation.*

Internal business changes

My findings suggest that the hub company's awareness of the existing bottlenecks in the mining industry gives rise to the identification of unmet customer needs existing in the market. The value that can be created by answering the unmet needs implies huge earning potentials for the hub company. Moreover, realizing the power and the potential disruption of digitalization in the market, the hub company took digitalization into its company-wide strategic focus. According to the hub company's strategy, it aims to transform itself from a traditional Original Equipment Manufacturer (OEM) to a digital company which focuses more on selling digital mining solutions. Realizing that it cannot achieve this ambitious transition alone, the hub company reached out to external partners to form the Intelligent Mine innovation ecosystem to co-create new digital solutions.

Such IT-enabled business transformation has been discussed in the literature (Vial, 2019). Vial (2019, pp.1) suggests that a digital transformation is a "process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies". Digitalization is a source of strategic disruption - it profoundly alters expectations of customers and business landscape (Vial, 2019). Thus, it can be understood that organizations who highly adapt digitalization in their business will likely have competitive advantages against others. In my findings, *digitalization has been used as a blueprint that guides the future of business development of the case hub company.* Because digital technologies enable the possibility to develop hard-to-imitate solutions by allowing a wide set of operational data to be digitally

generated and analysed, maintaining a competitive position in the market rely a lot on firms' capabilities to employ advanced technologies at a faster speed than the competitors.

My finding is, therefore, in line with Vial (2019) in a sense that *digitalization has triggered the hub company's business transformation, which leads to the formation of an innovation ecosystem as a result of the company's missing digital capabilities.*

2. Extending resources with ecosystem

In this subchapter, the answer to ER2 is discussed. The key resources that the hub company looking for in the emerging ecosystem were found to be intangible resources. First, complementing technical competences were needed to upgrade the hub company's outdated competence base. Second, because the hub company does not have sufficient in-house expertise or time to coordinate ecosystem activities (for example ecosystem administrative tasks, ecosystem meetings, etc.), it expanded its managerial resource by having a consulting complementor to assist in ecosystem management. Third, commercial resources such as a working relationship with the end-customer and marketing brand are among the identified motivations for the hub company to form its Intelligent Mine innovation ecosystem.

While contrasting my findings with the ecosystem literature, it was found that the resource-based view has been limitedly applied by previous researchers in the theory of ecosystem formation. When looking outside of the ecosystem literature, it came to my knowledge that organizational resource theory offers excellent support to the findings of my thesis. By viewing the formation of an innovation ecosystem as the hub company's actions of integrating specialized resources from the outside to increase the strength of the hub company's existing resource base, *we can gain a deeper understanding of why and how firms purposefully extend their competence base to stay competitive*. This view suggests that, by combining the total value of hub-company's and complementors' resources, each partner within the emerging innovation ecosystem shares a cumulatively stronger resource base that is valuable, rare, inimitable and non-substitutable (VRIN) by their competitors. The role of VRIN

resources to organizational survival was discussed by Barney (1991). In the spirit of Barney's view, it could be seen that *my findings are in line with Barney's suggestion when we enlarge the view to the ecosystem level. This motivates a company to renew is resource base via an ecosystem strategy.* Moreover, the capability to configure and reconfigure organizational resources in response to the changing environment is indeed a key element of dynamic capabilities framework (Teece et al., 1997; Eisenhardt et al.,2000; Helfat et al., 2007; Teece, 2007; Schilke et al., 2018). Thus, *the organizations' resource-based motivations could be seen as the heart of the dynamic capabilities framework, as well as the center of innovation ecosystem formation*.

My findings in this chapter contribute to the literature of both ecosystem and dynamic capability in the following ways: (1) it fills the gaps of existing literature by introducing the application of resource-based view on ecosystem formation, (2) it introduces key concepts to the resource-based view of dynamic capabilities by crystallizing the purpose of why companies dynamically engage with external actors and do so by forming an ecosystem.

Furthermore, my empirical findings suggest that the motivation for companies to form innovation ecosystems is to collaborate with external partners to *enlarge intangible resources*. Literature has described some forms of intangible resources such as knowledge, know-how, personal network, organizational reputation, marketing brand, database, intellectual property rights and customer relationships (Hall, 1993; Eisenhardt & Schoonhoven, 1996). Intangible resources like knowledge and know-how are argued to be factors that differentiate the winners from the losers and survivors (Bartlett and Ghoshal, 2002) because they are often difficult to imitate. Thus, this theoretical suggestion explains why the hub company in my empirical case was motivated to seek for intangible resources. However, it is important to note that, because my empirical findings are very case-specific, they can only be used as references for further discussions between scholars and practitioners.

3. Dynamic capability mechanisms

In this subchapter, the answer for ER3 is discussed. My research's results show two mechanisms which are central to the formation of an innovation ecosystem: resource sensing and resource seizing. Companies use their resource positions (for example, existing knowledge and reputation in the market) to sense and seize valuable, rare, inimitable and non-substitutable resources from the market (for example, specialized technical resources from external partners). This finding is in line with previous suggestions by well-known researchers such as Teece (1997, 2007) and Helfat et al. (2007). Through my findings, it shows that organizations create, extend and modify their resource base through a dynamic process of continuous scanning and seizing mechanisms. This finding contrasts the static view of traditional resource-based perspective (Barney, 1991), and in line with the argument of a dynamic resource-based view suggested by Eisenhardt & Martin (2000).

Whereas my initial theoretical model consists of three main building blocks: sensing, seizing and transforming & renewing***, it is important to note that the mechanisms of transforming & renewing were not visible in the empirical case***. A reason for the unavailability of the transforming & renewing mechanism in my research case could be that the emerging innovation ecosystem case was only going through its early formation stage. At the time of my study, the innovation ecosystem was going through its early planning activities. From the empirical findings, it came to my understanding that, during the early phase of the Intelligent Mine innovation ecosystem formation, ecosystem members did not have any concrete plans to commercialize the ecosystem's innovation outputs. There were uncertainties regarding how the hub company and complementors will create and capture value generated by the ecosystem. At the time I studied the Intelligent Mine innovation ecosystem case, no business model for the ecosystem was designed yet. Moreover, the hub company has not planned on how they will align the external and internal coherence of the ecosystem according to the future market changes. Thus, due to the absence of transforming & renewing mechanisms in the emerging

innovation ecosystem that I studied, such mechanisms are not included in my following discussion. Therefore, it is for other researchers to explore the role of transforming & renewing in the later phases of innovation ecosystems.

3.1 Resource sensing

According to my findings, the hub company performed market scanning, and complementors scanning. In market scanning, the hub company scanned for technological changes in the market to realign its organizational strategy. In complementors scanning, the hub company searched for capable expert partners both locally and globally. In the following sections, I will explain market scanning and complementors scanning in more details.

Market scanning

One of the hub company's key activities while sensing the market is to update technological changes. Digitalization was addressed as a change agent in the mining industry. Therefore, upon this acknowledgment, the hub company's top managers believed that digitalization was something they could not miss. Keeping digitalization at the heart of its strategy, the hub company aims to transform itself from a traditional Original Equipment Manufacturer focusing on developing heavy equipment to a company providing more digital solutions to the mines. Although not explicitly mentioned in the interviews, we could interpret that digitalization was seen as a threat and an opportunity for the hub company. Digitalization could be a threat to the hub company if it does not update its resource base (such as knowledge and know-how), thus, allowing competitors to win. On the other hand, digitalization brings plenty of opportunities as it enables smarter ways to optimize resources and better ways to enter new markets as well as new customers.

This finding is in line with the theory in various ways. The role of market dynamism was found critical to firms' evolution in the literature (Eisenhardt & Martin, 2000, D'Este, 2002; Mota & Castro, 2004). Firms' abilities to address the changes in the competitive environment and align their resources to the changed market conditions is critical for their survival (Forrant

& Flynn, 1999; Staber & Sydow, 2002; Alvarez & Merino, 2003). From my empirical findings, it became visible that the hub company has addressed the market change - which is digitalization - to transform its strategy to align with the changes in the environment. The hub company has a technological board that reviews the company's existing business portfolio, evaluates the performance of the existing portfolio, updates technological changes in the market, and then makes decisions to allocate the company's internal resources on key development areas. This organizational practice of balancing between technology push and pull enables the hub company to dynamically align itself with the changing market conditions, thus increases its chance to survive. Teece (1997, 2007) suggests that an organization's ability to survive market change is largely dependent on its market sensing activities. Thus, **my findings are in line with Teece (1997,2007**). Moreover, **my findings also complement the theoretical suggestions of Teece (1997,2007) by adding key concepts of how organizations perform market scanning in reality**.

Furthermore, my findings highlight how organizations scan for funding in the market. For example, in the Intelligent Mine innovation ecosystem, the hub company regularly updated information on upcoming funding programs to identify external financial instruments to boost its planned R&D activities. To the best of my knowledge, dynamic capabilities literature has focused largely on technological changes when it comes to market scanning activities. Yet, **the role of public funding on organizational sensing practices has not been discussed yet. Thus, this finding could be seen as a contribution to the dynamic capabilities literature.**

Complementors scanning

The hub company performed sensing activities in the search for complementing technological expertise. Acknowledging that the company could not stand alone in the mission of transforming itself from a traditional OEM company to a digital-focused company, the top managers recognized the need to upgrade the organization's technological resource base to the level required by digitalization. Consequently, the hub company searched locally and globally to identify capable partners who could co-create innovative solutions to the underground mining

industry. **My empirical findings shows that the hub company participated in various channels to identify capable complementors**. For example, the hub company created a thematic hackathon to identify complementors capable of providing new rock technologies. As a result of this hackathon, the hub company formed a partnership with a complementor who is now an official member of the Intelligent Mine innovation ecosystem. Moreover, the hub company attended international conferences and networking events to keep updated about complementing technologies. The hub company established contacts with potential partners through these networking events. University-industry partnerships were created between the hub company and academic partners to boost the development of new knowledge. The hub company also kept its radar on publications of universities to identify new areas of technologies that could be of relevance to the hub company's R&D plan.

From my findings, it is interesting to note that **both regional and international strategies were used by the hub company while searching for complementing expertise**. The regional strategy was highlighted in the literature as a way that companies can identify resources within specific regions that can potentially give them the best access and support (Arregle et al., 2009). Geographical proximity is an enabler for ecosystem formation as firms can spontaneously have face-to-face interactions, thus, increasing trust and strengthening social ties (Boschma, 2005). This regional strategy was visible in my findings as the hub company allowed companies within its geographical proximity to come for company visits. While opening the door for company visits, the hub company allowed the discovery of new opportunities, new technologies and new partners. Teece (2007) suggests that firms should overcome their narrow search horizon by exploring international markets to identify complementors. In the hub company's case, it performed international searches for complementors by attending international conferences, and networking events.

While contrasting my findings with the reviewed literature, it came to my knowledge that the existing literature in complementors scanning activities is ambiguous. Literature has mainly addressed the critical importance of leveraging complementing expertise to increase

organizational strength (Teece, 2007; Sirmon et al., 2011). Yet, to the best of my knowledge, existing research has not addressed where and how companies can scan those resources. Thus, **my findings fill in this literature gap by introducing new knowledge of various search channels where a hub company can scan for complementing expertise**. It is important to note that, **while the hub company is scanning the market, the complementors also engage in similar scanning activities to make themselves visible to the hub company**. For example, while the hub company attends the conferences to scan for partners, the complementors give presentations in the same conferences to scan for customers. In other words, **for resource scanning to be successful, there needs to be reciprocal sensing activities between the hub company and the complementors**.

3.2 Resource seizing

The empirical findings show that resource sensing activities must be followed by seizing mechanisms to fully capture and integrate sensed resources. The hub company used three organizational practices to seize resources. First, the hub company cast a vision of future benefits which helps it to persuade partners to commit their resources to the emerging innovation ecosystem. Second, the hub company facilitated the alignment of the members to allow easy plugin of external knowledge, remove conflicts, and increase knowledge sharing activities. Third, the hub company increased the commitment of the partners by dedicating its own resources and also, by reducing the partners' anxiety in joining the ecosystem, by managing appropriability issues.

Future shadow casting

The findings show that the hub company has leveraged its existing social resources which are reputation and industrial experience to influence the perception of the complementors. As a result, most complementors were convinced to join the ecosystem. They shared a common sense of future benefits perceived in the collaboration with the hub company. The amount of experience and knowledge that the hub company possesses in the

mining industry appeared to be attractive factors to complementors. Most future benefits perceived by complementors range from future funding possibilities, faster innovation development, easier market entry, gaining industry-specific knowledge, and access to data. Thus, by casting such future benefits on the complementors, the hub company has effectively persuaded partners to join the ecosystem.

While comparing my findings with the ecosystem-related theory, it was hard to find supporting theory in the ecosystem literature that explains resource seizing in the formation of innovation ecosystems. However, when going beyond the ecosystem theory, the theory of organizational resources supports my findings. For example, Eisenhardt & Schoonhoven (1996) suggest that a firm can attract more resources if it has strong social positions (for example a well-known brand and a good reputation). In my case study, the power of a strong social position was confirmed to be useful for the hub company when seizing external resources.

My findings also show that the hub company created a compelling vision for everyone within the ecosystem and communicated that vision widely to the external partners. **According to my findings, the visioning capability of the hub company is critical while seizing external intangible resources (such as knowledge and know-how).** Such capability is central for organizations to capture resources and most importantly, to realize value from the acquired resources. A visioning skill is needed to convince external partners to share their resources. **My research result shows that when the hub company formulates an inclusive vision for every member within the ecosystem, external partners are more convinced to commit their resources because they can see potential benefits for participating in the ecosystem**. To the best of my knowledge, similar empirical findings have not been found in the ecosystem literature. Thus, my research result promises a new light to the ecosystem literature with new understanding of which factor motivates external partners to commit their resources in ecosystems.

Alignment management

My research result shows that **the hub company created a modularized structure to enable knowledge integration in the ecosystem.** In my empirical case, **such supporting structure facilitates external resources to be integrated fully into the ecosystem**. This empirical finding is in line with ecosystem theory. This modular ecosystem architecture has been described as a critical condition for the emergence of ecosystems (Jacobides et al., 2018). Adner (2017) suggests that modularity facilitates architectural alignment because it removes conflicts between a multilateral set of partners. The flexible modular structure of loosely-coupled components can support knowledge integration (Akgun, Keskin & Byrne, 2012; Adner, 2017; Jacobides et al., 2018). Due to the weak linkages between the loosely coupled components, they allow each unit to have their autonomy, therefore, they can respond to changes quickly without affecting the other units (Beekun & Glick, 2001; Staber & Sydow, 2002). Moreover, one can flexibly modify a component without affecting the others, thus reducing unnecessary alteration costs (Richard & Devinney, 2005).

Moreover, **my findings give support to the literature on the importance of leadership in ecosystem (Adner, 2017)**. Studies show that managers having leadership skills and abilities to relate to others are more successful in managing inter-organizational networks (Parker et al., 1996). Since each member entering the ecosystem might have different goals and different ways of working, problems arise when their expectations and actions are conflicting. If the ecosystem leader can facilitate a greater consistency between the members' goals and their expectations, a higher likelihood that their actions will be convergent, which consequently increases the chance of generating positive innovation outputs (Adner, 2017). Leadership was found in my empirical research as an important factor to remove conflicts and misalignments between members. The overall leadership of the ecosystem was shared between the hub

company and a management consulting complementor. In the ecosystem case that I studied, coordinative and alignment tasks were performed regularly and communications were exchanged back and forth between the leaders and members so that tasks were aligned with the overall objectives of the ecosystem.

The coordination of knowledge exchange was seen as an important task in the ecosystem. Knowledge exchange is regarded as an important factor in inter-organizational networks such as ecosystems (Nambisan & Sawhney, 2011). Thus, the theory strongly supports my findings. In the empirical case that I studied, knowledge was exchanged within and across the boundary of each module. The exchanges of knowledge took place in meetings, emails, phone calls, and other informal interactions. The frequent knowledge interactions between members can be regarded as a "glue" to tie each loosely-coupled partner together. The frequency of meetings between members is a key indicator for creating alignment and facilitate knowledge exchange (Mothe & Quelin, 2001), especially during the emergence phase. Meetings were regarded as important also in my case study. They are the forums for members to increase social ties and trust, thus, increasing the likelihood of members sharing their valuable knowledge with others (Mothe & Quelin, 2001).

Resource commitment

Although organizational investment to ecosystem formation has not been discussed widely in the ecosystem literature, my findings show that the hub company needs to commit both human and financial resources to facilitate efficiently the development of the emerging innovation ecosystem. The dedication of the hub company's resources to the ecosystem increased the confidence of external partners to join, thus, influencing to commit their resources to the mutual innovation objectives. Although ecosystem literature has not discussed the organizational investment theme widely, dynamic capabilities theory offers support to my findings. Teece (2007) suggests organizational investment is important for capturing sensed resources as well as sensed opportunities. Timely investment decisions need to be made while taking into consideration the innovation uncertainties and risks so that organizations can stay

ahead of the competition (Teece, 2007). In ecosystem management, it is not sufficient that the hub company commit resources to the mutual objectives. It is crucial to have a resource commitment of all ecosystem members. When ecosystem members display a mutual commitment, they signal the interest of developing a long-term relationship and a determination to achieve innovation objectives (Osborn & Baughn, 1990).

Management of appropriability is critical for ecosystem development. This theme is discussed widely in ecosystem literature. Ecosystem literature suggests that firms have various concerns before joining an innovation ecosystem, ranging from potential opportunistic behaviors of ecosystem members to the protection of intellectual property rights (Nambisan & Shawney, 2011). To remove those concerns and encourage members to contribute, the hub company should orchestrate innovation appropriability (Dhanaraj & Parkhe, 2006). Better orchestration of innovation appropriability results in more effective knowledge sharing and more cost-effective development of complementary products/services (Nambisan & Shawney, 2011). Contractual frameworks and agreements can help firms remove their partners' fears for participating in the ecosystem and thus, reinforce their commitment towards the ecosystem's common goals. Contracts help to align partners' expectations, intentions and incentives (Furlotti, 2007) under the uncertainty of the future partners' actions (Argyres and Mayer 2005). Contracts also provide a mechanism to cope with uncertainties and risks (Mellewigt et al., 2012). Whereas the role of contracts is strongly emphasized as a critical factor in ecosystem management, **it is surprising to find out that heavy contracts were not desired in the emergence phase** of the innovation ecosystem case that I studied. **A light version of the contract - a letter of intent - was preferred by ecosystem members over a heavy contract during the emergence phase of the innovation ecosystem. This is a novel finding concerning the suitability of contracts in the early emergence phase of ecosystems.**

4. Refined framework

This thesis's findings suggest answers to my main research question: How a hub company can support the formation of its emerging innovation ecosystem. Firstly, my research shows that, by evaluating the organizational conditions against market demands, a company can realize if and when it needs to extend its competence base by forming an innovation ecosystem with complementing partners. Secondly, upon the realization of missing competences, a company needs to set clear objectives in order to efficiently sense and seize complementing resources into its ecosystems. Such sensing and seizing capabilities are critical for the success of their innovation ecosystem formation.

Moreover, *my research shows that two usually isolated theories - dynamic capabilities and ecosystem theory - are, in fact, very well connected.* The dynamic process of resource sensing and seizing - which are the building blocks of the dynamic capabilities framework - could be used to explain the formation process of an innovation ecosystem. It is important to note that, while transforming & renewing mechanisms were included in the initial theoretical framework, such mechanisms were not found in my empirical analysis. A reason for this could be that the case ecosystem that I studied was still in its emergence phase. The hub company and its partners had not decided on commercializing the ecosystem's future innovation outputs yet. Thus, the elements of my theoretical framework that belonged to the renewing mechanism of ecosystem, such as the management of external and internal coherence, were not found in my empirical case.

As a result of my research, I propose a new view to ecosystem formation. My proposition is that, we could view *ecosystem formation as a dynamic process of resource sensing and seizing* which are triggered by either external market conditions (such as technological bottlenecks and environmental concerns) and internal strategic changes (such as strategic business changes). During the ecosystem formation process, a hub company is motivated to extend its existing intangible resources base with complementing resources from

ecosystem partners. While forming an innovation ecosystem, a hub company senses external resources through various channels and seizes resources into the emerging ecosystem. *Sensing mechanism* consists of two main activities - market scanning and complementor scanning. Market scanning is a series of activities in which a hub company: (1) updates technological changes, and (2) maps R&D effort with market needs to create a strategic balance between technology push and pull. On the other hand, complementor scanning includes activities in which a hub company: (1) scans for technical resources in complementors' organizations via events and hackathons and (2) scans the technological developments in universities. *Seizing mechanism* can be seen as a critical process in which a hub company captures sensed resources into its ecosystem. The seizing mechanism includes: future shadow casting, alignment management and resource commitment. In future shadow casting, a hub company casts a vision of future benefits including funding, commercial benefits, and long-term partnership to influence partners to join the ecosystem. In alignment management, conflicts and misalignment between members are removed by using modular ecosystem architecture, leadership and knowledge exchange. In resource commitment, a hub company dedicates human resources as well as financial resources to ecosystem development, which in turn, increases the confidence of partners towards committing their own resources to the ecosystem. Appropriability is managed by using a light contract version which helps to reinforce partners' commitment towards the ecosystem.

In a nutshell, I propose that *ecosystem formation can be perceived as a process in which a firm uses sensing and seizing mechanisms to bundle its internal resources with valuable intangible resources from complementing partners into an ecosystem that can develop innovative solutions.* By doing so, the firm extends its resource base, takes advantage of market opportunities and eventually, creates long-term competitive advantages.

The following model **(Figure 11)** encapsulates my view on the formation of an innovation ecosystem from the angle of a hub company with the help of the dynamic capabilities framework.

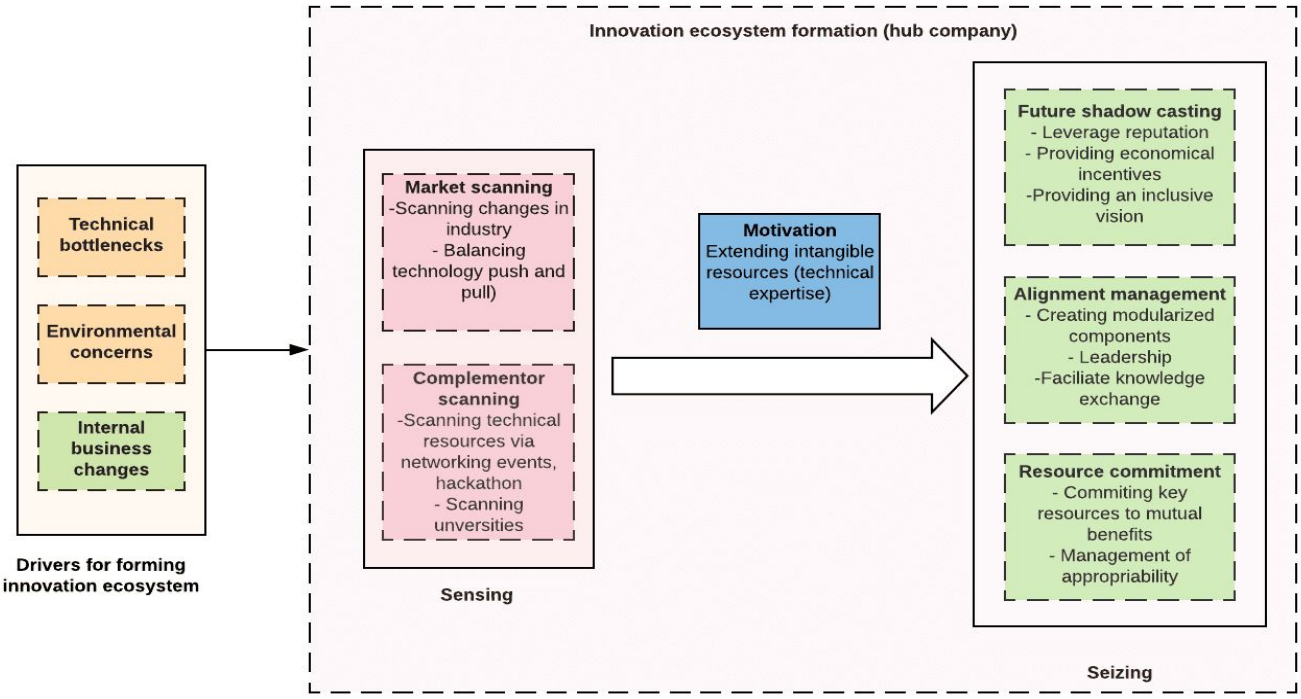

Figure 11: A proposed dynamic capability framework for ecosystem formation

VI. Evaluation

1. Research quality

Lincoln & Guba (1985) suggested a useful model to evaluate the trustworthiness and rigorousness of qualitative research. This model consists of four components: credibility, transferability, dependability, and confirmability.

First, credibility refers to the reliability and persuasiveness of the inferred interpretations (Lincoln & Guba, 1985; Thomas & Magilvy, 2011). Credibility was ensured in this research in various ways. First, to maintain the representativeness of data, the interview

guideline was designed iteratively, following the revelation of participants' experiences. The interview questions were formed through various discussions with other members of the research team. Two principles were kept in the interview guideline: (1) establishing a mutual ground with participants by using the same terms with the participants, and (2) inviting participants in the discussions to unravel their experiences with the help of open-ended questions. These two principles helped us to access the worldviews of the interviewees deeply, thus, assisting us in gaining more accurate interpretations of the empirical world. All interviews were recorded under the participants' permission. Transcriptions were documented and triangulated with other researchers. Gioia's method was followed consistently throughout the data analysis process. Visual representations of the data analysis were built to aid the discussions of my findings with other researchers. Other than the use of recorded data, meeting notes, industry reports and other online sources were used to enhance my understanding of the case context, thus greatly improving my ability to interpret the empirical case.

Second, transferability refers to the ability to determine the extent to which findings of a particular inquiry can be applied in other cases, other contexts, and with other participants (Lincoln & Guba, 1985). To establish transferability, I have described deeply the case context and factors that might have influences on the case. Detailed descriptions of companies and participants who participated in the research were documented to aid the understanding of other researchers in the case. Comprehensive explanations of the research design, research process, data collection, and data analysis are available in this work to enable other researchers to make their own judgments. While reporting the analysis, direct quotes were used extensively to ensure the transferability of the research findings.

Third, dependability relates to the stability of the findings over time (Korstjens & Moser, 2018). Moreover, to establish dependability, findings must be drawn from the grounded data and not under the influences of researchers' personal identities (Lincoln & Guba, 1985). To establish dependability. I conducted an internal audit trail to make sure that this thesis follows the guidelines for research dependability establishment of Thomas & Magilvy (2011): (1)

specific purposes of the research were described, (2) selection of participants was explained, (3) data collection method and data collection period were documented, (4) transformation of grounded data to conceptual themes were displayed coherently using Gioia's method, (5) research path was documented in detail, and (6) discussions and evaluations of the findings were conducted with other researchers.

Lastly, confirmability is related to the neutrality of the judgment made by researchers (Lincoln & Guba, 1985). To make sure that the findings are free of bias, I have conducted various comparisons between empirical findings and literature. Literature was sought to explain the new revelation of empirical data. On the other hand, empirical data gave me new insights to seek for new literature themes. Thus, this research was constantly updated with new insights from both the theory and the empirical data. Moreover, to improve the confirmability of the research, the author of this thesis discussed with her supervisor and instructor from time to time.

2. Limitations

While this thesis's theoretical model can be generalizable in theory, the generalizability of my empirical results is one of the largest limitations of this research. Since the research is conducted as a single case study, its findings are not generalizable to other cases and contexts (Yin, 2009). Moreover, because the case companies that I studied have their unique development paths and organizational history, their social positions might have affected my findings in some ways. Thus, it is important to note that this thesis's findings are case-specific. However, these findings can be used as references for future research in other case companies or industries. In an effort to help future researchers interested in using my findings for their work, my research case context, case background, interviewees' profiles, and the data collection methodology were described in detail in this thesis.

Another limitation of this thesis is the unavailability of some ecosystem members in the research. Despite my efforts in inviting all members of the ecosystem to participate in the

research, representatives of three organizations (including the end-customer of the ecosystem) could not participate in the research. Due to the lack of first-hand access to these three organizations, there was limited information regarding their perspectives in the emerging innovation ecosystem.

Finally, the research was not conducted in the mother tongue of the author, which might have hindered the author's ability to converse freely with participants. Similarly, most of the participants taking part in this research used English as a second language, thus, there might be some difficulties in their abilities to express their thoughts and feelings as well.

VII. Implications

1. Managerial implications

This thesis provides multiple implications for firms to build and benefit from innovation ecosystems.

First, the thesis suggests when firms should form their innovation ecosystems. By evaluating their organizational conditions against market demands, firms can realize if they need to extend their innovation efforts by collaborating with external partners. When the external market consists of challenging bottlenecks that hold huge business potentials for those who can tackle them, firms should start looking into ways to develop innovative solutions to resolve those bottlenecks. Such innovative solutions must be introduced as fast as possible so firms can gain the first-mover advantage in the market. Firms should carefully evaluate their existing capabilities to find out if they could develop such solutions all by themselves. If they do not have all needed competences, they need to collaborate with external partners to leverage on their complementing resources, thus reducing costs of building new innovation. The ecosystem case that I studied is an excellent example of why firms should form innovation ecosystems to create stronger innovation power. The hub company in my case study foresees

great market demand resulted from the challenges that its customers are facing from industry-wide technological bottlenecks and increasing environmental pressures. Acknowledging that the hub company did not have all the needed skills to produce innovative solutions to tackle existing bottlenecks, it formed an innovation ecosystem with external partners that provide complementing expertise to co-create new innovation to the market.

Second, this thesis highlights the benefits that companies will gain by forming innovation ecosystems. When firms are moving from innovating in-house to innovating in ecosystems, they face various organizational barriers that come from within their companies. Such barriers might arise from the uncertainties of the benefits in collaboration with external partners. Therefore, a clear understanding of the long-term benefits that firms will gain by forming innovation ecosystems with external partners can help them to reduce such barriers. By clarifying what firms want to achieve from the emerging ecosystem, they can motivate top managers to take actions toward their set goals, thus, improving the efficiency of their ecosystem formation. The ecosystem case that I studied provides a good understanding of the benefits that firms can gain by forming innovation ecosystems. For example, this thesis suggests that a firm can benefit from an emerging innovation ecosystem by leveraging intangible resources provided by external partners such as new technologies, new expertise, and new understandings of customers' problems. Moreover, they can strengthen their working relationships with partners and end-customers by collaborating intensively with them in innovation ecosystems. They can also benefit from extra management resources by sharing leadership tasks with ecosystem members. However, it is important to note that the benefits addressed in this thesis are case-specific, thus, they can only be served as a starting point for discussions in companies

Third, this thesis suggests ways in which companies can effectively sense and seize needed resources for the formation of their innovation ecosystems. In the era of talent scarcity and increasing competition in the market, the ability to identify and capture valuable resources quickly define firms' ability to succeed.

To *sense external resources*, firms should search in both local and international markets. Firms can use various channels to scan for talents, such as thematic hackathons, international conferences, and networking events. Opening up their doors for company visits is another way to enable new opportunities to discover new technologies and new partners. The use of personal networks is also critical while searching for partners. To gain the most up-to-date technological knowledge, firms should form partnerships with universities and follow academic publications. To timely identify new opportunities in the market, firms should have a dedicated team to follow the development and economic performances of key technological areas. This team also should monitor technological changes in the market so that they can align their organizational strategies with the changes. Furthermore, firms should seek information about new public funding programs so that they can gain extra financial resources to support the formation of their innovation ecosystems.

To *seize external resources*, firms should employ various tactics. First of all, they should leverage their reputation to attract the interest of external partners in the collaboration. They should motivate partners to commit their resources to the ecosystem by providing commercial incentives such as potential public funding or potential access to new business areas. The hub company must create a compelling ecosystem vision that takes partners' benefits into it.

To fully integrate external resources, the hub company should create an ecosystem architecture that enables easy plugin of external resources. By decomposing the complex end product into loosely coupled components, firms can flexibly experiment with the technical design of each component without affecting the other components. Thus, such a modular structure offers a great deal of flexibility and cost reductions to the development of innovation. Moreover, firms should provide leadership to their ecosystems so that they facilitate alignment between members' actions, remove conflicts and misunderstandings. Co-sharing the leadership position with other knowledgeable complementors might help firms to improve their efficiency in managing their ecosystems. Firms should facilitate knowledge exchange between members by creating a trustworthy environment so that members feel more comfortable in sharing their

valuable knowledge with others. Knowledge must be exchanged within the ecosystem through frequent formal and informal meetings. Online tools, emails, phone calls are also channels for communicating knowledge.

Lastly, firms should have dedicated human resources and financial resources which are reserved for the development of their innovation ecosystems. Such resource commitment can help them to effectively build as well as manage the ecosystem better. Moreover, by seeing serious commitment from the hub company in the ecosystem, complementors will be more convinced to commit their own resources in the ecosystem. During the emergence phase, a light contract version such as a letter of intent could be more useful for securing external resources than heavy legal contracts. This letter of intent, however, cannot replace legal contracts which are more important once the ecosystem matures.

2. Theoretical implications

Ecosystem literature is still a nascent field, despite it has been existed for some time (Hannah & Eisenhardt, 2017). To the best of my knowledge, theoretical understanding on the motivations of companies for forming innovation ecosystems and the capabilities supporting the formation of innovation ecosystems are still limited in ecosystem literature. Recently, the dynamic capabilities framework was suggested to be a useful toolkit to enhance the clarity of how ecosystems can be developed (Teece, 2017; Teece, 2018; Helfat & Raubitschek, 2018; Vial, 2019). However, these theoretical efforts are simply not sufficient considering the rapid changes in the business landscape. Schilke, Hu & Helfat (2018) encourage researchers to conduct further studies to bridge the dynamic capabilities framework and ecosystem literature because the connection between the two theories is remarkably underdeveloped. Thus, the gaps in literature call for further research, especially in building new theories to explore the connection between dynamic capabilities and emerging ecosystem development. Most importantly, new theories need to be grounded on empirical data to bring clarity to the currently ambiguous connection between dynamic capabilities and ecosystem formation.

Thus, *the results of this thesis fill the gaps in the intersection between dynamic capabilities and ecosystems literature.* This thesis proved the usefulness of dynamic capabilities framework in helping our understanding of innovation ecosystem formation. There, this thesis successfully built a bridge between two usually isolated literature - dynamic capabilities and ecosystem development. As Amabile (1996) and Shipilov & Gawer (2019) highlight, creative insights are created in the intersection of multiple areas of knowledge. Therefore, by connecting the two literature streams of dynamic capability and ecosystem development together, this thesis generated creative insights which could potentially help to illuminate academic discussions between scholars in both fields, so we could establish a holistic, multi-dimensional view on how hub companies engage in the development of ecosystems. While a full integration of both fields is not possible or desirable, a partial integration might help facilitate interdisciplinary theory development and empirical analysis (Durand et al., 2017; Shipilov & Gawer, 2019).

Furthermore, *this thesis established the first conceptual model that sheds light on the conditions that trigger the formation of an innovation ecosystem, motivations of the hub company while forming an innovation ecosystem, and the mechanisms that a hub company employed to support its innovation ecosystem formation.* Thus, this thesis has the potential to *tremendously contribute to the clarification of why and how an innovation ecosystem formed*. Such areas of knowledge are still missing in the existing literature (Jacobides et al., 2018, Shipilov & Gawer, 2019), thus, this thesis could *contribute greatly to advance ecosystem literature.*

3. Future research recommendations

The conceptual model of this thesis was established from a single case study, therefore, further evaluations and testings of this model are required. The validity of this model could be tested in multiple case studies conducted in other industries and with other case companies. Using the theoretical model formed in this thesis, longitudinal case studies could be performed

to establish deeper understandings of how companies can support the evolution of their innovation ecosystems overtime.

Furthermore, while conducting this research, interesting insights into the potential influences of public funding on the formation of an innovation ecosystem were observed. For example, in the case that I studied, the public organization required that parts of the project results and methods to be opened for public access. It could be interpreted that the requirements of public funding facilitated the formation of a *more open ecosystem*. As required by public funding organizations, the publicity of the end results enables more organizations in public and private sectors to build their own applications and products. Thus, the widespread use of knowledge is essential for ecosystem formation, growth and transformation. Thus, due to the open source nature of projects funded by public organizations, there might be uncontrollable growth of applications coming from new players outside of the initially closed network that the ecosystem begins with. Thus, future research could be performed to shed light on the roles of public funding on the formation of innovation ecosystems. Moreover, since this thesis is mainly focused on the role of a hub company in the development of an innovation ecosystem, other researchers could study the role of complementors in the formation and growth of an innovation ecosystem as well.

My research also shows the importance of technological bottlenecks to the formation of an innovation ecosystem. Future research could empirically test if there exists a moderation or mediation effect between technological bottlenecks and the success of forming collaborations with external partners.

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Appendix 1: Interview guidelines (first round)

I. Introduction

1. Asking for permission to record the interview. Clarifying the interview confidentiality.
2. Introduction of interviewer(s)
3. Introduction of the research topic and the thesis context
4. What is your background and current role in your organization / company? How long have you been working in your organization?
5. Could you briefly introduce your organization in general (e.g. core offerings)
6. How do you see mining technology industry evolve in the future? What role does digitalization play in this evolution? Do your top managers and owners support the development of the digital ecosystem?
7. What challenges and opportunities do you see companies in your industry have with this evolution?

II. Description of the emerging ecosystem

1. Key drivers

a. How did you get to know about this EU grant? (question for Sandvik)? How did the opportunity of joining this EU project came to your company? (question for ecosystem partners) When was the opportunity of this EU project came to known by you? Why are you engaging in this EU projects? (question for ecosystem partners)
b. Do you have similar experiences with such projects before? How are your experiences? Can you give examples?
c. How does digitalization play a role in this project ?
d. What changes might be required once the ecosystem is established?

2. Goals & vision

a. What does your organization want to achieve with this ecosystem (e.g. EU project)?
b. What is your vision of the ecosystem? What critical milestones (or requirements) do you see in the development of this ecosystem?
c. What are you planning to do with the project when it is over? How are you planning to integrate the learning from this project to your own company? What would you expect to learn/gain from the project?
d. Are you planning to build/ join similar projects like this in the future? Do you think that you can use your experiences and learning from this project for future projects? How will you use them?

3. ***Roles***
    a. Who are the key ecosystem members? How did you identify them? Why do you invite them in this EU project ecosystem? (question for Sandvik) How well do you know these members? When and how you approached these partners? How did you negotiate with them to join the ecosystem?
    b. Do you trust the other members in the ecosystem? What did they do to gain your trust?
    c. Can you describe how ecosystem members are linked together? What do they contribute to the ecosystem? Any one is missing from the chart? (We will bring a chart with names of ecosystem members to show the interviewees)
    d. Is there any contractual agreement that ecosystem members have to sign? What are the purpose?
    e. What is your organization's role in the ecosystem now? How do you see it evolve with time?
    f. Does your ecosystem require a coordinator? If yes, who could it be? What does the coordinator do?

III. Dynamic capabilities:

1. ***Adaptive component***
    a. Could you walk me through the actions that you took following the opportunities of this EU project? What did you do? Who did you contact? What were your thinking about this project?
    b. What are the challenges and opportunities that you can see in the ecosystem? How do you identify them? (Any methods or routines do you/your organization apply?)
    c. How will your organization overcome these challenges that the ecosystem creates?
2. ***Absorptive component***
    c. How will your organization acquire new knowledge from this ecosystem? Who or which department is responsible for it?
    d. Do you now have a specific department that is responsible for data sharing and capturing between ecosystem members?
    e. Which procedures or digital systems do you have for knowledge sharing between your organization and the ecosystem members? How do you apply them?
    f. Which procedures or digital systems do you have for transferring knowledge within your organization/company?
3. ***Innovative component***
    a. Can you describe your organization's resource for innovation? How large is the innovation/R&D department? How qualified are the people working there? How much funding your organization allocate for innovation yearly?

b. Who is responsible for innovation management in your company? And for managing collaborative innovation with partners?
c. Do you experiment to create innovation in your company? Can you give some examples? Why do you do it?
d. Have you also experimented with external partners? Any examples? Why? What did you achieve?
e. How do you encourage ecosystem members to participate in innovative ecosystem activities? (For example, do you have a reward system for the ecosystem members? Would it be needed? How could it be implemented?)
f. How do you build trust between your company and other ecosystem members?

IV. Ending questions

1. We need to mention the workshop in Tampere? WE will tell them that we will see them and create their collaboration model in Tampere.
2. Do you want to bring up any other important issues that have not yet been discussed?
2. Who could be other good informants from your organization regarding these topics?
3. Who could be other good informants from this ecosystem regarding these topics?

Appendix 2: Interview guidelines (second round)

I. Introduction

1. Introduction of interviewer(s)
2. Introduction of the research topic and the thesis context
3. Asking for permission to record the interview. Clarifying the interview confidentiality
4. Could you introduce a bit about yourself and your organisation?
    a. What is your background and current role in your organization/company? How long have you been working in your organization?
    b. Could you briefly introduce your organization in general? What are your organization's core offerings?
5. Now, could you share a bit about the digitalization strategy of your company? How does digitalization impact the mining industry's evolution in the future? What is your company's role in this digitalization?
6. What kind of support your top managers and owners provide to the development of digitalization in your business? How does they allocate incentives and funding for digitization projects?

II. Emerging ecosystem

1. Project proposal background & key members identification

1.1 Now we will discuss about the background of this EU project proposal. Who are the main responsible persons from your company in this project?

a. How and when did you get to know about this EU program call?
b. What are the main reasons for your company to engage in the proposal preparation for this EU project?
c. What does your organization contribute to this potential project?
d. What is your organization's role in this potential consortium? How do you see it evolve with time?

1.2 Could you walk me through what happened since your company got to know about this EU project opportunity? What did you do to get the proposal started? How did you get other companies on-board?

e. Who are the key members that were invited to join this project? Can you describe how they are linked together?
f. What do they contribute to this potential consortium? What are their core capabilities?
g. How did you identify them/how were you identified? How well do you know these companies? Have you worked with them before? What is your working experience with them?
h. How did you get them on board?

i. Does your organization have a program or a process to identify new and promising industry partners? Could you give an example of such program/process?
j. What critical milestones (or requirements) do you see in the development of the collaboration in this consortium?

2. Common goals and values

a. Have you already agreed upon some common goals for this potential consortium? If so, what are they?
b. What kind of value do you foresee for your company in this potential EU project? How would your company capture this value?

III. Outcomes of dynamic capabilities

1. Shared value logic

1.1 Now we will discuss about the major challenges that you have been facing during the starting phase of this consortium project.

a. What challenges do you see your organization and other members encounter during the starting phase of this consortium?

1.2 So how these challenges that you described can be overcome?

b. How trust can be created within the consortium?
c. How important are information sharing and knowledge co-creation for this consortium? How can they be facilitated ? Can somebody within your organization be responsible for it?

1.3 What can your organization learn from the experiences building this consortium? Can the learning be duplicated for other consortium projects?

d. Do you think the learning from this consortium can be duplicated for other consortiums? To what extent it can be duplicated? How can your organization learn from the experiences of this potential consortium?

2. Institutional stability

2.1 Now we will discuss about the the coordinator role in this consortium. Do you think such role is needed? What are the most important things to be coordinated (interest balancing, reward system, contracting, IPR agreement etc.)?

a. Does your consortium require a coordinator? If yes, who could it be? What are the most important things to be coordinated in the consortium?
b. How do you think your company's interest and the common interest of the consortium can be balanced? Can you think of any tools or practices that you can use?
c. Should there be any means to encourage members to collaborate? What could they be?
d. Is there any specific resource that you need to develop for this consortium? To what extent can you reuse it for other projects?

e. Do you think that a contract might be necessary between the members? Why? In what areas do you want to be protected by a contract? Why?
f. Have you agreed on the IPR for this future project already? What is the biggest questions for reaching the IPR agreement? How did you come up with this agreement? Or, How are you planning to negotiate?

IV. Ending questions

1. Do you want to bring up any other important issues that have not yet been discussed?
2. Who could be other good informants from your organization regarding these topics?
3. We will send to you an ecosystem chart that we created based on the interview for your comments. We will use this chart for other interviews.
4. Are there more companies that we can interview?