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WEB-BASED APIS IN DIGITAL PLATFORM INNOVATION

A DESCRIPTIVE MULTIPLE-CASE STUDY

UNIVERSITY OF JYVÄSKYLÄ
DEPARTMENT OF COMPUTER SCIENCE AND INFORMATION SYSTEMS
2020

TIIVISTELMÄ

Lampi, Mikko
Verkkopohjaiset ohjelmointirajapinnat digitaalisessa alustainnovaatiossa – kuvaileva monitapaustutkimus
Jyväskylä: Jyväskylän yliopisto, 2020, 140 s.
Tietojärjestelmätiede, pro gradu -tutkielma
Ohjaaja(t): Tuunanen, Tuure

Tämän tutkimuksen tavoitteena oli tutkia ja kuvailla, miten verkkopohjaisia rajapintoja (API) käytetään digitaalisessa alustainnovaatiossa. Tarkoitusta varten kehitettiin kaksi teoriaan pohjautuvaa avustavaa tutkimuskysymystä, joiden avulla määriteltiin keskeiset käsitteet. Teoriakatsaus käsitteli avointa ja hajautettua innovaatiota, digitaalisia alustoja, rajaresurssiteoriaa sekä rajapintoja. Teorian käsittely perustui systemaattiseen kirjallisuuskatsaukseen. Kirjallisuuden perusteella muodostettiin tutkimuksen teoreettinen viitekehys, joka kuvailee rajaresurssien vuorovaikutusta digitaalisen alustan ja sen innovaatioekosysteemin rajapinnassa. Digitaalista alustaa resursoidaan ja moderoidaan rajaresurssien avulla.

Tutkimus toteutettiin laadullisena monitapaustutkimuksena ja se perustui postpositivistiseen tutkimustapaan. Datankeruu toteutettiin kymmenenä asiantuntijahaastatteluna ja se kattoi seitsemän yritystä ja/tai julkisen sektorin organisaatiota. Data-analyysi perustui laadulliseen sisällönanalyysiin. Sen lopputuloksena aineistosta muodostettiin teemoja sekä typologia rajapintojen rooleista digitaalisessa alustainnovaatiossa. Iteratiivinen analyysiprosessi perustui teoriaan ja kirjallisuuteen, mutta mahdollisti dataan perustuvat havainnot. Typologiaa käsiteltiin kirjallisuuden avulla ja siihen verraten.

Tulokset osoittivat, että rajapintojen roolit voidaan koota kolmeen suurempaan rooliryhmään: 1) palvelu- ja liiketoimintainnovaatiot, 2) kehittäminen ja operatiivinen toiminta, sekä 3) ekosysteemi ja yhteistyö. Jokainen ryhmä sisältää useita yksityiskohtaisempia rooleja, jotka liittyvät digitaalisen alustainnovaation erilaisiin mekanismeihin ja näkökulmiin. Roolit kattavat innovaatiomahdollisuuksien luomisen, niiden hyödyntämisen sekä sellaisen vuorovaikutuksen, jonka kautta innovaatio-, liiketoiminta- ja alustaekosysteemit kietoutuvat toisiinsa ja vaikuttavat alustainnovaatioon. Lisäksi rajapintoja niputetaan usein yhteen muiden rajaresurssien kanssa ja ne toimivat tarkistuspisteinä vuorovaikutukselle alustan kanssa. Tutkimustulokset tukevat useiden aiempien tutkimusten asettamien tutkimusongelmien ratkaisemista ja laajentavat orastavan rajapintatutkimuksen monimuotoisuutta osana tietojärjestelmätiedettä.

Asiasanat: avoin innovaatio, hajautettu innovaatio, alustatalous, digitaalinen alusta, rajapinta, rajaresurssi

ABSTRACT

Lampi, Mikko
Web-based APIs in digital platform innovation – a descriptive multiple-case study
Jyväskylä: University of Jyväskylä, 2020, 140 pp.
Information Systems, Master's Thesis
Supervisor(s): Tuunanen, Tuure

The purpose of this study was to explore and describe how web-based APIs are used in digital platform innovation. Two supporting and theory-based research questions were formulated to understand and define the key concepts. A systematic literature review was done to cover essential research on open and distributed innovation, digital platforms, boundary resources, and APIs. Literature was synthesized into a research framework that describes interaction between platform boundary resources, such as APIs, and distributed innovation ecosystems. Platform boundary resources are used to resource and secure the platform.

The research was carried out as a qualitative multiple-case study and utilized a post-positivist approach. Ten experts were interviewed from seven companies and/or public sector organizations. Qualitative content analysis was done to develop themes and finally a typology of API roles in digital platform innovation. The analysis process was iterative and based on theory but also allowed data-based findings. The typology was discussed and compared with literature.

The findings indicated that the use of APIs can be aggregated into three high-level roles: 1) service and business innovation, 2) development and operations, and 3) ecosystem and collaboration. Each aggregation includes several more detailed roles that focus on the different mechanisms and aspects of digital platform innovation. The roles are related to the creation of innovation opportunities, to their exploitation, and to ecosystem and platform interactions that intertwine with the innovation, business, and platform ecosystems and influence digital platform innovation. Furthermore, APIs are often bundled with the other types of boundary resources and operate as platform control points. The study contributed to several research questions put forward by prior research and pursued to contribute to the diversity of emerging API literature.

Keywords: open innovation, distributed innovation, platform economy, digital platform, API, boundary resource

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1 INTRODUCTION

Digitalization is a megatrend that shapes the economies of the world. Products are becoming services and digital platforms have emerged transforming the logic of innovation and value creation. The change is enabled and catalyzed by digital technology, i.e. software and data, which intertwines and interacts with the physical world. Digital platforms structure and orchestrate resources and capabilities into complex service systems that are connected through the Internet by application programming interfaces (APIs). New digital economy calls for an innovation logic suitable for distributed ecosystems, digital platforms, and service co-creation. Open and distributed innovation models are utilized in the service innovation of the digital age. However, openness needs to be governed to foster generativity without chaos and control without stagnation. Service systems span the boundaries of platforms and organizations. In this environment, APIs are more than just technology. They are the fabric of networked digital service economy and digital innovation.

1.1 Background

Digital innovation is an important change agent in service economy (Barrett et al., 2015). It can be defined as "the carrying out of new combinations of digital and physical components that produce novel outcomes" (Yoo et al., 2010, p. 725). Furthermore, the characteristics of digital technology influence digital materiality and innovation. Digital products and services are malleable and incomplete. Data and its processing capabilities are loosely coupled and can be configured and reconfigured into almost infinite combinations. Self-referential nature enables positive reinforcement and generativity that increase the usefulness and innovation potential of digital technology. (Yoo et al., 20120).

Information systems (IS) research considers digital innovation, and therefore digital platform innovation, as a sociotechnical concept (Nambisan et al., 2017). There are several aspects and models that can be used to study, describe, and explain it. This research utilizes open and distributed innovation models to describe digital platform innovation. In addition, digital innovation and technology are assumed as cross-cutting and ubiquitous themes. Like Nambisan et al. (2017) describe, digital innovation is a complex concept that includes aspects such as digital platforms and artefacts, environments, ecosystems, and relationships. It has had a transformational influence on service innovation and value creation.

Open and distributed innovation models can be used to study and describe digital innovation and digital platform innovation (Nambisan et al., 2017; Chesbrough, 2012; West & Bogers, 2017; Anttiroiko & Valkama, 2013). In the recent decades, innovation has undergone a paradigm shift from closed to open. Open innovation is based on the inbound and outbound knowledge flows and malleable innovation processes boundaries. Inbound knowledge flows enable technology and knowledge insourcing and utilization of external innovation mechanisms. Outbound knowledge flows provide new paths to market and commercialization opportunities. (Chesbrough, 2003). Together these two types of knowledge flows enable ecosystem interaction and feedback loops that increase generativity and innovation (Aitamurto & Lewis, 2012). Boundary crossing open innovation targets and utilizes resources, processes, and knowledge that are distributed across the organizational landscape and ecosystems (Nambisan et al., 2017; West & Bogers, 2017). The locus of innovation has shifted from centralized organizations to unevenly distributed knowledge. Moreover, the innovation opportunities have become distributed as well. (Lakhani & Panetta, 2007; Sawhney & Prandelli, 2000). Management of open and distributed digital innovation requires new kinds of architectures, knowledge, and resources (Nambisan et al., 2017; Yoo et al., 2010).

Digital platform is a relevant and important topic in IS research and practice (Yoo et al., 2010; de Reuver et al., 2017; Smedlund & Faghankhani, 2015). It can be conceptualized as a sociotechnical system that acts as a foundation for development of processes and digital applications and services. A platform includes a multitude of elements such as digital artifacts, organizational processes, structures, standards, and the surrounding ecosystem. (Anttiroiko & Valkama, 2013; Yoo et al., 2010; de Reuver et al., 2017).

Digital platform innovation is influenced by the characteristics of digital technology and mechanisms of open and distributed innovation. More specifically, digital platform innovation is enabled and accelerated by generativity, positive reinforcements, cumulative and combinatorial innovation, ecosystem interaction, openness, and facilitated collaboration. (Tilson et al., 2010; Chesbrough 2012; Smedlund & Faghankhani, 2015; Anttiroiko & Valkama, 2013). However, digital platforms include an inherent paradox of control and openness that influences digital platform innovation. The paradox must be continuously managed and balanced to enable generativity and stimulate innovation but also maintain stability. (Tilson et al., 2010; de Reuver et al., 2017). Moreover, digital platform innovation is intertwined with platform business models and platform governance (Parker & Alstyne, 2016; Chesbrough, 2012), and ecosystems (de Reuver et al., 2017; Han et al., 2017; Smedlund & Faghankhani, 2015).

Platform boundary resource is an emerging concept in digital platform research and comprises of software and regulations that facilitate the relationships between a platform and its users and developers. Boundary resources are important for platform interaction and innovation. (Ghazawneh & Henfridsson, 2013; de Reuver et al., 2017; Yoo et al., 2010). However, boundary resources need to be tuned and aligned with platform ecosystem needs and platform objectives (Eaton et al., 2015). Application programming interfaces (APIs) are one of the most common platform boundary resources, but also other types of technical and social resources exist (Ghazawneh & Henfridsson, 2013; dal Bianco et al., 2014). Platform boundary resources are utilized to both resource and secure the platform. Resourcing enables generativity, creativity, diversity, and innovation. Securing moderates resourcing and provides control points and maintains stability. (Ghazawneh & Henfridsson, 2013; dal Bianco et al., 2014; Eaton et al., 2015; Yoo et al., 2010). Platform boundary resources are also utilized for service specialization (Chesbrough 2012) and service innovation (Barrett et al., 2015).

Application programming interfaces (APIs) are machine-readable software that provide connectivity and enable interaction with software modules and information systems. Moreover, they enable combinations of different modules, increase interoperability, and provide abstraction for the underlying software and modules. (Wulf & Blohm, 2017). This study focuses especially on web-based APIs that operate on the Internet. Web-based APIs are typically organizational boundary crossing interfaces that enable value creation, combinatorial innovation, integration of resources, access to functionalities, and creation of service configurations (Tan et al., 2016; Huhtamäki et al., 2017; Bonardi et al., 2016; Aitamurto & Lewis, 2012). APIs are often bundled with other types of platform boundary resources to enable and stimulate external innovation mechanism (Yoo et al., 2010; Ghazawneh & Henfridsson, 2013). APIs are also technological building blocks for modern service architectures and applications (Tan et al., 2016; Basole, 2016; Evans & Basole, 2016; Weiss & Gangadharan, 2010). APIs enable and influence platform ecosystem interaction but also require new kinds of management, governance, and innovation strategies (Huhtamäki et al., 2017; Weiss & Gangadharan, 2010; Basole, 2016; Bonardi et al., 2016).

Web-based APIs are enablers and catalysts for digital platform innovation. Moreover, they are an emerging research topic in platform and service innovation research (Basole, 2016; Huhtamäki et al., 2017; Wulf & Blohm, 2017). Studying APIs as platform boundary resources provides a fresh sociotechnical lens to study digital platform innovation and digital platforms. APIs interact with and influence platform ecosystems, business models, management, and other aspects that are related to innovation and should thus be studied from the IS perspective (Huhtamäki et al., 2017).

1.2 Research problem and objectives

The objective of this research is to explore and describe use of web-based APIs in the landscape of digital platform innovation. Digital platform research is current and relevant topic in IS research (Smedlund & Faghankhani, 2015; Yoo et al., 2010; de Reuver et al., 2017). Platform boundary resources provide a fresh sociotechnical lens to study the phenomenon. Moreover, APIs are popular in practice and have had a major impact on digital economy (Basole, 2016; Evans & Basole, 2016; Tilson et al., 2010). Bonardi et al. (2016) have identified a lack of collaboration between practitioners and academia in API research and use. APIs have been traditionally considered technical concepts and studied in technical domains, such as software engineering research (Bonardi et al., 2016; Huhtamäki et al., 2017). Digital innovation capabilities are an important source of performance and competitive advantage for companies (Wu & Chiu, 2014). In addition, Tan et al. (2016) and Han et al. (2017) recommend carrying out practical API research that studies and can contribute towards solving real-life problems. Thus, the objectives of this study include developing applicable knowledge for practice. These findings indicate studying a current IS topic from a fresh point of view can contribute towards both research and practice. Moreover, the research problem and domain are interesting from the researcher's point of view and provides a solid foundation for further studies.

The research problem is unraveled by one primary research question and two supporting research questions. The supporting questions are used to dismantle the primary question and help in consolidating a coherent literature-based answer to it. The primary research question is *how web-based APIs are used in digital platform innovation?* The two secondary supporting questions are as follows: 1) *What is a web-based API as an IS concept?* and 2) *What is digital platform innovation?* The choice and formulation of the research questions were influenced by the prior research and the recommendations of experienced researchers. Barrett et al. (2015) asked in their research how the paradox of generativity and control can be managed in service systems. The question is related to the mechanisms of digital platform innovation and the role of platform boundary resources. Yoo et al. (2010) raised questions such as what the strategic roles of platform boundary resources are. Ghazawneh and Henfridsson (2013) call for digital platform research that studies the mechanisms and opposing forces in innovation. Wulf and Blohm (2017) argue a research gap exist in overarching theories and viewpoints in service innovation and APIs. The same argument is made by Huhtamäki et al. (2017) and Bonardi et al. (2016).

Therefore, the research problem and the selected research questions are justifiable and based on both literature and practical applicability and aligned with the interests and the working career of the researcher. This study increases the understanding of APIs in digital platform innovation and contributes to emerging API literature in IS research. Furthermore, it enables exploration of the topic and provides foundations for future doctoral thesis by the researcher.

1.3 Methodology

This study includes two parts: 1) a literature review and 2) a qualitative empirical multiple-case study. The literature review is based on the systematic literature review (SLR) by Okoli and Schabram (2010). The eight-step model provides literature-based approach that is suitable for a thesis work in IS research. Recommendations and best practices were also drawn from Hirsjärvi et al. (2018). The purpose of the literature review is to familiarize the researcher with the topic, analyze relevant research, and develop a research framework for the study. SLR includes discovery, filtering, prioritization, and analyzing of literature, and building a synthesis of it. The findings are presented in detail and then summarized and developed into a research framework. They are also utilized in the design of the empirical study and interpretation of the findings.

This research is a qualitative multiple-case study. Qualitative research is justifiable choice for IS research when studying complex sociotechnical phenomenon (Myers & Avison, 2002; Conboy et al., 2012; Sarker et al., 2013; Goldkuhl, 2012). Qualitative case studies in IS research focus primarily on *how* and *why* questions. The majority (67%) are *how* questions. *What* is also present in 26% of questions. (Sarker et al., 2013; Ponelis, 2015). Therefore, the research questions are aligned with the selected approach. The research is based on post-positivist approach that considers knowledge about reality subjective and impartial (Ryan, 2005; Shanks, 2002). The combination of post-positivism and qualitative research fits the research objective. Positivist approach is more popular in IS research, but interpretive approach fits qualitative research better; both are utilized in IS research (Orlikowski & Baroudi, 2002; Goldkuhl, 2012). Case research is justifiable choice for research of real-life context when the phenomenon of interest and its boundaries are fuzzy (Myers & Avison, 2002; Myers, 1997; Darke et al., 1998) and supports well research in organizational context (Gordon et al., 2013; Ponelis, 2015). The purpose of multiple-case approach is to provide better applicability to other settings and enable a larger sample size and a wider exploration of the phenomenon.

Data collection is based on semi-structured thematic interviews. The interview themes are based on the literature review but enable discovery of novel findings from the data. Theory is utilized as a starting point and guide but does not limit the analysis of data-based findings. Case selection is based on both practical reasons, e.g. access to research sites, and the literature findings, e.g. API economy profile. There is a total of ten interviews and seven case organizations. Furthermore, the interviewees are selected based on their expertise and position in their organizations. The interview recordings are used to make observations and proceed to data analysis without a detailed transcription. The choice is based on suggestions by researchers (e.g. Hirsjärvi & Hurme, 2015) and the availability of time and resources and the scope of the study.

Data analysis is based on qualitative content analysis. It is a commonly used method in qualitative research (Ponelis, 2015). The process is as follows: 1) capture of notes and observations, partial transcription, and data reduction, 2) development of case narratives, 3) clustering and classification, 4) theming, and 5) typing. The classification scheme is literature-based but developed further based on the findings and interesting observations. Themes are developed based on the reduced, clustered, and classified data, and the typology is developed based on the themes. The typology is the conclusive research outcome of this study. Theory is utilized as a guide throughout the analysis as recommended by Tuomi and Sarajärvi (2018), Ponelis (2015), Sarker et al. (2013), and Walsham (2006). The data and findings are structured and displayed visually in a tabular format during the analysis and to present its outcomes. Finally, the findings are described, interpreted, and compared with literature.

1.4 Outline

The rest of this thesis work is organized as follows. The next three sections comprise the literature review. The section two provides an overview of digital innovation literature. It focuses on the characteristics of digital technology and open and distributed innovation models and mechanisms. The section three provides and overview of digital platform literature with focus on digital platform innovation. It describes digital platforms, ecosystems, platform boundary resources, and APIs. Moreover, it explores their connection with the concept of digital platform innovation. The section four provides a summary and a synthesis of the literature. The fifth section describes the literature-based research framework that is used throughout the empirical study and its interpretation. The sixth section describes the research strategy, approach, and methods in detail. In addition, case selection and case descriptions are provided, and data analysis is described and illustrated with examples. The seventh section describes the research cases, findings, and provides a tabular representation of the summarized themes and the typology. The eight section discusses and interprets the findings and their relation to literature, and contributions to research and practice are discussed. The section nine concludes the research and provides a summary of the key findings and their meaning, and thus provides a solution to the research problem. In addition, future research suggestions are provided, and the limitations and criticism are addressed.

2 DIGITAL INNOVATION LITERATURE

This section provides a brief overview of digital innovation and digital technology in IS literature. The concepts of open and distributed innovation are discussed in more detail. The primary focus is on understanding innovation in digital context, but the phenomenon is also intertwined with the physical reality and its structures. Therefore, the phenomenon is discussed in a wider scope to understand the big picture.

2.1 Digital technology and innovation

Digital technology is pervasive and embedded in society, business, and the everyday life. Objects that in the past included only physical materiality have been infused or augmented with digital features. Furthermore, new kinds products and services comprising of only digital materiality have emerged. (Yoo et al., 2012). Digitalization and characteristics of digital materiality enable new and powerful affordances in which digital innovation is based on. (Yoo et al., 2012; Nylén & Holmström, 2015).

Innovation is a realized idea or concept that is technologically and geographically novel and is successfully diffused into a new market. The market presence can be either commercial or non-commercial. Innovation can be categorized by its scope, such as radical or incremental innovation. Radical innovation has more profound impact than incremental innovation. However, it is more difficult to achieve and succeed in. On the other hand, incremental innovation is more common and frequent, thus providing benefits in faster cycles. (Bogers & West, 2012).

Based on prior literature, Nambisan et al. (2017, p. 223) define digital innovation as "use of digital technology during the process of innovating". However, they expand the definition with the results of exploitation of digital technology. These results are such as new market offerings, business processes, and business models. Their definition includes three aspects of digital innovation: 1) innovation outcomes, 2) digital tools for innovation, and 3) innovation diffusion via platforms. (Nambisan et al., 2017). Yoo et al. (2010, p. 726) describe digital innovation as “carrying out of new combinations of digital and physical components to produce novel products”. They utilize a product-based approach on digital innovation as opposed to traditional process-based approach in IT innovation research. Barrett et al. (2015) differentiate between product and service innovation. However, in their paper, they acknowledge that some researchers do not find meaningful to separate products and services from each other and instead focus on the implications of digitalization in service innovation. The definition of innovation and its boundaries and characteristics in service innovation are often blurry (Bogers & West, (2012; Nylén & Holmström, 2015).

Innovations in the digitized and digitalized world are convergent and generative by nature. Convergence means previously separate capabilities, user experiences, and even industries are coming closer each other. Thus, innovations are becoming similar with each other as physical barriers become obsolete. Generativity is a result of digital materiality. Unlike physical products, digital products are malleable, dynamic, and reprogrammable. They are not limited to predetermined and predesigned form and function. Digital innovations can contribute towards and trigger other innovations and create unpredictable and unanticipated wakes of innovation. (Yoo et al., 2012).

Nylén and Holmström (2015) emphasize aligning digital innovation and business. Evaluating value from IT and innovation investments is not a straightforward task. Companies need to scan for innovation opportunities even from unexpected sources and develop competencies in digital innovation. However, the generative and combinatorial nature of digital technology and the rapid pace of change introduce new challenges and needs. Flexibility and ability to improvise are needed to tackle the continuous change. Distributed and open innovation require tolerance for lack of control and the ability to control and coordinate collaboration. (Nylén & Holmström, 2015).

Digital innovations share three core traits: 1) digital technology platforms, 2) distributed innovation, and 3) combinatorial innovation (Yoo et al., 2012). Digital platform is a core concept in this study and is discussed in more detail in the next main section. However, it is important to understand the general idea of digital platforms and how they relate to digital innovation. Platforms have become a center of digital innovation. Multiple industries have observed a shift from product-centric innovation into platform-centric. For example, enterprise resource planning (ERP) systems can be considered as platforms for business processes and tools instead of stand-alone products. Digital technology platforms relate to many core concepts in digital innovation. Standardization of technologies and tools has led to convergence of digital information, designs, and architectures. Furthermore, new kinds or relationships have emerged as organizations share and reconfigure information and processes via boundary-crossing digital platforms. (Yoo et al., 2017).

Distributed innovation is related to the concept of open innovation (West & Bogers, 2017). The idea in distributed innovation is that innovation has shifted from centralized to boundary crossing process that can mix and match heterogenous resources across organizations (Yoo et al., 2012). Digital technology enables and empowers distributed innovation. Distribution means geographical and democratic distribution. Resources and knowledge required for innovation, and even the innovation process itself, are often spread across organizational landscape and multiple organizations. Innovations can emerge from unexpected sources, such as completely different industries or seemingly unrelated bodies of knowledge. (Yoo et al., 2012).

Distributed innovation environments are temporary and dynamic. Relationships between organizations are based on the needs and capabilities of the involved actors. Platforms enable distributed innovation via sociotechnical artifacts, such as application programming interfaces (APIs) and software development kits (SDKs) that enable capability sharing and shared innovation processes. These artifacts include built-in social norms, organizational principles, and roles that shape and moderate relationships and potential for distributed innovation. However, distributed innovation introduces new kinds of risks, like decontextualization of innovation and inflated expectations. (Yoo et al., 2012).

Combinatorial innovation refers to the ability to mix and match digital technology to produce innovations. Digital technology can be combined in immeasurable configurations that enable vast innovation potential and accelerate the pace of further cumulative innovations. Recombining existing and known modules and components also decreases the required learning curve in innovation. In addition, it increases knowledge sharing and the diversity of problem solving. The concepts of combinatorial, distributed, and open innovation are related. Combinatorial innovation assumes the boundaries of digital technology are malleable and fluid, and thus decentralized and less controlled. (Yoo et al., 2012; Weiss & Gangadharan, 2010).

Modularity and standardization decrease the barriers to innovate and increase the potential and pace of combinatorial innovation (Yoo et al., 2012; Weiss & Gangadharan, 2010). However, combinatorial innovation is often unpredictable. The exact modules that lead into an innovation are not necessarily known in advance. Due to the characteristics of digital materiality, modules and services can remain incomplete and unfinished until suitable business models and opportunities emerge. For example, online APIs can be utilized to develop new and unpredictable services and products based on the data and functionalities they expose. However, during the design of APIs, the exact nature of the services is not known. Google Maps API is an example of such module. (Yoo et al., 2012).

Unpredictability can lead to serendipity. However, fostering serendipity and avoiding the risks in combinatorial innovation requires constant lookout for emerging innovations and exploitation opportunities. At the same time, innovation diffusion could be accelerated by the familiarity and convergence of the innovations. Yet, wakes of innovation and recombining innovations can cause mutation, increase complexity, further unpredictability, and even systemic failures. (Yoo et al. 2012).

2.2 Open innovation

Chesbrough (2012, p. 20) defines open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation". Chesbrough's view on open innovation is pragmatic above all. He argues openness drives intercompany collaboration and coordination but is not in conflict with intellectual property protection and commercialization. On the contrary, Chesbrough emphasizes the importance of market entries and the social impact of successful commercialization. (Chesbrough, 2012). West and Bogers (2017) define open innovation as business-aligned and distributed innovation processes that are based on interorganizational knowledge flows. Therefore, the concepts of open and distributed innovation are related. Open innovation is based on the fundamental idea that innovation capabilities and processes expand outside of the organizational boundaries (Chesbrough, 2012; West & Bogers, 2017). A distinction should be made between open innovation and open source innovation. Open source innovation is not a business model or an innovation concept but rather a development philosophy. Moreover, open innovation does not mean outsourced innovation. (Chesbrough, 2012).

Knowledge flows are the medium for open innovation. There are two kinds of knowledge flows: inside-out [outbound] and outside-in [inbound] knowledge flows. Outside-in knowledge flow refers to the opening of internal innovation processes to external inputs and contributions. In inside-out knowledge flow, underutilized or unused ideas are permitted to leave the boundaries and control of the firm or organization. External actors can use these ideas in their business or activities according to their own business models and objectives. (Chesbrough, 2012). Inside-out is far less explored and exploited knowledge flow type than outside-in (Chesbrough, 2012; West & Bogers, 2017). However, West and Bogers (2017) found the two knowledge flow types can be exploited in parallel, in a coupled mode of open innovation, but it is rare for companies to do so. Furthermore, Bogers and West (2012) agree that companies need to acquire external knowledge, such as scientific research or market knowledge, to enable and accelerate their innovation processes and to pursue external commercialization opportunities and benefits of knowledge spillover. (Bogers & West, 2012).

2.2.1 Open innovation system

The model for open innovation system can be explained by a comparison with the closed innovation model. Traditional organizational innovation is carried out through closed innovation where the so-called innovation funnel is kept inside the organization from the start to finish. The technology and knowledge base are internal and located within the organization. Also, the paths to market and commercialization mechanisms are internal and controlled by the organization itself. R&D projects enter a closed innovation funnel-shaped pipeline. Each step forward the pipeline the funnel becomes narrower as unattractive projects are cancelled. Finally, few projects emerge and are introduced to the market by the company. The boundaries of the innovation funnel are rigid and there is only one entry and exit point for the innovations, or they can be cancelled. (Chesbrough, 2012).

The principal difference between open and closed innovation systems is the openness of the innovation funnel, i.e. process. In open innovation system, ideas, knowledge and technology base, and R&D projects in progress can enter and exit anywhere in the innovation funnel. External ideas are permitted to enter the innovation pipeline and contributed to the process becoming additional sources of innovation. Startup collaboration is a common technology and knowledge insourcing method. New paths to current or potential markets become additional exit points and provide new opportunities for such as spin-off businesses and out-licensing. (Chesbrough, 2012; Chesbrough, 2003). A comparison of open and closed innovation systems is illustrated in figures 1 and 2 based on Chesbrough (2012, p. 23).

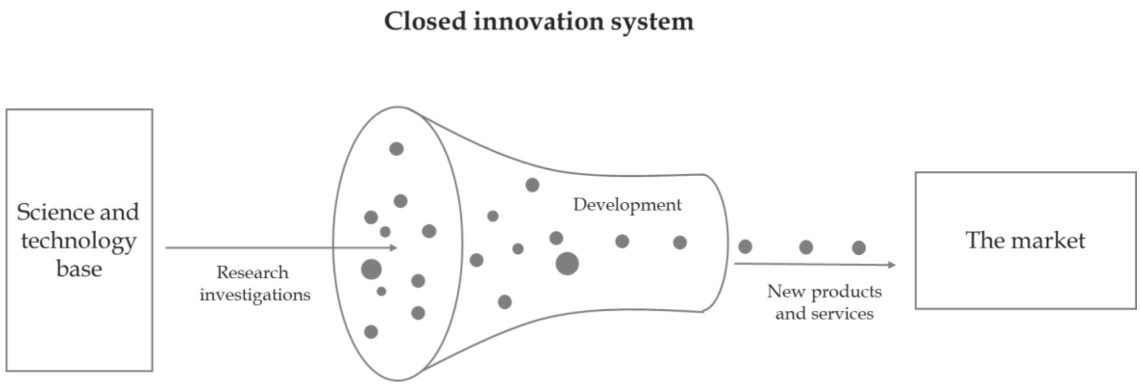

FIGURE 1 Closed innovation system.

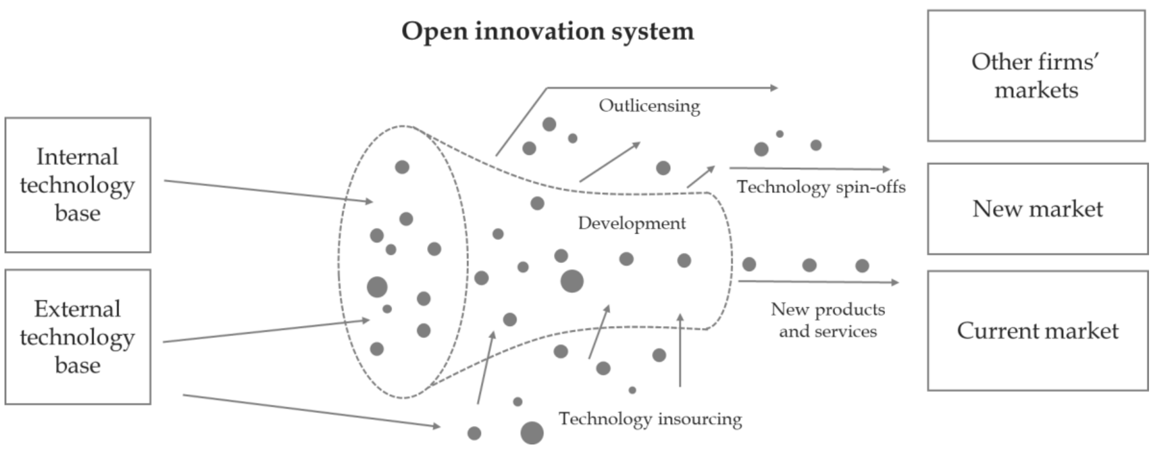

FIGURE 2 Open innovation system.

2.2.2 Mechanisms and outcomes

Knowledge spillover is a beneficial and important mechanism in open innovation. It can be used for risk mitigation and to deal with false negatives, i.e. projects that do not appear feasible but could succeed and generate benefits. Instead of canceling risky projects, outbound knowledge flows could be utilized. Knowledge spillover can create a remarkable asset base and open new revenue streams. Together openness and knowledge spillover enable and support strong generative innovation mechanisms. (Chesbrough, 2012).

However, open innovation also introduces challenges and requirements for effective exploitation of inbound and outbound knowledge flows. New kind of innovation architectures, supporting systems, platforms, value capture mechanisms, and organizational structures and roles are needed. (Chesbrough, 2012).

Examples of open innovation benefits include Procter & Gamble that has gained remarkable increases in productivity by exploiting inbound knowledge flows, and Hewlett-Packard that established new revenue streams by outsourcing their innovations as outbound knowledge flows. (Aitamurto & Lewis, 2012).

Aitamurto and Lewis (2012) studied open innovation in news organizations. They found out that opening and sharing content created outbound knowledge flows that generated new kinds of applications for their content and ideas on how to utilize the content for a better market fit. Furthermore, the case organizations managed to establish inbound knowledge flows and a feedback loop that provided valuable market insights and product ideas that decreased the need for internal innovation and provided time and cost savings. New paths to market became available and their revenue increased. (Aitamurto & Lewis, 2012). Their findings also demonstrate the coupled mode of innovation Bogers and West (2017) described. Furthermore, Aitamurto and Lewis (2012) agree with Bogers and West (2017) in that the coupled mode is an understudied theme in open innovation research. Topics, such as open business models, platform business models, alliances, partnerships, and collaboration for value co-creation and resource complementarity could be studied further and provide a linkage between platform innovation and open innovation (Aitamurto & Lewis, 2012).

Henfridsson and Bygstad (2013) present a case study that demonstrates digital platform and infrastructure innovation in Scandinavian Airlines. They explained digital infrastructure evolution and digital innovation by open innovation model. The case company decreased the level of centralization and control on its digital platform and permitted external partnerships-based access to their resources through APIs. Open innovation was aligned with their business objectives. The company managed to attract external innovation partners and benefit from positive network effects. Most importantly, it succeeded in creation and exploitation of strong inbound knowledge flows. (Henfridsson & Bygstad, 2013).

2.3 Distributed innovation

Knowledge is unevenly distributed in society and difficult to relocate and transfer. Furthermore, the locus of innovation has shifted from organizations to knowledge. Users are the source of novel needs and knowledge regarding them. Thus, users could potentially produce more novel innovations. (Lakhani & Panetta, 2007; Sawhney & Prandelli, 2000). Moreover, the boundaries of innovations have become less bounded, and innovation outcomes often remain fluid and incomplete. Digital transformation and the characteristics of digital technology are increasingly scattering innovation landscape and speeding up digital innovation. Digital platforms and infrastructures are in focus of distributed and digital innovation research. Digital technology and distributed innovation are highlighted as current IS research topics and connected with themes such as digital platforms. (Nambisan et al., 2017). The trend over the recent decades has been towards more decentralized and flexible research and development systems (Howells, James & Malik, 2003).

Companies need to gain access and exploit external knowledge and technologies to remain competitive (Howells, James & Malik, 2003). In addition, firms are specializing and focusing on a narrow scope of knowledge to compete in technology market. It requires collaboration with partners and customers to create knowledge and technological capabilities and to innovate. (Sawhney & Prandelli, 2000; Howells, James & Malik, 2003). Industries and businesses dominated by information and knowledge are early adopters of distributed innovation. However, already ten years ago, it was expected to expand into a multitude of other domains. (Lakhani & Panetta, 2007). Innovation opportunities are distributed in the corporate environment. Technological advancements and market disruptions are major drivers for companies to pursue distributed innovation opportunities. (West & Bogers, 2017).

2.3.1 Distributed innovation systems

Distributed innovation is strongly connected with mechanisms and dynamics of knowledge co-creation and sharing (Sawhney & Prandelli, 2000; Howells, James & Malik, 2003). Distributed innovation systems are characterized by decentralized problem solving, self-selected participation, self-organizational coordination and collaboration, free access to knowledge, and hybrid organizational structures that combine commercial and community success. Open source software communities are the best-known example of a distributed innovation system. (Lakhani & Panetta, 2007). However, distribution increases the complexity of innovation systems (Howells, James & Malik, 2003).

Traditional vertically integrated innovation system is linear. Innovations start with academic knowledge, continue with firm's internal development processes and finally to commercialization attempts into market. There are four phases in the vertically integrated innovation path: 1) basic and applied research, 2) invention, 3) development, and 4) production. The company carries out all activities from transforming research knowledge into commercially relevant inventions, developing them into marketable innovations, and distributing them to market. The centralized innovation model favors large enterprises due to their vast resources and capabilities. However, smaller organizations lack assets and control power and thus face challenges with the innovation model. (Bogers & West, 2012). Also, Sawhney and Prandelli (2000) pit distributed innovation systems against the traditional closed innovation systems. Yet, there are some similarities with open innovation and traditional vertically integrated innovation. These include the firm as the unit of analysis and interest in profit and economies of scale. Yet, the mode and locus of innovation is critically different in the two models and attitude towards external innovators and knowledge spillover are the opposite. (Bogers & West, 2012).

According to Bogers and West (2012), distributed innovation encompasses open innovation, which is the firm-centric aspect of distributed innovation. The user-centric aspect of distributed innovation is known as user innovation. Even if this study focuses on the firm-centric innovation the concept of user innovation can provide interesting viewpoints. User communities, like developer and open source communities, could provide valuable inbound knowledge flows (Bogers & West, 2012). Moreover, Lakhani and Panetta (2007) mention the importance of open source software communities in studying distributed innovation. The literature confirms distributed and open innovation are related concepts and the two innovation systems share characteristics. However, they have a different focus on the phenomenon and its mechanisms. This study focuses on the firm-centric aspect of distributed innovation. However, user innovation is not excluded.

2.3.2 Distributed innovation management

The outcomes in distributed innovation are unpredictable and multiple heterogenous actors contribute towards them. Each actor can have a different motivation and objective for innovation. Moreover, they can have different capabilities and resources as well. (Nambisan et al., 2017; Lakhani & Panetta, 2007). The motivation for innovation and related decision-making and objectives could be divergent even within the firm. Constant evaluation of firm's own and its partners' (i.e. innovation network) competencies is required for exploitation of distributed innovation and for the related risk management. (Howells, James & Malik, 2003).

The boundary crossing nature of distributed innovation sets requirements also for innovation governance, management, and architectures. They need to tolerate and foster decentralized innovation ecosystems and processes. Digital innovation and development of digitalized products and services are converging in a sense. The models of development and innovation are both becoming increasingly distributed. Some of the tools for coordination, control, and facilitation, such as platform boundary resources, are also similar. (Yoo et al., 2010).

Digitalization and distributed innovation also increase complexity that needs to be managed. New kinds of socio-cognitive sensemaking, orchestration, integration, and continuous solution-problem matching are needed. (Nambisan et al., 2017). Successful utilization of distributed innovation provides multiple technological routes for innovation. However, coordination and management are needed for cohesive and aligned innovation processes and outcomes. Otherwise, there is a risk of divergence and fragmentation. (Howells, James & Malik, 2003).

Different timeframes and horizons need to be considered in distributed innovation management. The objectives and expectations of knowledge acquisition, partner relationships, types of knowledge, functional focus, and risks are different in short- and long-term scope of distributed innovation. Collaboration in both timeframes can be focused on partnerships or technologies. (Howells, James & Malik, 2003).

Short-term collaboration is focused around specific outcomes on products and processes and is often contract-based. Therefore, short-term collaboration is referred to as problem-oriented innovation. Uncertainty and risks are typically low. However, the impact of failure could still be high. The innovation timeframe increases with reciprocal collaboration that can include informal and non-contractual cooperation between different organizations. Joint ventures and other ownership-based collaboration spans even longer time horizon. Ownership-based collaboration opens new kinds of opportunities, such as technology insourcing. In long-term collaboration uncertainty and risks tend to increase and are generally high. Alignment with future markets and competencies is important in long-term distributed innovation. (Howells, James & Malik, 2003).

Business models for distributed innovation must consider how actors outside their organizational boundaries can be motivated and involved in innovation processes, and how value could be captured. An example of contribution motivation can be drawn from open source development communities. The contributor, i.e. external innovator, expects to benefit from the contribution in future. However, a business or technical need is often required to contribute in the first place. In user communities, there are also personal reasons to contribute to distributed innovation. For example, a software developer could contribute for personal reputation, skills development, learning, job market signaling, or satisfaction and entertainment. The cost and effort to participate in distributed innovation must be low to decrease the barriers to entry and to increase the diversity and number of contributors. (Lakhani & Panetta, 2007).

Distributed innovation calls for openness, collaboration, and knowledge sharing. In addition, intellectual property policies need to be aligned with the principles of open and distributed innovation. However, the level of openness needs to be negotiated and tuned. (Lakhani & Panetta, 2007). However, there are shades and fine-grained levels between open and closed innovation systems and models (Sawhney & Prandelli, 2000).

Inbound and outbound knowledge flows require different kind of capabilities for value capture. Inbound knowledge flows call for internal capabilities, such as knowledge absorption, to capture value from external innovation sources. Stakeholders and communities can help to discover innovation sources, but the firm itself needs to able to internalize the knowledge. On the other hand, outbound knowledge flows require balancing between controlling and empowering innovation. Value capture relies on intellectual property protection and monetization of external use. For instance, licensing can be used to project control on outbound knowledge flows. However, strong intellectual property protection is likely to be detrimental to distributed innovation mechanisms. (Bogerst & West, 2012).

Sawhney and Prandelli (2000) claim managing distributed innovation is constant balancing and governance between order and chaos. They propose a governance mechanism called *community of creation* that balances between closed hierarchical innovation model and open market-based innovation model. Distributed innovation management requires structure to control chaos and coordination mechanisms for knowledge creation but also freedom and openness to trade and access knowledge. Community of creation is based on transaction cost theory, community management, intellectual property rights analysis, and complexity theory. (Sawhney & Prandelli, 2000). The literature implies that distributed innovation and its management are complex topics. Therefore, they core ideas of distributed innovation are covered in this study, but the phenomenon is not discussed or presented in detail.

Finally, it should be noted that distributed innovation is not a replacement for in-house innovation. Rather, it expands and complements it. (Lakhani & Panetta, 2007; Howells, James & Malik, 2003). Distributed innovation is unpredictable and cannot deliver on-demand outcomes. Aligning business models with open and distributed innovation can be challenging. For instance, many open source projects fail in a commercial sense. Openness requires a transformation of intellectual property protection and innovation models. There are both real and imaginary risks in relinquishing control and decreasing secrecy regarding innovation. (Lakhani & Panetta, 2007). There is also a risk in over expanding outsourcing of knowledge and technological capabilities. It can lead to weakened technology and innovation capabilities, core competencies, and knowledge absorption capabilities within the firm. Vendor locks in technology and partners should be avoided to maintain flexibility. It should also be noted that successful management and exploitation of distributed innovation is harder than of the traditional centralized innovation. (Howells, James & Malik, 2003).

3 DIGITAL PLATFORM LITERATURE

This section reviews literature on digital platforms and digital platform innovation. The concept of boundary resource is defined and its connection with digital platform innovation is described. API is defined and presented as a type of platform boundary resource. Finally, the roles and influence of APIs in digital platform innovation is explored.

3.1 Digital platforms

Digital platforms are a current and important research topic in information systems (Yoo et al., 2010; de Reuver et al., 2017). The popularity of digital platforms in research and practice was fueled by the early success and spread of mobile platforms and the related software-based ecosystems. (Smedlund & Faghankhani, 2015). The influence of digital platforms in modern service-based economy is remarkable. For instance, Facebook has transformed social media and social interaction, Android and iOS have transformed mobile ecosystems, and other examples could be found in many other industries, such as payments, mobility, healthcare, music, hospitality, and ecommerce. Digital platforms enable creation of new kinds of services and business models. Furthermore, digital platforms have redefined and transformed the dynamics and relationships of business and innovation ecosystems. The diffusion and success of platforms is strengthened by positive network effects and generativity of digital technologies and innovations. (de Reuver et al., 2017; Smedlund & Faghankhani, 2015).

Platform is a "physical, technological, or social base on which socio-technical processes are built" (Anttiroiko & Valkama, 2013 p. 239). Platforms provide both the structure and environment for applications and processes to be built on (Anttiroiko & Valkama, 2013). De Reuver et al. (2017) conceptualize digital platform as software artifacts and their surrounding ecosystem. Their definition is in line with the prior definition by Yoo et al. (2010) and agrees that digital platforms are socio-technical systems which include technological elements and organizational processes, standards, and other non-technical elements. However, different fields of research conceptualize platforms differently. IS research approach studies both technology and the organizational and managerial aspects of digital platforms. (de Reuver et al., 2017). From a technical point of view, digital platforms can be products, system architectures, communication protocols, operating systems, applications, or devices and their embedded firmware (Dal Bianco et al., 2014). Smedlund and Faghankhani (2015) argue digital platforms are both services and products. Furthermore, the product and service aspects are inseparable from each other. For instance, a sensor platform consists of hardware sensors and their firmware but also a backend system to process and store the information. A digital platform can be classified open or closed depending on third party access to it and their ability to integrate offerings into the platform. (Smedlund & Faghankhani, 2015).

Digital and non-digital platforms are set apart by the characteristics of digital technology: homogenization of data, editability, re-programmability, distribution, and self-referentiality. However, a digital platform can include both physical and digital materiality. (de Reuver et al., 2017). Yoo et al. (2010) describe a layered-modular architecture that explains and analyzes how digital modularity and layers of physical materiality coexist in digital platforms. Subsequent research (e.g. de Reuver et al., 2017) build on the concept of modularity and agrees on its importance in digital platform research. The modular and combinatorial nature of digital innovation increases the complexity of digital platforms. According to prior research (e.g. de Reuver et al., 2017; Tilson et al., 2010), digital platforms can form larger supersystems and infrastructures that comprise of multiple platforms. Thus, a digital platform could be defined as a subset of digital infrastructures in some cases. The scope and boundaries of digital platforms can be fuzzy and difficult to define (Tilson et al., 2010). Platforms can emerge from within or based on other platforms. For instance, mobile devices and their operating systems are platforms that host other application-based platforms, for instance digital advertising platforms. (de Reuver et al., 2017). The concepts of digital platforms and software platforms are related to each other but perhaps not interchangeable. For software platforms Tiwana et al. (2010) and Ghazawneh and Henfridsson (2013) use the definition of software-based core functionalities that are shared via interoperable modules and interfaces. Applications and services are developed with common resources on software platforms. These common resources can be provided to third-party developers to foster digital platform innovation. (Ghazawneh & Henfridsson, 2013).

Digital platform is a sprawling multidimensional research topic that can be studied from multiple perspectives and through multiple lenses. It is related to concepts such as digital infrastructures (Nambisan et al., 2017). A digital platform can evolve into infrastructure (de Reuver et al., 2017), has similar mechanisms and innovation logic (Henfridsson & Bygstad, 2013), and can have dependencies with them (Tilson et al., 2010). Therefore, multidisciplinary theorizing is recommended for digital platform research (Nambisan et al., 2017).

3.1.1 Platform and service innovation

Digital platforms have transformed digital service innovation and creation of service offerings. Furthermore, in-house research and development has been partially replaced and supplemented by external partnerships and collaboration. Organizations are looking for opportunities to join platforms as complementors or establish their own platform for others to join and innovate on. It has become increasingly difficult to innovate new products and services and introduce them to market without utilizing platforms and other existing technology base through combinatorial innovation. (Smedlund & Faghankhani, 2015).

Generativity is a core enabler for digital platform and service innovation. Co-creation of services, digital artifacts, and platform business models are based on collaboration and participation through digital platforms and infrastructures. Service convergence and divergence are both consequences of generativity. Novel and diverse combinations of digital services are emerging in different industries, leading into service divergence. However, the digital technology itself is converging. New businesses, digital platforms, and other infrastructures are based on the prior platforms and infrastructures. Combinatorial service innovation can lead to recursive wakes of innovation. Based on the characteristics of digital technology, digital platforms and infrastructures remain incomplete and open for future modifications and expansions. In addition, the scaling costs are marginal or near zero. However, it should be noted that social constraints, such as contracts and license, can limit scalability, recursion, and flexibility. (Tilson et al., 2010).

Service platforms can solve the issue of balancing between service standardization and customization. Standardization makes reproduction of services easy and increases efficiency. However, it decreases the possibility for customizations and therefore value creation. On the other hand, customization increases value creation potential and helps to meet customer needs more accurately. The downside is decreased efficiency and increased costs. The idea of service platform is to open a standard platform for external service innovation and development. The third-party developers can then create the customized and specialized services based on the market needs. An integration architecture is needed for open innovation platforms to avoid technology divergence and fragmentation. The platform strategy must enable the third parties to profit from the open service platform and base their business models on it. (Chesbrough, 2012).

Platform success requires ambidextrous approach. Platform offerings need to be continuously renewed and the platform itself must evolve. However, at the same time it needs to be efficient and able to capture value. Therefore, platform innovation is critical for platform success. Furthermore, innovations are unlikely to emerge without collaboration between the platform participants through the platform interfaces. The four elements of platform success are 1) co-creation of value, 2) interdependency and complementarity of platform components, 3) surplus value creation, and 4) evolutionary growth. Platform offerings and value are co-created by the platform participants, including end-users, in value constellations. Each component in the platform contributes towards a functional system and complements each other creating surplus value for the ecosystem. Platforms evolve and adapt by means of o-creation and facilitation of capabilities and complementary components that expand the platform boundaries and capabilities. (Smedlund & Faghankhani, 2015).

Anttiroiko and Valkama (2013) have studied digital platforms and service innovation in smart cities. They found that the landscape of service economy and innovation is changing. Services are being unbundled from their production processes, digital technology is becoming ubiquitous, and service production and consumption are undergoing a transformation. New co-operation and operating models have emerged in service innovation, production, delivery, and consumption to respond to these changes. Circulation and sharing of knowledge are essential to the new service innovation logic. Moreover, service networks have enabled reconfiguration of services by combinatorial innovation following the logic of distributed and open innovation. In context of smart cities, the citizens and communities are co-designers and co-producers of service innovations. (Anttiroiko & Valkama, 2013).

Another finding by Anttiroiko and Valkama (2013) was that digital platforms have a vital role in interoperability of public services and creation of digital service offerings. Service integration requires common standards, boundary crossing collaboration, and platform governance. Platform-based digital services increase the flexibility and responsiveness of public organizations in service innovation and delivery. However, it emphasizes the role of technology gatekeepers. The role of digital platforms in smart city service innovation were to provide access to service processes, foster service innovation and creativity, increase knowledge sharing and collaboration, and enable system integration. (Anttiroiko & Valkama, 2013).

3.1.2 Paradox of control and openness

Digital platforms are paradoxical by nature (de Reuver et al., 2017; Tilson et al., 2010). There is a constant conflict of stability through control and generativity through flexibility and openness. Growth and evolution of digital platforms leads to emergence of new combinations of digital services and capabilities which stimulate generativity and drive forward platform evolution and divergence. However, at the same time the organizational boundaries and roles become blurred which calls for more control. (Tilson et al., 2010).

Without adequate stability new digital artifacts and processes cannot be innovated and deployed efficiently, and without flexibility the growth and its potential are bounded and limited. Stability is increased by limiting changes and the vice versa. The two forces are dependent on each other and have an inverse relationship. Without stability there cannot be flexibility. For instance, digital platforms and infrastructures can be accessed through APIs. Should stability be too low the technical and social foundations are too volatile and unpredictable to be built on, and thus no innovations can be achieved. (de Reuver et al., 2017; Tilson et al., 2010). The same observation was made by Nylén and Holmström (2015); they agree that digital platforms should maintain adequate control without hindering creativity and generativity. This balance is an important success factor for innovation and platform success. Moreover, digitalization has shifted business and innovation opportunities and affordances to the organizational boundaries. The historical need for control in use of information systems should be re-evaluated. A set of research questions has emerged related to how to manage generative digital platforms and their control points and boundaries. (Tilson et al., 2010).

Platform openness has a few different definitions that can include technical and social elements. For instance, it can be defined as technical openness, such as open source development and licensing, open APIs, or use of open standards. Openness can also mean open rules for platform entry and exit. Different platform strategies influence the level of openness. Some platform strategies focus on data sharing and others on reusable resources and capabilities. It should be noted that some of the extraordinarily successful platforms, like Facebook, Google, eBay, and Amazon, are partially or completely closed domain. However, the Internet and open standards encourage platforms to be more open. There is a tension between closed and open platforms and business models. In addition, platform openness is component-specific, i.e. it can be different for different aspects of the platform. For example, a government data platform could provide open access to data through a set of open APIs, but the platform itself could be implemented as a closed-source platform. (de Reuver et al., 2017). Parker and Alstyne (2016) define openness as absence of control. There is an inverse relationship between openness and control. Their definition also includes platform governance models and intellectual property rights (IPRs) as part of the openness umbrella.

Open platforms require aligned open business models to exploit and benefit from external innovation. Organizations need to identify when and how to absorb third-party innovations, i.e. inbound knowledge flows, and open them through their platform for the benefit of the ecosystem thereby enabling outbound knowledge flows and external innovation. Outbound knowledge flows also share risks and enable use of shared resources in platform innovation. (Parker & Alstyne, 2016).

Open innovation strategies are interconnected with platform and business strategies. There are different platform strategies available for the platform owner depending on the market position and objectives. It is suggested to not adopt any extremes in openness or control. Instead, an optimal balance must be evaluated for openness and control for maximum value creation and minimum risks. There must also be a balance between taxing external innovators through value capture and innovation absorption and fostering future innovation and third-party interest in the platform by not imposing too strict regulation. Openness positively influences profitability, ecosystem growth, network effects, downstream development, and reduces the fear of vendor locks. On the other hand, openness introduces new risks, such as reduced switching costs, increased forking, and competition, and thus reduces the ability for the platform owner to capture value. (Parker & Alstyne, 2016).

Different governance models can be used to support platform business models and strategies. Permissionless innovation model is well-suited for open innovation strategies. All parties forgo their IPRs and provide each other access to their intellectual property (IP). The model eliminates lots of negotiations and contracts in IP exchange. However, third-party developers need to be attracted to the platform and motivated to continue innovation on it even if they will expose their IPs and they are subject to innovation absorption. Mutual knowledge spillover is a mechanism that motivates and encourages to participate in open innovation platforms. In mutual knowledge spillover, developers gain more resources and potential value for themselves than they forgo and share because of access to other innovations absorbed into the platform. The platform owner also benefits from the inbound knowledge flows and co-created value. (Parker & Alstyne, 2016).

Long-term benefits and ecosystem profits are strong business drivers for platform openness. Short-term rents and royalties gained by control are often less valuable. Moreover, aggressive behavior in value capture and innovation absorption will likely deteriorate developer interest towards the platform. However, the cost of free access to innovation resources should be proportional to the expected innovation output of the third parties. The value gained through openness increases with the number of external developers and end-users. It is important for the platform owner to enforce open innovation that benefits all parties and enables beneficial knowledge spillover. (Parker & Alstyne, 2016). Platforms enable and support positive network effects and multisided markets. A positive feedback loop can continuously encourage more users and service providers to join the platform and increase the pull effect for both market sides. Business opportunities and potential profits will increase in tandem with the number and diversity of platform service offerings. (de Reuver et al., 2017). Chesbrough (2012) goes even further and claims that platform business models are the most valuable business models. Competitive advantage is gained through built-in external innovation mechanisms that enable third-party developers to innovate on the platform and co-create value (Chesbrough, 2012).

3.1.3 Platform ecosystems and innovation orchestration

Platforms and ecosystems are interlinked (de Reuver et al., 2017). However, the definition of ecosystem is often ambiguous among the practitioners and academics alike (Han et al., 2017). Platform value creation and evolution requires an ecosystem of users and developers. Ecosystem can include one or more competing or collaborating platforms. There can even be overlapping and interdependency between platforms within their ecosystem. In future, platform cooperation and integration are likely to increase. For instance, Facebook is primarily a social media platform, but also a technology platform that enables third-party service innovation. APIs play a key role in platform innovation and integration of services and resources. (de Reuver et al., 2017).

Han et al. (2017) have conducted a systematic literature review on ecosystems and their definition. An ecosystem can be defined as a set of companies that co-evolve and work both cooperatively and competitively to create new products and to provide value to their customers through innovation. An innovation ecosystem can be defined as "sum of technology interdependence among the focal firms, upstream components, downstream complementors, and end-users". The boundaries of business and innovation ecosystems are often fuzzy. The major difference is that business ecosystems focus on value capture and innovation ecosystems on value creation. (Han et al., 2017).

Furthermore, the study on seminal works on ecosystems by Han et al. (2017) revealed various roles, such as keystone and niche players, of ecosystem actors. Each role has a different objective and ecosystem strategy. Digital platform owners are keystone players who seek to co-create value. Dominators pursue capturing maximum value. Niche players are typically application providers and developers who co-create and co-capture value and complement the ecosystem offerings. (Han et al., 2017). Another role typology is presented by Smedlund and Faghankhani (2015). It includes end-users as demand side role of the multisided market, platform owner who controls the platform core, an intermediary platform provider who mediates the platform delivery, complementors as supply side role of the multisided market, and orchestrator who fosters the value co-creation between the ecosystem participants. The platform owner typically assumes the role of orchestrator as a secondary role. (Smedlund & Faghankhani, 2015).

The ecosystem structure and roles define how power and influence are distributed within the ecosystem and what are their conceptual boundaries. Loose coupling of roles is required for the balance and self-organization of individual agendas and activities. Technological relatedness and heterogeneity within the ecosystem create and maintain resource-based hierarchies that have influence on decision making and responsibilities. A moderate hierarchy is needed to reduce and manage ecosystem complexity and increase coordination within it. Modularity enables open-ended structures that enable generativity and combinatorial innovation opportunities. In addition, control mechanisms are needed to enforce interoperability and shared vision for boundary-spanning business models and ecosystem co-evolution. (Han et al., 2017). Platform-based networks, i.e. ecosystems, have two trajectories. A goal-directed ecosystem has a common goal the ecosystem actors collaboratively aim for. Serendipity, on the other hand, has no shared goal and instead relies on evolution-based innovations. (Smedlund & Faghankhani, 2015).

The platform owner has a focal role in platform ecosystem and is typically responsible for ecosystem orchestration (Smedlund & Faghankhani, 2015; Han et al., 2017). The platform owner is sometimes termed as a sponsor or a keystone player. It is not mandatory for the platform owner to become the orchestrator. However, the owner controls platform's technologies, interfaces, and core, and thus has an advantage in the role. Orchestration can be defined as promotion and facilitation of processes that lead to activities among platform participants and as influencing the multisided markets in the platform ecosystem. However, orchestration does not automatically mean centralized control in the ecosystem. (Smedlund & Faghankhani, 2015).

Platform orchestration increases and fosters platform innovation, development, and efficiency. Based on the firm literature, innovation is a core task of any company and mandatory for sustained competitive advantage. Different orchestration modes can be utilized as per platform strategy and the platform type which are internal, open, closed, and leading platforms. Leading platforms are best suited for innovation. Each orchestration mode has their benefits: the mode of efficiency is best suited for internal platforms, and mode of development fits open and closed platforms the best. (Smedlund & Faghankhani, 2015).

Leading platforms enjoy positive network effects, are attractive for participants and likely include a wide variety of end-users and complementors. However, platform and ecosystem complexity are higher than in the other three platform types. Orchestration in leading platforms focuses on co-creation of novel offerings within the platform ecosystem. Value co-creation logic is chaotic but self-organizing and competencies are continuously created and renewed. Orchestration in leading platforms must facilitate ad-hoc interactions and the emergence of new knowledge and offerings. Interdependencies and relationships are trust-based. Growth is based on innovation activities and increased platform diversity and reach. Orchestration logic for innovation can be described as a self-reinforcing loop where the creation of novel offerings attracts more platform participants who interact with each other. The interactions and transactions between the participants call for facilitation. Over time the participants get locked into the platform and create more novel offerings continuing the loop. (Smedlund & Faghankhani, 2015).

The development mode of orchestration fits best open and closed platforms. Value co-creation logic is organic and based on dialogue between the platform participants who pursue incremental improvements and co-elevation of their capabilities. The orchestration processes facilitate mutual long-term interactions, refining of knowledge, and increased platform robustness. Platform openness is defined by the amount of control platform owner retains on platform entry and participation. Closed platforms have well-known participants and value is typically created through front-end development. Open platforms do not limit interactions or participation and enable stronger combinatorial value co-creation and innovation potential. In both cases the orchestration mode must be tailored based on the needs and business model of the platform. Internal platforms are completely controlled by the platform owner. Organizational boundaries limit participation and the focus is on mechanistic transaction-based value creation and efficiency instead of innovation. (Smedlund & Faghankhani, 2015).

3.2 Boundary Resources

Platform boundary resources are an important concept and unit of analysis in digital platforms research. Studying the platform boundaries and boundary crossing innovation and resourcing activities provides a fresh lens and approach into the dynamics of digital platforms and platform innovation. In fact, focusing only on the platform core is likely too restrictive and narrow approach. (de Reuver et al., 2017; Ghazawneh & Henfridsson, 2013; Eaton et al., 2015; Barrett et al., 2015).

Boundary resource is defined as software and/or regulations that facilitate relationships between the platform and its developers (Ghazawneh & Henfridsson, 2013). Furthermore, they are dynamic by nature and collectively tuned by the platform actors (Eaton et al., 2015). Boundary resource can be categorized into technical boundary resources, such as APIs and SDKs, and social boundary resources, such as documentation and regulations (Ghazawneh & Henfridsson, 2013; Dal Bianco et al., 2014).

In addition, the use and dynamics of boundary resources can be described by a model introduced by Ghazawneh and Henfridsson (2013). The model is illustrated in the figure 3. The basic idea of the model is that the platform owner can design, develop, and modify the boundary resources based on the external innovation opportunities, expected third-party contributions and benefits, and perceived need for control. The design of new boundary resources is typically triggered by emerging needs and requirements that cannot be satisfied by the existing resources. (Ghazawneh & Henfridsson, 2013).

The exposed boundary resources are used to both resource and secure the platform. They can be used to enable and empower third-party developers' ability to build on the platform. Developers use boundary resources to gain access to platform capabilities and resources. However, boundary resources can be used to set rules and the use of additional securing resources, e.g. a license, could be mandatory. The use of boundary resources enables the platform owner to benefit from distributed innovation and external innovation contributions. Furthermore, resourcing expands and increases the diversity of the platform ecosystem and its offerings. Boundary resources can also be used for platform securing. Typically, platform exposure and use are governed and regulated by both social and technical boundary resources. For example, APIs could be used to moderate what resources are available outside the platform boundaries, or a social contract could be required to access other boundary resources. The platform ecosystem needs to be aligned with the platform objectives, business model, and selected strategy. The alignment of heterogenous interests and objectives reduces risks and increases mutual benefits. However, the level of control is dynamic and variable over time. It is based on the platform ecosystem and environment but also the industry and needs. (Ghazawneh & Henfridsson, 2013).

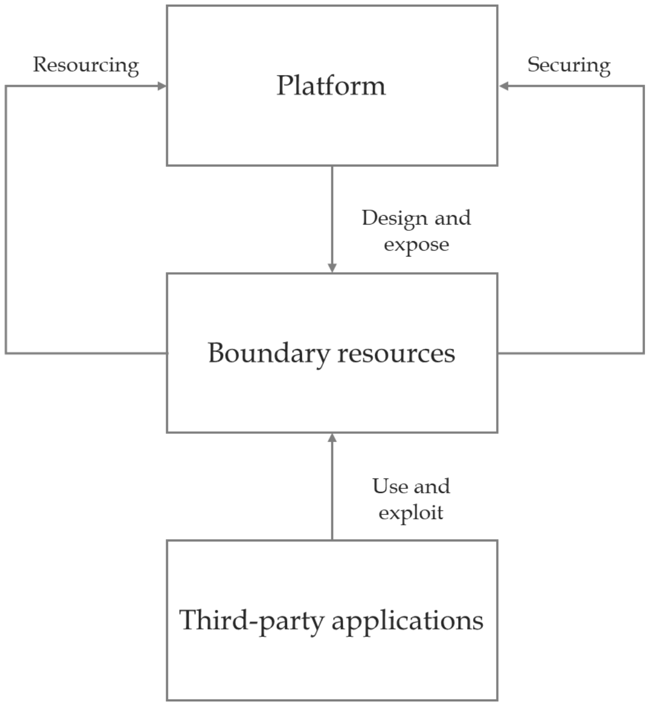

FIGURE 3 Boundary resource model.

Dal Bianco et al. (2014) present the onion model that describes and categorizes boundary resources. The model, like an onion, comprises of nested layers. The layers are the categorization of boundary resources. Social boundary resources (SBR) is the outmost layer that includes all the other categories, development boundary resources (DBR) is the middle layer, and application boundary resources (ABR) is the core of the model. Low-level categories are included in the higher ones. (Dal Bianco et al., 2014). The onion model is illustrated in the figure 4.

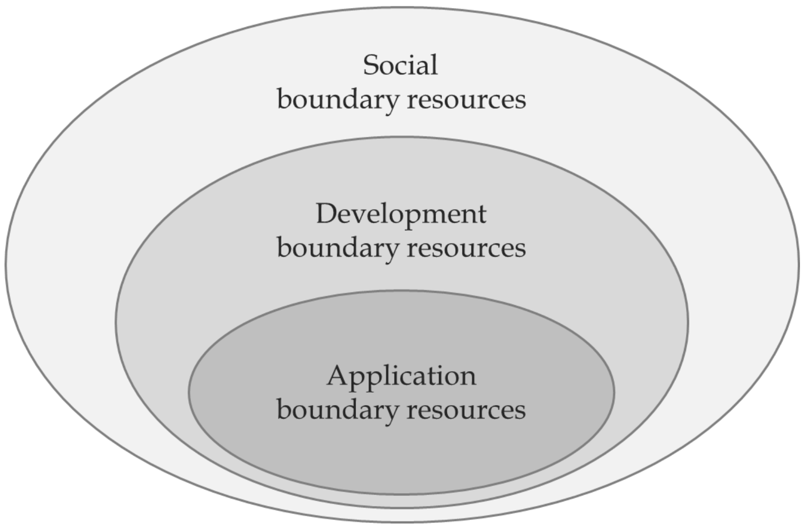

FIGURE 4 Boundary resource onion model.

Application boundary resources are the minimum technical resources required to interact with the platform. Without them, any interaction would be impossible. Development boundary resources enable development of applications and services based on the platform. They expand the options for the use of the platform. Additional developer resources are included to the application boundary resources to create development boundary resources. These two resource types are categorized as technical boundary resources. The social boundary resources are a kind of superset of technical boundary resources. Social boundary resources are used to transfer knowledge and moderate and coordinate the use of platform and its resources. (Dal Bianco et al., 2014).

API, as an example, can be considered both a technical and social boundary resource. It is an application resource because it enables interaction with the platform. In addition, it enables development of new applications and its functionalities can be embedded in other software, Thus, it is also a development boundary resource. However, an API can be considered as a social boundary resource that transfers knowledge, such as semantic information and methods, regarding the platform and the API itself. Typically, APIs are also bundled with other social boundary resources, such as developer documentation or portal, which expand it and support its use. The example also provide evidence that the boundary resource classification is non-exclusive and indeed nested. It also illustrates how boundary resources are often bundled. (Dal Bianco et al., 2014).

3.2.1 Roles and functions of boundary resources

The success of software ecosystem is dependent on the quantity and quality of its end-user applications. Therefore, the platform needs to attract external developers and facilitate application and service development. Platform boundary resources expose and expand the platform to reach these objectives. They act as tools for communication and knowledge transfer, enable external development activities, and help to minimize the need for coordination. However, platform-centric approach and design of boundary resources is likely to produce unsatisfactory results. Instead, a developer orientation is required yet it is more difficult to achieve. (Dal Bianco et al., 2014).

Ghazawneh & Henfridsson (2013) and Eaton et al. (2015) define the core function of platform boundary resources to be providing access to the platform's resources, stimulating generativity, and enabling infrastructure control. Boundary resources are used to design and create more flexible products that have less-rigid boundaries and thus increased innovation potential. Platform strategies are critical for innovation in distributed and fast-paced environments. Boundary resources can be considered as strategic key resources for digital platforms. (Yoo et al., 2010).

The paradox of control and openness is relevant to boundary resource literature. The tension between the logic of generative and democratic innovation and infrastructure control can be managed through boundary resources. In fact, the use of boundary resources is mandatory to benefit from open innovation in digital platforms. Platform control is critical to reduce and avoid incompatibility and manage the power asymmetry in platform ecosystems. Moreover, boundary resources are used to lower the barriers to entry and increase the potential of platform participation. Open innovation through boundary resources can lead to co-creation of diverse and unanticipated innovations. (Eaton et al., 2015). However, there are tensions regarding the boundary resources themselves. A balance must be reached and tuned between creativity and usability in boundary resource design. Should the resources be too generic they become unusable for specific needs and too abstract to be useful. On the other hand, too specific and specialized resources are more restricted and limit the use of the resources for open and combinatorial innovation. An ideal balance between creativity and usability would have as low barrier to entry as possible through ease of use, low complexity, and fast deployment and utilization time. However, to increase usability of the resources interoperability and stability needs to be increased and maintained. The technical boundary resources need to be supplemented with social boundary resources that support different learning styles, resource consumption, and use cases. (Dal Bianco et al., 2014).

Resourcing and securing are the two primary roles of platform boundary resources, as presented in the boundary resource model by Ghazawneh and Henfridsson (2013) and illustrated in the figure 3. The two roles are interconnected and influence each other. In general, resourcing refers to design and development of boundary resources for external developers to use and exploit. Securing refers to the use of boundary resources to control and regulate the access and use of the platform and its capabilities and resources. Resourcing and securing needs to be constantly balanced and tuned to manage the tension between control and openness. (Ghazawneh and Henfridsson, 2013).

The primary objective of resourcing is to increase the number and diversity of new applications on the platform. The creation of applications expands the platform boundary and reach and stimulates platform evolution. External developers can create new kinds of boundary resources to overcome the perceived limitation of the existing resources via self-resourcing. Self-resourcing can be sanctioned or unsanctioned by the platform owner. Unsanctioned self-resourcing, e.g. jailbreaking of iOS platform, implies a need for rebalancing of resourcing and securing. Typically, securing is carried out through regulations and social contracts rather than technical restrictions. Technical limitations can lead to the increase of unsanctioned self-resourcing. Securing is also needed to maintain the platform sovereignty and manage the risks and platform evolution. (Ghazawneh and Henfridsson, 2013).

3.2.2 Practice and case studies

Ghazawneh and Henfridsson (2013) studied the use and roles of platform boundary resources in Apple's iPhone and iOS platforms. They were interested in how boundary resources help to cultivate external development and innovation. An SDK and a collection of APIs were provided for platform resourcing.

The SDK provided the development tools and environment and APIs the access to the platform and its services and resources. App Store was used as a distribution channel and accessible through the development platform. However, Apple also utilized boundary resources for securing. App Store and the process of publishing applications were strictly regulated and moderated as based on Apple's governance model and review processes. Therefore, the boundary resources enabled App Store with its terms of use to operate as a control point. (Ghazawneh & Henfridsson, 2013).

However, the boundary resources Apple provided were perceived insufficient and limiting and were targeted by criticism. The external developers started to self-resource the platform by e.g. jailbreaking the platform. Apple had to react and rebalance resourcing and securing. They redesigned social boundary resources and exposed new technical boundary resources to solve the issue and increase the diversity of the ecosystem and the emerging innovations. Later, Apple changed its approach to secure the platform sovereignty through boundary resources by limiting cross-platform development to answer the threat of its competitors. (Ghazawneh & Henfridsson, 2013).

Dal Bianco et al. (2014) explored how platform boundary resources were used in software ecosystems and as innovation resources. They studied F-Secure's CAN platform and use of its boundary resources in a hackathon. Based on the findings, they developed the boundary resource onion model to classify and describe the different types of resources. They concluded the platform owner can utilize boundary resources to facilitate and enable external innovation and application development. However, the design of boundary resources heavily influences their usefulness and innovation potential. Platform-centric design and exposure of existing internal interfaces as boundary resources is likely to produce little value and ineffective boundary resources. In fact, they could even have a detrimental influence on external application and service development. A developer-centric approach is necessary for boundary resource design and publication. However, it also calls for a transformation from closed product-like platforms to open platforms and innovation models. They found the transformation is often difficult to achieve. It is not enough to open the internal platform and resources as such. New kinds of resources and resource bundles need to designed and exposed. Moreover, the internal platform architecture can be a source of technical limitations and/or social restrictions. The assumptions and decisions done during the design of the platform and its boundary resources are critical and need to be updated to the open innovation paradigm. (Dal Bianco et al., 2014).

3.3 APIs

Application programming interface (API) is a machine-readable piece of software which provides connectivity and means of interaction for applications and abstracts the inner workings of an information system. API can be conceptualized as a platform boundary resource and a distribution channel for software, data, and infrastructure. (Wulf & Blohm, 2017). Additionally, it can be conceptualized as a technological artifact, contract, and mediator between software. The primary functions of APIs are to provide interoperability, extensibility, linkage of functionalities, and added value creation potential. (Huhtamäki et al., 2017). Aitamurto and Lewis (2012) also consider APIs both software and a set of rules and mention interoperability as their key role.

API per se is not a new concept. However, the roles and use of APIs has been dramatically changing in the past years. The use of digital technology has transformed and influenced value creation in the networked economy. It requires reconceptualization of APIs, especially web-based APIs, as a more diverse concept than just a piece of technology. APIs are building blocks, enablers, and catalysts for the digital transformation. Moreover, they are control points and strategic resources for digital services and sharing of data. This makes APIs interesting research topic in digital platforms and digital innovation. (Basole, 2016; Evans & Basole, 2016; Tilson et al., 2010).

APIs can be categorized into open and closed APIs (Aitamurto & Lewis, 2012; Wulf & Blohm, 2017). Open-close classification is based on the API availability in respect of organizational boundaries. Closed APIs are available and usable only within the organizational boundaries. Open APIs, on the other hand, are usable by anyone with adequate technical skills and available online. Well-known examples of open APIs include Facebook's, Amazon's, and Google's service interfaces. They permit external access to platform functionalities and data by external developers who can use the resources to develop new applications and gain benefit by doing so. (Aitamurto & Lewis, 2012). Moilanen et al. (2018) include partner API as a third category in between the open and closed end. A partner API is contract-based and available only for platform partners and stakeholders (Moilanen et al., 2018). APIs can be classified as functional or data APIs based on their purpose and capabilities. Functional APIs execute functions to facilitate business processes. Data APIs provide data as a service without any further functionalities. (Wulf & Blohm, 2017).

Bonardi et al. (2016) call APIs the wholesale version of the web presence. APIs provide external developers an extensive access to and integrate possibilities of platform resources into their own applications and information systems. Furthermore, APIs have contributed towards a paradigm shift in software engineering and are used in distributed and collaborative software development. (Bonardi et al., 2016; Aitamurto & Lewis, 2012). The paradigm shift and its impact on digital services development has further fueled the rapid digital transformation (Basole, 2016).

At present, a multitude of industries and businesses already utilize APIs in a wide scale. They are utilized to provide infrastructure as a service by companies like Amazon and consumed by other companies, such as Dropbox and Netflix, which base their services on APIs. A lot of functionalities in digital platforms are based on and built with external capabilities available through APIs. These include such as advertising, social networking, messaging, and payments to mention some. (Tan et al., 2016). APIs are especially useful for incumbent firms that can gain access to resources, capabilities, and knowledge they would otherwise lack (Tan et al., 2016; Vukovic et al., 2016). APIs enable and catalyst combinatorial innovation and combinatorial service development both internally and externally (Tan et al., 2016; Yoo et al., 2010).

APIs are an increasingly important topic in digital platform and infrastructure research. However, the technical discussion has been ongoing already over a decade in software engineering. The conceptualization of web-based APIs as platform boundary resources that enable and empower boundary crossing value co-creation has fueled new kind of interdisciplinary API research. (Huhtamäki et al., 2017). Based on the above-mentioned literature (e.g. Wulf & Blohm, 2017; Dal Bianco et al., 2017; Ghazawneh & Henfridsson, 2013; Huhtamäki et al., 2017), APIs can be conceptualized as platform boundary resources that have a strong connection with digital innovation and digital platform innovation. Furthermore, Wulf and Blohm (2017) argue there is a lack of research that considers APIs from the service innovation perspective and enables the development of overarching theories explaining APIs.

3.3.1 The emergence of web-based APIs

The emergence of service-oriented architecture laid the foundations for modern web-based APIs and the API economy in the early 2000s (Vukovic et al, 2016; Wulf & Blohm, 2017; Tan et al., 2016), and the early eCommerce companies, such as Amazon and eBay, popularized public APIs (Wulf & Blohm, 2017). Initially APIs were used to increase modularity, enterprise interoperability, and legacy system integration (Vukovic et al., 2016; Lanthaler & Gütl, 2010; Tan et al., 2016). However, the early SOAP-based APIs were complex and heavy. Web-based interfaces such as RESTful APIs were designed to overcome the constraints and technical hindrances of the prior technologies. (Lanthaler & Gütl, 2010). Technological advances in APIs enabled the increase of diversity in service creation and service ecosystems. In a way, the Internet and Web became frameworks for participation and service co-creation through web-based APIs (Lanthaler & Gütl, 2010; Huhtamäki et al., 2017).

Over time APIs were increasingly used to ease and speed up software development and better reuse software components and other information resources. APIs helped to unlock the potential of previously static resources for both internal and external use. (Vukovic et al., 2016). Today REST-based APIs have superseded their SOAP-based predecessors almost completely. However, there are some scenarios, such as legacy systems, that still utilize the older generation of APIs. (Tan et al., 2016; Lanthaler & Gütl, 2010). Modern web-based APIs enable new kinds of service creation models, such as mashups, which were not feasible before. Mashups are combinations of resources, capabilities, and user interfaces connected by web-based APIs. For example, Google Maps API is often used to build mashup applications. (Huhtamäki et al., 2017).

Many organizations have been increasingly opening the access to their information resources and platforms to foster the co-creation of value-added services and benefit from unanticipated innovation (Lanthaler & Gütl, 2010). Moreover, new kinds of business models emerged and put even more emphasis on APIs in digital service creation. Thus, web-based APIs became even more important for business and more widely adopted and used. In 2017, the Programmable Web API catalog listed more than 18 000 public APIs across the various industries and domains. For example, Salesforce operates more than 60% of its customer traffic via APIs and 60% of eBay's revenue is generated via APIs by external websites. (Wulf & Blohm, 2017). At the time of writing, the abovementioned catalog lists more than 23 000 APIs.

3.3.2 API ecosystems and economy

API economy is an emerging sociotechnical phenomenon. It can be studied from its technological perspective but also through service innovation and service network lenses. API economy is based and enabled by software ecosystem and modern service-based software architectures. API-based architectures have largely replaced the legacy style monolithic architectures and the transition is still ongoing. Moreover, API-based architectures enable more malleable and horizontally integrated architectures than the previously dominant monolithic information systems. External features, capabilities, and data can be utilized by third parties to develop richer user experiences and new kinds of applications, such as mashups. At large, API economy is about opening ICT and business assets and utilizing external, shared assets outside of the organizational boundaries. It has been proposed that the phenomenon should be studied as a multidimensional concept and not only through a technological software engineering-based point of view. (Bonardi et al., 2016).

Evans and Basole (2016) have analyzed over 11 000 APIs and 6 000 mashup applications to build a visual overview of the API ecosystem. Their findings revealed concentrations and uneven distribution of APIs in different industries. APIs were utilized the most in enterprise software and tools, finance, messaging, social media, and ecommerce sectors. The runner-up sectors were mapping, science, government, and payment. Transportation was predicted to be an important emerging sector in future. (Evans & Basole, 2016). Also, health and wellness and analytics were predicted to emerge in API economy (Basole, 2016). A study by Basole (2016) presented a visual network analysis of API ecosystems and economy. There were five major clusters: 1) social and entertainment, 2) enterprise and communications, 3) search and reference, 4) data analytics and security, and 5) finance and ecommerce. The core of the API ecosystem is formed around social, search, and software tools categories. Basole concluded these capabilities are critical in development of most types of digital services. In addition, the core capabilities needed for service innovation are supplemented by data related capabilities such as analytics and visualizations. Moreover, capabilities such as cloud, storage, mobile, and security act as API ecosystem connectors. These connections indicate the structure of digital services and relations between the sectors and technologies. For example, finance is a relatively small sector but connected with a multitude of services that rely on it to provide economic transaction capabilities. (Basole, 2016).

Another API ecosystem study is provided by Huhtamäki et al. (2017). They also utilized a data-driven visual analytics approach to map the ecosystem and its structures but wanted to have a deeper understanding on co-innovation and co-creation. They combined API and mashup application data with startup and growth company data to create a visual map of API economy. The data set included over 6 000 APIs and their connection to companies and their geographical location. Based on the results, Europe and United States dominate API economy. The key locations were Silicon Valley, New York, Seattle, and London. A strong correlation was found between the clusters of API ecosystem and the Global Startup Index. A suggested cause was that startups are more likely to develop and exploit APIs and thus participate in the API economy. Moreover, it was suggested that a shared physical location contributes towards API and company success. (Huhtamäki et al., 2017).

Digital platform ecosystem and API ecosystem are related but different concepts. For example, different governance models are utilized for APIs and platforms. Platforms and platform-based value co-creation are typically governed and controlled by the platform owner. Value co-creation is enabled and fostered through platform boundary resources, such as APIs. The innovation and value creation models in API ecosystems are much more distributed and combinatorial. New services are constantly created by evaluating, mixing, and matching the existing resources and APIs. The switching costs for APIs are typically low, which means that unattractive APIs can potentially lose their user base at a quick pace. The API lifecycle is shorter, and their volatility is higher. (Huhtamäki et al., 2017).

User and developer communities are conceptually included in the API ecosystem. For instance, open source communities have greatly boosted the availability and the quality of API software and tools. However, the API economy is yet to reach its full potential and reach. There is a major gap between API forerunners and the late adopters and laggards. Tech giants, like Google, IBM, and Amazon, and innovative startups and growth companies are on a different level on API use and innovation than most traditional industries, public sector, and a wide percentage of SMEs. The API adoption is largely hindered by a lack of understanding and knowledge. (Bonardi et al., 2016).

A mashup is an application that combines internal and external resources. The external resources are sourced through APIs and often included in a digital platform. The creation of new mashup applications is relatively quick and thus attractive. Mashups often focus on fulfilling a specific user need and the users are often involved in co-creating mashups. (Weiss & Gangadharan, 2010). Huhtamäki et al. (2017) define three types of mashups: 1) collection of combined data sources, 2) compilation of application logics, and 3) creation of user interfaces based on the existing components.

Mashup ecosystems are related to API ecosystems. Weiss and Gangadharan (2010) studied mashup applications and APIs to understand their relationship. Their study represents the early emergent API research even if the data itself was collected over a decade ago. Already, as early as 2005, they found tech giants, e.g. Google, were keystone players in API economy. The positive network effects explained the concentration of users around successful platforms and fueled their growth even further. The number of users also increased the attractiveness of an API which has a positive impact on attracting even more users. API success was also explained by complementarity. Some APIs would complement other APIs and thus contributed to their popularity. For example, Flickr API enabled to fetch and display photos that were connected to a location that was possible to display using Google Maps API. It also provided opportunities for specialized niche providers. Another interesting finding was that the number of APIs has grown linearly but the number of API providers has not. The findings are also useful in understanding the reasons of API success and popularity and their role in digital service innovation, value creation, and platforms. Position within API and platform ecosystems influences use and adoption of released APIs. The number of users and interactions are strong indicators of API popularity and its perceived quality and usefulness. Low learning curve and ease of use and integration contribute towards use, adoption, and combinatorial innovation potential of APIs. (Weiss & Gangadharan, 2010).

APIs have a significant role in digital platform ecosystems. The keystone player and/or a platform owner creates and governs the platform boundary resources, such as APIs, and utilized them to moderate and facilitate the ecosystem. The boundary resources expand the platform boundaries and enable external innovation and application development. (Dal Bianco et al, 2014). Companies that want to become a keystone player in their platform ecosystems must create and expose open APIs. However, they need to consider the market saturation and competition. The barriers to entry for new APIs and new ecosystem players could be substantial. Nonetheless, the technical barriers to entry have become low as the technology has matured and is widely available. API ecosystem is constantly evolving, and the currently peripheral APIs could increase their centrality over time as the business and API landscape shapes. Moreover, the evaluation and selection of API strategies are important to succeed in API economy. For example, differentiation and positioning are important to define the value creation model for APIs. In addition, an API portfolio should include both current core APIs and peripheral APIs that have significant future potential. (Basole, 2016).

Zuccalà and Verga (2016) have studied APIs and data ecosystems in the context of smart cities. Their study was conducted in multiple European cities, such as London, Lisbon, and Milan. Smart city means that digital technology is integrated with and supporting the most aspects of urban life. According to the study, the management of a vast number of connected things introduced a technical challenge and required new kinds of solutions and knowledge. Moreover, value co-creation needed boundary-crossing data sources and processes. The innovation drivers included cost savings, monitoring, citizen engagement, and environmental values. Open APIs had a central role in enabling the co-design of smart city services and modern service architectures. In addition, APIs enabled access to and servitization of data sources and other digital capabilities. Open APIs were chosen to distribute open data, strengthen public sector interoperability, and enable open innovation through citizen engagement. APIs were supplemented with social boundary resources, such as policies, guidelines, and contracts, to enable open innovation ecosystem. (Zuccalà & Verga, 2016).

Bonardi et al. (2016) provide another case example of API ecosystem. Their study shed light into some prominent domains in API economy: tourism, hospitality, mobility, and smart city. They presented the E015 API ecosystem that provided collaboration opportunities for API researchers and practitioners alike. In addition, they called for deeper collaboration so that practical challenges could be answered by applied research and real-life environments could be used as data sources in academic studies. (Bonardi et al., 2016).

3.3.3 APIs in digital platform innovation

APIs influence and contribute to the ongoing massive digital transformation. They trigger combinatorial and cumulative digital innovations but also have a disrupting impact and contribute to the creative destruction that is related to the digitalization megatrend. (Basole, 2016). Wulf and Blohm (2017) review API and platform literature and discuss the dimensions of API-based service innovation. They argue APIs influence the service concept, client interfaces, service delivery systems, and technological options in service innovation. However, they claim that many organizations struggle to design and benefit from APIs and API-based service innovation. (Wulf & Blohm, 2017).

APIs enable innovation mechanisms for external (i.e. third party) innovation and cross-organizational partnerships in digital platforms. In fact, APIs are considered as vital strategic innovation assets in the emerging hyperconnected service economy. (Wulf & Bohm, 2017; Yoo et al., 2010; Huhtamäki et al., 2017). APIs provide a fresh lens to study digital innovation and platform innovation. They enable a better problem-solution match through mix and match service creation and combinatorial innovation. Furthermore, APIs make possible to design and establish new kinds of control mechanisms and relationships in the platform ecosystem. API-based digital platforms provide new kinds of value co-creation opportunities and influence the dynamics, such as network effects and externalities, of digital platforms and platform innovation. (Huhtamäki et al., 2017).

Open innovation and open APIs share similar characteristics, and the open innovation literature can be utilized to explain and study APIs in digital innovation. Open APIs create and foster inbound and outbound knowledge flows and could enable the coupled mode of open innovation. The outbound knowledge flows are generated by providing external actors access to platform functionalities and data, and by permitting third parties to develop own business based on the APIs. The inbound knowledge flows are created by permitting new technical and market knowledge to flow back to the platform owner and its ability to learn from the surrounding communities and the ecosystem. Open APIs enable data and functionalities to re-emerge in new environments and forms. (Aitamurto & Lewis, 2012). Open APIs enable external innovation based on the exposed platform resources. In addition, APIs often include mechanisms for the API provider to capture value and benefit from the external innovation. The benefits of open APIs in literature is like what Chesbrough (2012) discussed: access to new markets, development of new offerings, and increased positive network effects. (Basole, 2016).

Furthermore, API-based mashup platforms are related to distributed and user innovation. APIs increase the pace of innovation and the speed of user feedback cycles and decrease the cost of distributed innovation. In addition, utilizing APIs in user innovation is likely to lead in a better problem-solution fit and provide new incentives for customers and partners to assume innovation responsibilities. Moreover, companies have become increasingly dependent on external innovators who can provide complementary components and participate in their innovation processes. This enables the focal companies to focus on innovation architectures and assets, such as APIs as boundary resources. However, the keystone players do not have a direct control of the external actors. Instead they need to attract possible partners and relinquish control and ownership of the exposed resources, such as platform data. (Weiss & Gangadharan, 2010).

Discovering an optimal configuration of APIs and their fit in the company's innovation architecture and problems at hand might be challenging. However, it can greatly strengthen the potential and capabilities for cumulative and recombinant innovation. Often investments in standardization and quality are required. Also, the keystone player should foster the complementor specialization and participation in the platform ecosystem. New challenges could emerge from integration of resources. However, the potential for value co-creation and positive network effects outweighs the possible challenges. For example, Google, as a keystone player in its ecosystem, has provided access to its proprietary platform through APIs. Google has chosen to retain its architectural control but permit others to build services and businesses on their platform. This way it can benefit from the external innovation and the external actors can benefit from the shared capabilities, user base, and future innovations. (Weiss & Gangadharan, 2010).

APIs enable important benefits in platform innovation. For example, new revenue streams, increased innovation potential and service development opportunities, and powerful open innovation knowledge flows. In addition, the costs of service innovation and co-creation are shared and thus decreased, and flexibility and productivity in service creation is increased. APIs provide new means for technology and knowledge insourcing. (Evans & Basole, 2016). External developers can participate in platform innovation and extend platform offerings through APIs (Wulf & Blohm, 2017). APIs, and other boundary resources, are medium for transferring design capabilities between the platform and its users and for generating complementary assets and novel applications (Huhtamäki et al., 2017). Furthermore, APIs remove many technical limitations in service innovation and software development (Bonardi et al., 2016).

3.3.4 API strategies and management

API strategies are vital for the success and growth of digital platforms and companies relying on them. However, the API ecosystem is constantly evolving and changing as part of digital economy. Therefore, also API strategies need to be re-evaluated and adapted. (Basole, 2016). In addition, business models need to be designed based on the APIs rather than fitting APIs into legacy models. For example, partner and customer relationship management are much more important in the networked API economy. Developer orientation ensures external participation and platform evolution. This enables all parties to focus on their core competencies and business models and benefit from the complementary services in the ecosystem. (Vukovic et al., 2016). API strategies are still in early stage even if APIs are trending and the technology is already mature. However, the non-technical aspects are often ignored (Bonardi et al., 2016).

Governance is a critical part of API management and strategies. It should be analyzed through multiple lenses that consider innovation, partnerships, technology, and management aspects. (Huhtamäki et al., 2017). Bonardi et al. (2016) argue APIs are much more than technology. They suggest four perspectives that help to bridge the gap between business, technology, and innovation. The four perspectives in API initiatives are 1) organizational roles and processes, 2) reference architecture, standards, and guidelines, 3) onboarding initiatives, and 4) policies and business models. Each of the perspectives includes multiple more detailed considerations. The perspective of organizational roles and processes covers strategic and technical governance and partnerships. The strategic level focuses on the involvement and consensus of strategic partners, initiative promotion, and business KPIs. Technical level focuses on technical architecture, interoperability, compliance, and technical KPIs. Reference architecture and processes for interaction and collaboration need to be defined on both strategic and technical levels. The innovation approach must consider API and technology evolution, future trends, and innovation. In addition, technical architecture must be designed for digital assets, such as APIs. Open standards and guidelines are important for sharing, interaction, and interoperability, and should be based on best practices, research, and domain knowledge. API onboarding initiatives encourage participation and API adoption. Business should be primary driver of API initiatives and cultural change, not technology. Finally, business rules need to be defined to regulate and govern third-party participation and relationships. The dynamics of n-sided markets influence how value is co-created for all market sides. (Bonardi et al., 2016).

APIs can potentially create significant revenue streams and are identified as important business assets (Basole, 2016; Vukovic et al., 2016). They enable new business models, additional monetization opportunities, and distribution channels. However, APIs typically accelerate digital transformation that might be incompatible with legacy business environments. (Vukovic et al., 2016). Salesforce and eBay, for example, have successfully exploited APIs in their businesses. The operating and business models for APIs are dependent on the company and its strategy even within a business domain or an industry. For example, Amazon has built its business around APIs. On the other hand, Walmart has just few APIs to support their traditional core business. Thus, different API strategies are fit for different roles and positioning in the ecosystem. Digital leaders often benefit from inbound knowledge flows and network effects by exposing digital assets and capabilities for external use. (Basole, 2016). Huhtamäki et al. (2017) underline that selected business strategy drives the use of APIs, not technology; and selected API strategy influences the design and exploitation of APIs in business.

There are various API strategies for innovation and value creation. The alignment of the two aspects is important to foster the developer ecosystem and encourage innovation activities. (Wulf & Blohm, 2017). API strategy should cover boundary crossing collaboration and innovation activities that includes companies, public sector, and academia (Bonardi et al., 2016). However, APIs are also part of digital platforms and influenced by the platform strategy (Dal Bianco et al., 2014). Therefore, API strategy and design choices need to be aligned with the platform design choices, architectures, and governance model. APIs are important resources in platform innovation and can either hinder or support it. (Wulf & Blohm, 2017; Dal Bianco et al., 2014). API design should be based on business and use cases. Furthermore, the basic and advanced level of use should be considered different use cases. (Dal Bianco et al., 2014; Vukovic et al., 2016). Also, the level of abstraction should be balanced. Too much abstraction limits usefulness and too much details limits generativity. Finally, APIs should be consistent with the design of other boundary resources. (Dal Bianco et al., 2014).

Positioning in the ecosystem is part of the API strategy. Well-positioned APIs can benefit from other popular APIs through complementarity. However, a solid understanding of API ecosystem and its dynamics is required to identify niche players and opportunities. (Weiss and Gangadharan, 2010). API popularity influences its exposure. The API owner must consider the benefits and risks of exposing resources and how they are accessed and secured. The API provider needs means to measure the outcomes of API use. The API consumers constantly evaluate usefulness and terms of use to determine social and technical barriers to entry. (Vukovic et al., 2016).

Wulf and Blohm (2017) have identified three types API innovation archetypes with different purposes and strategies: 1) integrator, 2) free data provider, and 3) mediator. The integrator archetype utilizes existing APIs to integrate resources and functionalities with their information systems to generate service innovation. Most integrator type APIs are functional instead of only data sources. Typically, integrators enable their clients to integrate their offerings with consuming information systems. For example, Salesforce utilizes the integrator approach. Free data provider archetype provides data APIs without other functionality than data access. Typically, open APIs are provided as an alternative distribution channel for resources. The purpose of free data provider is to stimulate open innovation activities within large populations, such as the general public. For example, New York Times and Australian National Library have adopted free data provider approach as part of their strategies. The mediator archetype includes APIs which are used to build an ecosystem around an existing service or platform. Typical APIs in this archetype are functional and encourage external development and innovation of new service offerings. Mediators provide access to their customer base and use APIs to attract external developers who in turn create complimentary offerings for their customers. Facebook, Amazon, and LinkedIn are examples of the mediator archetype. (Wulf & Blohm, 2017).

Another approach to API design is through service innovation and its underlying dimensions of service concept, client interface, service delivery, and technologies. Service concept is the description of a problem-solution pair and its pricing model. The concept includes how APIs extend the software product to support its purpose, core business, and archetype. Client interface considers APIs as client interaction and distribution channels for an external user base. Software developers can access and exploit the platform's marketing resources and directly provide value-added services to its end-customers. (Wulf & Blohm, 2017). Furthermore, client interfaces operate as control points for accessing the platform's internal resources and capabilities. There must be a balance between access and control so that it encourages innovation but retains the control of strategic assets. (Wulf & Blohm, 2017; Tilson et al., 2010). However, the free data provider archetype demonstrates a strategy where control has been relinquished for other benefits. Service delivery, i.e. product complementarity, is about using APIs as development resources for complementary products, such as third-party software modules, which supplement the platform and provide value adding innovations to the platform. In addition, revenue sharing models are related to the service delivery and are critical success factors for APIs in the service ecosystems. Technology influences the available API design choices, such as communication and security, and has a relation to barriers to entry and all the above-mentioned dimension of service innovation. (Wulf & Blohm, 2017).

Typically, the born-online and incumbent firms benefit from different kinds of API strategies. The born-online companies typically enjoy a so-called first-mover benefits and are likely to discover a demand for their APIs. The incumbent firms, on the other hand, must explore the market and adapt their strategy to it. Moreover, they likely need to re-engineer their business models to respond to rapidly changing market and API ecosystems. Entering an API market can be a challenge for any company. There are already available APIs in most domains. However, a successful API strategy can provide the required edge to compete through user experience, differentiation, and positioning. (Vukovic et al, 2016).

In addition, successful APIs share a set of common features, i.e. success factors. Successful APIs are reusable and easy to consume. They are based on solid business case that drives forward API adoption and ensures a market fit and remain malleable for unanticipated and even accidental reuse. However, the initial API strategy must be a business case based. Long-lasting APIs with a loyal customer base are reliable and well supported and the API provider is trustworthy. It should be noted that many of the success factors are not only technical matters. (Vukovic et al, 2016).

Aitamurto and Lewis (2012) conducted a multiple case study to explore the impact of open APIs in open innovation. Their research focused on digital journalism and big news organizations such as New York Times, The Guardian, USA Today, and NPR. The industry going through digital transformation as the traditional revenue streams are declining. The organizations embraced open innovation to solve the crisis. Open APIs are a manifestation of open innovation. They are interfaces, structures, and rules that define how information is accessed across software systems. Open APIs enable content sharing between providers and third parties, such as developers. The same transformation has happened in the past in different industries. For example, already in 2012 digital technology giants, such as Google and Facebook, were utilizing open APIs to attract external developers and enable value co-creation in their platforms. (Aitamurto & Lewis, 2012).

The researchers found that open API initiatives enabled three kinds of benefits for the case organizations: 1) accelerated research and development, 2) new commercialization paths, and 3) innovation networks. The findings confirmed there is a tension between the open and closed modes of innovation. The studied open API initiatives provided internal research and development benefits even when the innovation objectives targeted an external audience. Furthermore, the internal use of the same APIs led to increased pace of development and innovation and increased modularity and collaboration. External innovation efforts and application development provided important inbound knowledge flow that also stimulated internal innovation and provided market knowledge. The need for expensive and resource demanding internal research, development, and experimentation was decreased. The researchers found open APIs and the API ecosystem operated as an external and organic innovation lab. Inbound knowledge flows introduced new paths to market and other important commercial opportunities. External actors could develop and commercialize offerings to niche audiences thus reducing commercial risks and the case organizations could leave future opportunities open. Even if the case organizations did not develop applications themselves, they controlled the core product, i.e. news content. The APIs provided additional distribution channels and enabled service innovation which resulted in new revenues streams through advertising and license fees. In addition, the brand coverage and online presence of the case companies were both improved. (Aitamurto & Lewis, 2012).

The study by Aitamurto and Lewis (2012) confirms business strategy is often the driver for open innovation initiatives. In addition, it demonstrated the relevance of the paradox of control and generativity. External innovation was made possible by relinquishing control and exposing previously protected resources. The case organizations transformed from traditional news organizations into digital platforms. Open APIs provided control points and enabled measuring the use of content better than the traditional online distribution channels. Moreover, the case organization were able to establish new partnerships based in the emerging API ecosystem and benefitted from mutually reinforcing innovation loops and value co-creation. The boundary between the two modes of open innovation was blurred. Internally created content was mixed with externally developed applications, service delivery channels, and monetization methods. However, new challenges were also introduced. New business and innovation strategies and processes were needed to be designed. In addition, organizational culture turned out to be a barrier to adoption of open innovation. Both developers and management needed to be convinced. Finally, the monetary impact of open innovation was relatively small during the study. The researchers concluded that the benefits were long-term and yet to be realized. (Aitamurto & Lewis, 2012).

4 SUMMARY OF LITERATURE

This section summarizes the core concepts and definitions covered in the literature review. The backbone of this study is the concept of digital platform innovation. However, the research focus is on the roles and mechanisms of platform boundary resources, especially web-based APIs, in digital platform innovation.

Innovation is technologically and geographically novel idea that is realized and diffused into a new market (Bogers & West, 2012). Digital innovation is further defined as the use and the result of digital technology in innovation process (Nambisan et al., 2017). Digital innovation includes three core traits: 1) digital platforms, 2) distributed innovation, and 3) combinatorial innovation. Digital technology is by nature convergent and generative. Together, these characteristics enable vast and often unpredictable innovation potential and cycles of continuous innovation. (Yoo et al., 2012).

Open innovation is defined as the exploitation of inbound and outbound knowledge flows that accelerate and enable the utilization of external innovation processes. The boundaries of open innovation processes are permeable and flexible. Knowledge, resources, and innovation outputs can flow past the organizational boundaries through insourcing and outsourcing. (Chesbrough, 2012; West & Bogers, 2017). The two types of knowledge flows can coexist in the coupled mode of open innovation. However, it is rarer than the single direction knowledge flows. (West & Bogers, 2017).

Digital technology has transformed the logic of innovation and its environment. Innovation opportunities, capabilities, and processes are distributed across the environment and actors with diverse objectives, resources, knowledge, and capabilities. Collaboration and coordination are required to manage distributed innovation and benefit from it. (West & Bogers, 2017; Nambisan et al., 2017; Lakhani & Panetta, 2007; Sawhney & Prandelli, 2000; Howells, James & Malik, 2003). Distributed innovation includes the concept of open innovation as its firm-centric view of the phenomenon. (West & Bogers, 2017).

Digital platform is defined as a software artifact that operates as a technological and social foundation for processes and applications and its surrounding ecosystem (Anttiroiko & Valkama, 2013; De Reuver et al., 2017). Platforms can be open or closed. Open platforms permit the integration of external product and service offerings into the platform. (Smedlund & Faghankhani, 2015).

Digital platforms and service systems are paradoxical by nature and include an inherent conflict between control and generativity. (Tilson et al., 2010; de Reuver et al., 2017; Eaton et al., 2015). Control is required to secure, govern, and stabilize the platform. However, control decreases flexibility and openness. Both are required to enable and foster generativity. Yet, generativity and creativity require adequate stability. At the same time, generativity leads to divergence and blurs the platform boundaries. The increased divergence calls for control to cope with the decreasing stability. (Tilson et al., 2010; De Reuver et al., 2017; Nylén & Holmström, 2015).

Standardization and customization in service platforms introduce another issue to be balanced. Standardization increases the efficiency and reproduction of services. However, it decreases customization potential. Customization increases value creation potential and customer satisfaction. The downside is decreased efficiency and increased costs. The balance can be achieved by opening the platform for external innovation and seeking external customizations based on standard platform resources. (Chesbrough, 2012). Utilizing open innovation in digital platforms calls for design and development of supporting governance and business models and platform strategies (Chesbrough, 2012; Parker & Alstyne, 2016).

Ecosystems are critical for digital platform innovation and value co-creation (De Reuver et al., 2017). Innovation is also a success factor for digital platforms (Smedlund & Faghankhani, 2015). Ecosystem players can utilize different innovation strategies depending on the objectives, position, and environment. Platform owners often look for niche players to join the platform ecosystem and co-create value. However, it requires orchestration and coordination and a suitable ecosystem structure. (Han et al., 2015; Smedlund & Faghankhani, 2015).

The boundary crossing mechanisms of digital platform innovation can be studied with boundary resources (de Reuver et al., 2017; Ghazawneh & Henfridsson, 2013; Eaton et al., 2015). Boundary resource is defined as software and regulations used to facilitate the relationships between a platform and its external developers. Boundary resources can be non-exclusively classified into social and technical resources. (Ghazawneh & Henfridsson, 2013; Dal Bianco et al., 2014). They can be designed and used to resource and secure the platform and the related innovation processes. They expose internal resources and capabilities but also provide control points to secure the access. (Ghazawneh & Henfridsson, 2013). Moreover, they can be used to balance and tune the paradox of generativity and control (Eaton et al., 2015; Huhtamäki et al., 2017). However, boundary resource design choices, governance models, and strategies need to be aligned with platform strategies (Dal Bianco et al., 2014; Ghazawneh & Henfridsson, 2013).

APIs are a relevant topic in digital platform and innovation research and have had a transformational impact on digital economy (Basole, 2016; Evans & Basole, 2016; Tilson et al., 2010; Huhtamäki et al., 2017; Bonardi et al., 2016; Wulf & Bohm, 2017; Yoo et al., 2010; Aitamurto & Lewis, 2012; Weiss & Gangadharan, 2010). API is defined as a machine-readable piece of software that provides abstraction, interoperability, connectivity, and means for interaction and value creation between two or more software. API can be conceptualized as a sociotechnical boundary resource. (Wulf & Blohm, 2017; Huhtamäki et al., 2017; Aitamurto & Leweis, 2012). APIs enable access to and integration of platform resources and capabilities for third party developers (Bonardi et al., 2016).

Albeit APIs and digital platforms are related concepts, they require different research lenses. The strategies and models for innovation, governance, and business have similarities but also differences. API-based innovation is typically highly distributed and combinatorial. Moreover, APIs provide a fresh angle to study digital platform innovation. (Huhtamäki et al., 2017; Weiss & Gangadharan, 2010; Basole, 2016). API is a boundary resource that is used to moderate the platform ecosystem and enable and govern external innovation, value co-creation, and partnerships. (Dal Bianco et al, 2014; Huhtamäki et al., 2017). APIs influence and are influenced by service and platform innovation and business models (Aitamurto & Lewis, 2012). Therefore, API strategies overlap and are included in business and platform strategies. Organizations are increasingly dependent on external innovation and ecosystems (Weiss and Gangadharan, 2010). A few API strategies are available for platform innovation, growth, and success. However, they need to be well-aligned with the platform ecosystem and the respective higher-level business and innovation strategies. (Basole, 2016; Wulf & Blohm, 2017). APIs can be classified based on their archetype. Wulf & Blohm (2017) have identified three core archetypes: 1) integrator, 2) free data provider, and 3) mediator. Each archetype has a different kind of focus and approach to digital innovation, business, and ecosystem. Furthermore, they call for different kinds of governance models and design choices. (Wulf & Blohm, 2017). The archetypes are summarized in the table 1.

TABLE 1 API archetypes.

Archetype	Description
Integrator	Integration of resources and capabilities for service innovation through functional APIs. Permit integration of platform offerings into third party systems.
Free data provider	Free and open access to data through non-functional APIs to establish alternative distribution channels and stimulate open innovation in large populations.
Mediator	Ecosystem building and shared customer base around an existing service or platform through functional APIs to attract external developers and foster service innovation.

5 RESEARCH FRAMEWORK

This section describes the research framework that provides the theoretical foundation for the empirical part of this study. A research framework is needed to set the research lens and scope for any research (Alasuutari, 2011). Furthermore, it enables to explore and describe the empirical findings in connection with the prior literature and to provide research contributions. The framework is based on a systematic literature review and a synthesis of the key concepts and mechanisms in digital platform innovation.

Digital platform innovation is a complex sociotechnical phenomenon and includes multiple dimensions through which it can be studied. The scope and primary focus of the framework is on the roles and mechanisms of platform boundary resources, especially web-based APIs. They are sociotechnical artefacts and constructs that enable open innovation knowledge flows, distributed and combinatorial innovation processes, and value co-creation and capture on the boundaries of the digital platforms.

Platform boundary resources operate in the boundaries of digital platforms. They enable resourcing the platform, i.e. exposing internal resources and capabilities, for external use to enable and stimulate innovation. In addition, APIs operate as control points and rules that help to secure the platform and moderate access to the platform core. This creates an inherent paradox between openness and control. However, platform boundary resources enable to tune resourcing and securing to manage the paradox. The innovation (and business) environments and ecosystems are distributed. The framework aims to make sense on how platform boundary resources are utilized in fostering and exploiting the distributed innovation opportunities through open innovation. The framework touches themes like platform strategy, business models, value creation and value capture but does not linger on those topics. However, innovation is related to and dependent on, perhaps even subordinate, to these topics. The figure 5 structures the core concepts into a coherent and literature-based framework.

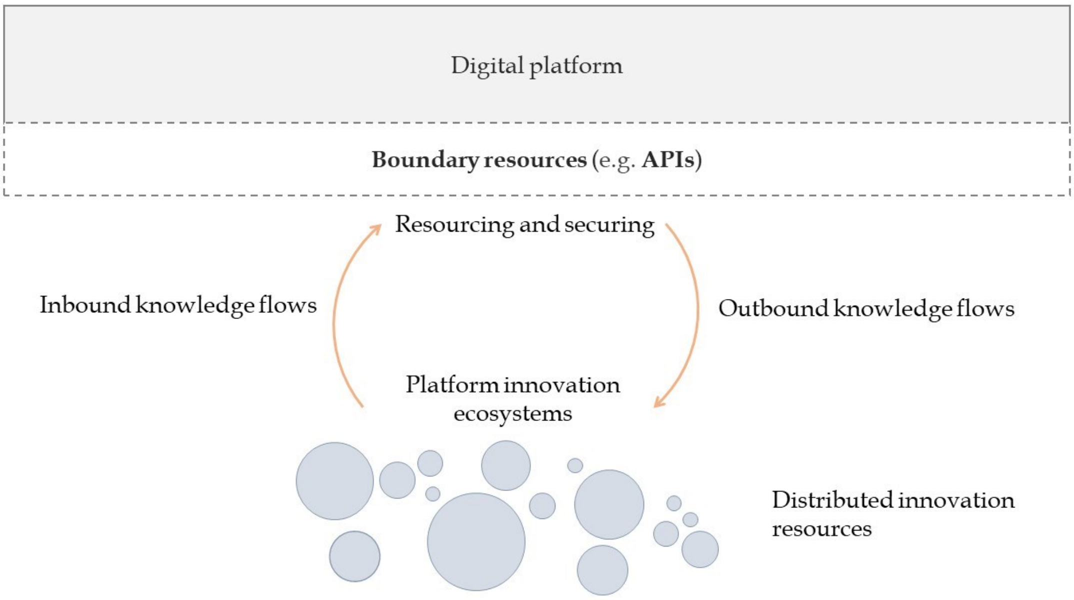

FIGURE 5 Research framework.

The research framework is a synthesis of IS literature on a few related models and concepts. It aims to define and describe a novel research lens into digital platform innovation and support the objective of making sense of and describing the phenomenon. However, many of the topics are huge research areas as such and together they form a sprawling and even fuzzy research area. Yet, the framework highlights the diversity of the research topic and multifaceted nature of APIs in IS domain. It is not possible to cover the whole topic in a master-level thesis. Therefore, the framework provides the starting point for the empirical part of the study and the feedback to the literature.

In addition, the framework helps in connecting the conclusions and contributing to the emerging API research in IS domain. The framework is aligned with the research question set in the introduction of this study. Furthermore, it is considered pragmatic enough to provide practical implications.

6 RESEARCH METHODS

This section describes the research design and methods in detail. It provides literature-based reasoning on what methods were selected and why, and describes how they were utilized. First, the research approach is provided as the starting point. Next, methodological choices are described for data collection and analysis. Selected research sites are described briefly in connection to data collection. The section concludes with a discussion on relevance, credibility, and rigor.

6.1 Research approach and methodology

Research design is the logic and the link that connects research problem with research processes and enables drawing of conclusions based on them (Ponelis, 2015). This research is a qualitative multiple-case study. Qualitative research is a good choice in IS research when the phenomenon of interest is complex and socio-technical by nature (Myers & Avison, 2002; Conboy et al., 2012; Sarker et al., 2013; Goldkuhl, 2012). Moreover, qualitative research can provide fresh and even creative ideas, that quantitative research might not (Sarker et al., 2013). During the past decades, the focus in IS research has shifted from technological issues to managerial and organizational topics and to the relationships of organizations, people, and technology (Myers & Avison, 2002). At the same time, the number of qualitative studies in top IS journals has steadily increased (Sarker et al., 2013).

In qualitative research, the interest lies in solving a puzzle, i.e. research problem, instead of experiment-based approach like in quantitative research. However, the qualitative and quantitative approaches are not mutually exclusive. In qualitative research, data is often rich, structured, or non-structured, and the analysis is based on interpretation and content analysis more than e.g. statistics. Qualitative research in often criticized for rich but unreliable results. (Alasuutari, 2011). The findings and acquired knowledge are good for exploring topics on the field and in detail. In addition, the findings provide basis for hypothesis and theory building and further quantitative research. (Ponelis, 2015; Alasuutari, 2011). Qualitative research is based on idiographic research strategies that focus on a single entity or a phenomenon in its context (Benbasat et al., 1987).

This study adopts a post-positivist approach to qualitative research. The approach mixes positivist and interpretive research approaches and the underlying philosophies (Ryan, 2006). The research objective of this study is to describe the phenomenon of interest. Descriptive objectives fit positivist approach. However, as the phenomenon of interest is a complex socio-technical concept developing its description would likely benefit from an interpretive approach as well. Moreover, interpretive approach is well suited for qualitative research. According to Ryan (2005) and Shanks (2002), post-positivism recognizes knowledge imperfect and socially constructed, not neutral, perfect, and existing by itself. The juxtaposition of subjective versus objective knowledge should be surmounted as the researcher influences the findings and conclusions through his or her knowledge, experiences, and values. However, some level of neutrality and objectivity is sought. The approach requires distancing to understand the big picture and context. The research design is about learning and co-learning and not that much about testing of hypotheses. Problem-setting is more common research objective than problem-solving. Post-positivist research can aim to increase awareness of the complexity of the phenomenon. Overall, the worldview is more alike to interpretivist than traditional positivist. Universal laws or overall truths are not pursued or even possible. Instead, knowledge is discovered and constructed through dialogue and interviews. (Ryan, 2006).

Shanks (2002) recommends positivist IS researchers to embrace post-positivism to overcome identified and agreed issues in traditional positivism. Only imperfect knowledge can be obtained regarding reality. The researcher draws subjective, fuzzy, or probably conclusions (Shanks, 2002). Also, Goldkuhl (2012) has found support for dualist approach to qualitative IS research. It should be noted it is not a unified voice of the IS research community (Goldkuhl, 2012). The mixed approach that post-positivism provides supports drawing influences from both interpretivist and positivist approaches and underlying philosophies. It is also more modern approach than traditional positivist. Next, both positivist and interpretivist approaches are briefly discussed and evaluated against the research approach and problem.

Positivist approach is the dominant perspective in IS research (Orlikowski & Baroudi, 2002) and usable in qualitative research (Sarker et al., 2013). However, it is not as popular approach as interpretive approach (Goldkuhl, 2012). Positivism focuses on a single, tangible, and fragmentable phenomenon that is possible to have a best-fitting description. The phenomenon and the researcher are independent of each other. Values have no influence on the inquiries and human actions are rational or boundedly rational and intentional. It is assumed the researcher is only a neutral observer and the context of the research is not relevant. (Orlikowski & Baroudi, 2002). Therefore, positivism assumes reality is objective and tries to study it through empirical investigations and theory and hypothesis testing (Myers, 1997; Shanks, 2002). The focus in positivist research is on the facts not interpretation. The research objective is often to formulate generalizable and universal laws where social and historical context are not relevant or have minimal weight. However, criticism has been expressed towards positivism. The design and use of information technology are influenced and connected with social context, time, and culture. Positivist approach pays little or no attention to these topics. (Orlikowski & Baroudi, 2002).

This study assumes a facts-based approach to data collection and analysis. According to Alasuutari (2011), the approach is not interested in the expressions and language. They are considered more like devices to transfer knowledge. The actual interest lies in the knowledge and facts in contains. Facts-based approach assumes knowledge is true, i.e. a fact. It means an assumption that the data sources are reliable and truthful. Yet, the approach requires source criticism and careful site selection. A claim about reality could be a fact but its contents not necessarily so. (Alasuutari, 2011).

Interpretive approach is by far less popular in IS research than positivist approach (Orlikowski & Baroudi, 2002) but dominant in qualitative research, even in IS domain (Goldkuhl, 2012). Moreover, its popularity in IS research is increasing (Walsham, 2006). Interpretive approach is mainly used in in-depth studies of social issues related to information systems and has a focus on human interpretation and meanings (Walsham, 2002). Also, it focuses on complex sense-making instead of predefined variables (Myers, 1997). Interpretive approach focuses on the subjective meanings, actions, and interactions through which humans construct and reconstruct their reality. Social structures and relations are not necessarily objectively known and unproblematic, as in positivism, and social systems, such as organizations, do not exist apart from humans. (Orlikowski & Baroudi, 2002). Knowledge is a social construction (Ponelis, 2015). Thus, interpretive research cannot be purely objective, and research has influence and requires some level of participation. Interpretive research is not value or context neutral, (Orlikowski & Baroudi, 2002), and the findings are influenced and constructed based on both theory and values (Ponelis, 2015).

Myers and Avison (2002) argue the distinction between different approaches and research philosophies are not definite and exclusive by default. There is no single valid configuration of principles and approaches in qualitative research (Sarker et al., 2013). Positivism and interpretivism are not simple opposites. There are a plenty of positivist qualitative case studies and interpretive case studies which do not include every feature of interpretivism. (Conboy et al., 2012). The research objective of this study is to describe the phenomenon of interest. This could be achieved through both interpretive and positivist approaches. Interpretivism does not exclude description even if fits positivism better (Galliers & Land, 2002). There are also issues in applying positivist approach to social phenomena (Orlikowski & Baroudi, 2002). The concepts of this study are socio-technical by nature. Therefore, both approaches can contribute towards the research design and approach. The objective is to develop as neutral as possible description that is interpreted through dialogue and subjective findings. Context has some importance, but the approach is more facts-based than interested in the expressions and language. The research problem is also about understanding the phenomenon of interest, which according to Goldkuhl (2012), aligns with the interpretivist approach. However, Walsham (2002) mention possible conflicts between the two approaches. There are differences in use of theory, stance on knowledge, and in the research processes. Post-positivism is utilized in hope for solving these conflicts and utilizing an established approach.

Case study is utilized as a research method in this study. Case study is a common method in qualitative research in IS domain (Sarker et al., 2013; Myers & Avison, 2002; Myers, 1997). It is an empirical research method suitable for research in real-life context where the boundaries between the phenomenon and the context are not definite. (Myers & Avison, 2002; Myers, 1997; Darke et al., 1998) and is a justifiable choice when studying organizational phenomena (Gordon et al., 2013; Ponelis, 2015). According to Benbasat et al. (2002), there is no standard definition for case study-based research. However, there are some shared characteristics that can be used to define it. The research is carried out in a natural setting and no experimental control or manipulation are involved. Data collection can happen by multiple means and there are only few or just one entity, e.g. person, group, or organization, to be studied. The complexity of the unit of analysis can be high. (Benbasat et al., 2002). Gordon et al. (2013) define case-based research by its small sample size that are studied individually and within an established context. Both positivist and interpretivist approach can be used with case study research (Shanks, 2002).

Case study and multiple-case study are suitable for descriptive and explorative research and development of hypotheses and theory in research of contemporary phenomena. In addition, it is useful when research and theory are only emerging or in early stage. (Benbasat et al., 2002; Gordon et al., 2013; Darke et al., 1998). According to Gordon et al. (2013), IT innovation is a fruitful topic for case-based research. Gordon (2008) claims business theory is in constant development and qualitative case research fits studying and developing it. In addition, case research enables the capture of practitioner knowledge (Benbasat et al., 1987). In emerging IS research topics, academia is often behind the practice due to fast pace of technological advancements, innovations, and their impacts. Case-based research enables deriving conclusions and findings from data instead for predefined and theory-locked variables. (Benbasat et al., 2002). Case-based studies also complement large-sample research and support theory development. Case research can follow a multitude of techniques and methodologies, such as positivist and interpretivist paradigms. However, positivist case studies are most common in IS research. (Gordon et al., 2013).

A multiple-case study enables cross-case analysis and provides more general results than a single-case study. Moreover, it enables exploring the relationship between information technology and strategy in an organizational context. Multiple-case study is better suited for theory building and testing than a single-case study. (Benbasat et al., 2002). Furthermore, multiple case-design is better for a descriptive research (Benbasat et al., 1987) and allows investigation of the phenomenon in more diverse settings (Darke et al., 1998). Thus, a multiple-case approach was chosen for this study and its research problem. Prior research (e.g. Aitamurto & Lewis, 2012) in APIs and innovation has utilized similar methods.

Criticism towards case research exists and is worth mentioning. According to Benbasat et al., 2002), case research is not a popular research method in IS domain. However, there are opposing arguments made by others (e.g. Myers & Avison, 2002; Gordon et al., 2013). Furthermore, case studies often fail to present and describe their research objectives, data collection methods and site selection rationale in an adequate detail. (Benbasat et al., 2002; Myers and Newman, 2006). Lack of generalizability is another common weakness (Benbasat et al., 2002; Gordon et al., 2013). The criticism has been acknowledged. This study aims to describe the research problem and methods and their rationale in an adequate detail. The selection of multiple-case study aims to provide better applicability for other settings than just a single case. However, the research objective is not to develop a universal description but to increase understanding of the phenomenon and provide a good-enough description of it. Based on Benbasat et al. (2002), the research problem is well aligned with case research.

This study aims to explore and describe the use and role of APIs by organizations in context of digital platform innovation. The access to this information is reached through the case organizations. Darke et al., (1998) instruct to choose the unit of analysis based on the research problem and how it can be answered. Therefore, the unit of analysis are the organizations. Typically, unit of analysis in case-based IS research is an organization or several organizations in multiple-case study (Gordon et al., 2013). It is worth noting social systems, such as organizations, are complex (Gordon, 2008).

6.2 Data collection

Case-based research can combine multiple data collection methods (Darke et al., 1998; Ponelis, 2015). During this study both primary and secondary data are collected. The primary data sources comprise of thematic semi-structured interviews and the secondary data source are websites and other digital materials that provide background information on the case organizations. The analysis is based on the primary data. The use of secondary sources is only to provide background information and elaborate selected case organizations as required. Walsham (2006) recommends using secondary data to complement interview data.

An interview is a traditional and widely used data source in qualitative research (Myers & Avison, 2002; Sarker et al., 2013; Myers & Newman, 2006) and in case research (Benbasat et al., 2002; Myers & Newman, 2006; Ponelis, 2015). The objective of an interview is to capture practitioner knowledge. The premise is that the locus of knowledge is the interviewee, not the interviewer (Ruusuvuori & Tiittula, 2017). Interviews are considered interaction. Interviewer directs the interview based on the preselected themes and questions and aims to co-create an event of knowledge creation with the interviewee. (Myers & Newman, 2006; Darke et al., 1998; Hyvärinen, 2017; Ruusuvuori & Tiittula, 2017). A qualitative interview can be described as drama where both the interviewer and the interviewee are actors and audience that follow and improvise based on a script prepared by the researcher (Myers & Newman, 2006). Interviews are especially useful data collection method when an interpretive approach is utilized (Darke et al., 1998). In a thematic interview the direction of further questions and answers can unravel themes naturally (Hyvärinen, 2017). Neutral and facts-based approach is important in a traditionally conducted interview (Ruusuvuori & Tiittula, 2017).

Interview is a justifiable data collection method in research that explores new topics that might lack established question patterns (Hirsjärvi & Hurme, 2015). Unstructured and semi-structured interviews are the most common types of qualitative interviews. The two types of interviews are relatively similar. The researcher has an incomplete script or some prepared themes and questions, but the interview requires improvisation. (Myers & Newman, 2006). A semi-structured interview allows the direction and scope of the interview to drift as needed to capture sprawling answers to the research questions. The order and scope of interview themes could vary from interview to interview. Some answers can require further questions to unravel interesting findings. Typically interviewing enables capture of rich and complex data. (Hirsjärvi & Hurme, 2015). Furthermore, a semi-structured interview enables exploration of topics where academic terminology could be perceived confusing or unfamiliar by the interviewees. The interviewer has a possibility to explain and elaborate concepts. Typically, the interviewees do not lack understanding and knowledge on the topic, but the academic language can cause confusion. (Ponelis, 2015).

The research objective influences the data collection methods (Alastalo et al., 2017). This study aims to explore and develop a description of the use of APIs in digital platform innovation. Therefore, the way in which the interview questions are answered is not relevant. The capture of nonverbal elements and context of the interview itself are considered out of scope for this study. Instead, the facts and views said by the interviewees are considered interesting. Following the post-positivist approach, the relationship between the interviewer and interviewee cannot be truly neutral and value-free. However, both roles are considered professionals of the similar trade. Therefore, trust is not required to be established for trustworthy and valid answers. It is also expected the interviewees participate willingly and are motivated to provide truthful answers. The style of data collection can be described as an outside researcher. Walsham (2006) refers to the outside researcher as a style of involvement that does not include action research or participation in the field. Outside researcher aims to be neutral but is nonetheless biased to some degree. Background, knowledge, and other factors influence the data collection. (Walsham, 2006). The interview situation could be influenced by the research. It is important to understand one's role in constructing the collected data. Professional relationship between the researcher and interviewees is equally important. In an expert interview the knowledge levels should match to maintain professionalism and establish a positive relationship. (Myers and Newman, 2006). The researcher in this study has more than a decade of professional working history in the field of IS and IT and profound practitioner knowledge. Thorough preparation for data collection compensates the lack of professional research experience.

Interviews are based on three tiers of questions. The first-tier questions are the research questions that guide and align the research. The second-tier questions are asked in the interviews to collect data. The third-tier questions are asked from the data. It is important to note the answers from interviewees are not answers to the research questions. Only questions from the data can be used to formulate these answers and is done as part of the data analysis. In a thematic interview, the exact questions are not chosen before the interviews. Instead, questions are based on themes which are in turn based on the literature. They are often based on high-level constructs, their subconstructs, and/or on a literature-based classification. Thematic interview is a more structured type of a semi-structured interview. (Hyvärinen, 2017). The exact wording is not important as the questions are often formulated during the interview and based on the interaction and previous answers (Ruusuvuori & Tiittula, 2017). Parts of the interview could be predefined and others more flexible. For instance, questions could be formulated but their order, scope, and wording could be improvised according to the interview situation. There is no universal definition for a thematic interview. Moreover, different data collection and analysis could be utilized. (Hirsjärvi & Hurme, 2015). Still, there are some guidelines. Hyvärinen (2017) recommends defining the themes and their relative importance in advance. In addition, it should be decided how much the interviewees can influence the importance and scope of the themes (Hyvärinen, 2017). As a data collection method, a thematic interview is oriented towards descriptive research objectives (Hirsjärvi & Hurme, 2015).

In an expert interview, the interviewees are considered experts in their profession and have practical knowledge of the researched domain. The interviewed professionals had different kinds of backgrounds, education, and expertise. Each was considered to have professional-level knowledge on digital platforms and related topics, such as APIs, digital innovation, and service innovation. A diversity of profiles was pursued in the interviewee selection to provide more general description and better applicability of the findings. According to Alastalo et al. (2017), expert interview is not a data collection method per se. Instead, it is a special kind of an interview and influences the interactions of the interview. To conduct an expert interview, it is important to identify and define the required expertise and the experts who possess it. Expertise can be based on work experience, education, background, and position. Expert interviews can be carried out as interpretive, semi-structured and thematic interviews. (Alastalo et al., 2017).

The interviews were primarily done in person. However, due to challenges in distance and resources, namely time and funding, some interviews were carried out via phone. According to Novick (2008), phone interview is used in qualitative data collection to overcome challenges related to geographical distances and the related costs. However, it has been considered problematic and less attractive option to in-person interview. A phone interview does not enable the capture and observation of rich context, such as body language and unsaid expressions, and does not include rich discussion clues. (Novick, 2008; Ikonen, 2017; Hirsjärvi & Hurme, 2015). It has been argued phone interviews need to be shorter than face to face interviews, they can increase social distance, and detecting influences in the responses is harder. Furthermore, the interviewees could be distracted by carrying out other tasks while being interviewed via phone. Even if those are possible there is little evidence that phone interview is inferior and likely to cause such issues. (Novick, 2008; Ikonen, 2017). On the other hand, verbal data collected via phone interview is likely high-quality and could be even richer than data collected via in-person interview due to lack of other means of communication (Novick, 2008; Ikonen, 2017). Moreover, phone interview could facilitate openness and decrease possible awkwardness of the interview situation (Novick, 2008). The research objective of this study does not require capture of rich context and thick data. The primary interest is in the facts and contents of the interview, not in the manner how they were expressed and communicated. Therefore, phone interview is possible and suitable data collection method even if not the gold standard in qualitative research.

The primary data source in this study are thematic semi-structured expert interviews. The interview themes are developed based on a literature review conducted before the empirical research and its design. A research framework was built based on the theoretical findings and utilized in the theme development. Each theme includes a set of subthemes and topics. The early version included sample questions but those were left out to provide better flexibility during the interviews. The defined themes are as follows: digital innovation, digital platforms and ecosystems, platform boundary resources, and APIs. The themes have thematic connections with each other. APIs and boundary resources were consolidated as a single theme based on the literature. Digital innovation, platforms, and ecosystems were used as more broad themes to open the discussion and provide context for the use of APIs in digital innovation. The themes and their translations are provided in the Appendixes 1 and 2. The interviews were carried out in Finnish and the recording or transcriptions are not available in English. The decision was made because all the interviews were done in Finnish organizations and all interviewees were native Finnish speakers. The interviews started with a warmup type of background questions and then proceeded into the broader themes to discover interesting topics and avenues to direct the interview towards the more specific core themes. The rationale for the selected order was to make the interviewees comfortable and enable them to focus their thoughts and views. More details were likely captured when the interviewees were gradually introduced to more detailed themes and their answers could be based on the preceding discussion. Each theme included a few discussion topics. However, not all were mandatory or discussed in the same order and depth. The provided answers, selected focus, and flow of the discussion influenced what topics were discussed in more detail. Sometimes answers could be asked deeper and sometimes a previous theme already explored a topic in an adequate detail already. The length of each interview was decided to be approximately one hour but was not fixed or limited. Interviews were between 52 minutes and 73 minutes in length. The secondary data included background information of the organization and other materials, such as websites, related to the topics of the interview. The purpose was to elaborate the organizational context of the research and the research sites.

According to Sarker et al. (2013), it is important for a qualitative researcher to justify and provide reasoning for site selection. Site selection was based on two factors: 1) findings in API economy literature (e.g. Basole, 2016; Evans & Basole, 2016), and 2) a combination of an interesting sites and access to them. In addition, the site selection was also based on recommendations by e.g. Sarker et al. (2013) and Benbasat et al. (1987). The objective was to have good representation of different kinds of organizations and innovation objectives. It was based on an aspiration for rich representation of the roles and functions of APIs in digital innovation and platforms. Darke et al. (1998) and (Ponelis, 2015) mention gaining access to research sites could be challenging. Some organizations refused participation in this research because of its timing (namely due to the ongoing COVID-19 pandemic), due to their lack of resources, or because they were in early stages of digital platform innovation. The selected sites represent private and public sectors and organization of different age, size, and profile. Furthermore, they had vastly different objectives and goals for innovation and digital platforms. All research sites were in Finland and many of them were in South Savo region. The reason for that is twofold. First, the researcher wanted to support the nascent digital innovation ecosystem in the region. Second, the researcher had best access to local businesses and organizations. It is noted that in future studies the site selection could be less pragmatic and more based on literature. However, the selected sites are aligned to the literature findings.

The interview data included seven organizations and a total of ten interviewees. The number of interviews was decided to be one or two people per organization depending on the need and availability of interviewees. It was anticipated no more than two people would be required per organization. The case organizations were small and medium-sized. The scope of their digital innovation activities was small enough to capture adequate data with small number of interviewees. For a high saturation, the total number of interviews could have been higher, but the scope of the study had to be kept in mind. Traditionally, grounded theory-based approach had required a high saturation and had been adopted as a general guide for other types of research interviews as well (Hyvärinen, 2017). Sarker et al. (2013) have studied case based IS research and concluded that between 4 and 10 cases is usually adequate for a qualitative study. Furthermore, Ponelis (2015) mentions the number of participants in case studies tend to be relatively small. However, multiple cases provide more robust outcomes. The choices in data collection were based on the research objective. Theory building, generalization, and cross-case comparison were not included in the research objectives and scope. Therefore, the number of cases was justified. Tuomi and Sarajärvi (2018) mention that often the number of interviewees is set by the available time and other resources. They continue that size of the research data is not a top criterion in a thesis and typically the size of the research data is relatively small (Tuomi & Sarajärvi, 2018). Also, according to Hirsjärvi and Hurme (2015), the amount of data is not a value per se in an interview study. A diversity of backgrounds and profiles was sought in site and interview selection. As suggested by Myers and Newman (2006) a variety of voices was pursued. Ponelis (2015) recommends selecting cases based on their relevance to the research problem and the ability to provide valuable and interesting information. Thus, people in different positions were interviewed. The positions included C-level executives, directors, middle management, and other specialists and roles connected with the research topic. All interviewees were involved in research and development activities and/or operations related to digital platforms and innovation activities. The roles they had in their organizations were diverse. The identity of the interviewees was collected during the data capture but not included in the report. Moreover, the findings are reported in such a manner that it would not purposely reveal their identities. However, the case organizations are mentioned by name to provide a context for the study and discuss the findings. No commercial secrets or other sensitive information was revealed, and it was pointed out in the interview not to discuss topics that would be secret or sensitive.

The interviews were recorded using a recording software on an Android phone. They were carried out either in person or via phone between 24.2.2020 and 26.3.2020. The recordings are digitally stored by the researcher in case they are needed later. A permission was acquired from each interviewee via email and confirmed before each interview. The email also described the purpose and objective of the study. The permissions included the use of the data for this study and possible dissertation by the same researcher. If requested, the data is not kept after this study has been completed and accepted by the university.

6.3 Case organizations

This section briefly describes the case organizations, i.e. data collection sites, to provide an organizational context for the research. The descriptions are based on the secondary data collected through websites and complemented with primary data collected in interviews.

6.3.1 Active Life Lab

Active Life Lab is a Mikkeli-based research and development unit operated by South-Eastern Finland University of Applied Sciences (Xamk). It was established in 2018. In addition to R&D project activities it provides wellbeing services, such as health measuring services. Active Life Lab's mission statement is to increase health through effective wellbeing services. In addition, it operates as a learning environment. The purpose of the activities is to create new knowledge, develop better services, and to co-create and accelerate innovations in the domain of health and wellbeing through partnerships. As a research and development unit it is primarily focused on applied research but collaborates with universities and companies alike. Active Life Lab has developed methods, tools, and protocols to enable and support its activities. The tools and methods combine software and other digital technologies, physical devices, and professional wellbeing services. For instance, a smart gym enables data capture and the measurement of wellbeing activities and their effectiveness. In addition, the data can be complemented by questionnaires and health tracking devices. The data is collected into a database and used in research and development activities. In future, the data is anticipated to enable new kinds of business models and research opportunities. APIs are used internally to catalyst innovations and with partners to co-create services and laboratory infrastructure.

6.3.2 Forum Virium Helsinki

Forum Virium Helsinki is a non-profit innovation company owned by the City of Helsinki. Its objective is to co-create and develop Helsinki into a more functional smart city and enable better and more sustainable urban life. It collaborates in local, national, and international scope with companies, universities, public sector, and the citizens of Helsinki. Forum Virium Helsinki engages in different activities ranging from fast experiments to long-term development programs in multiple domains such as smart city, digital and cyber-physical services, user innovation, smart mobility, and sustainability. Forum Virium Helsinki has carried out over 80 projects with numerous partners and employs over 40 people. Helsinki Region Infoshare is one of the most well-known initiatives. Due to this, it is also an independent data collection site in this study. Digital and data-driven themes are present in many of the development programs, initiatives, and projects. Open data and APIs are the cornerstones of interoperable service infrastructure and the city as a platform concept. APIs indirectly enable the development and piloting of new services and third-party applications and the utilization of the resources provided by the city.

6.3.3 Helsinki Region Infoshare

Helsinki Region Infoshare (HRI) is an open data service managed and funded by the cities of Espoo, Helsinki, Vantaa, and Kauniainen. Initially it was an open data initiative started by Forum Virium Helsinki. Currently, its activities are directed by a board consisting of funders and partners. The primary role of HRI is to publish and provide open data for the above-mentioned capital region cities. At the time being it covers over 600 open datasets and over 140 open APIs. In addition, it provides guidance and shares best practices and other knowledge on open data, e.g. how to produce, open, share, and utilize open data. The most visible part of HRI is its open data service that comprises of a web portal and data catalog. The service aims to ease the access to the data and catalyst the use of the open data for service innovation and development, business development, and research and development. The data catalog primarily consists of metadata and information on how to access the datasets. APIs and web-based user interface are provided as access methods and client interfaces. The data includes such as housing, local governance, maps, culture, traffic, education, constructed and natural environments, city economy, health and social services, population, and employment. Many of the data sets are GIS-based and/or statistics.

6.3.4 Metatavu

Metatavu is a Mikkeli-based software startup founded in 2016. It focuses on software development as a service and open source technologies. In addition, it has a small software product portfolio. From technological perspective the primary business is the development of tailored API-based web and mobile systems based on the customer needs. Often, it also requires service design, system integrations, and such. Metatavu does not have a dedicated technology stack like many software companies. Instead technologies are chosen based on an optimal problem-solution fit. The primary customer segments include manufacturing industry, agriculture, public sector, services, and SMEs. The scope and breadth of the business is likely to focus as the business scales and matures. Currently, Metatavu has 13 employees and enjoys from a rapid cash-flow financing-based growth. Metatavu is both an API consumer and a developer. Modern software development has emphasis on the use of APIs as construction blocks in digital products and services. Most software solutions and services developed and used by Metatavu are API-based. Its own products, such as KuntaAPI and an artificial intelligence-based chatbot Metamind are API services that can be attached to any user interface and integrated with other software. The rationale to use APIs is are related to software development and business model.

6.3.5 MPY Palvelut

MPY Palvelut is a business to business IT service company based in Mikkeli. It belongs to a group that emerged from a traditional telecommunications company which was originally founded in 1888. During its history MPY has carried out multiple transformations. Today, MPY Palvelut is a public company that provides modern IT and infrastructure services to organizations and businesses. Its service offering includes cloud services, business software, telecommunications services, data centers, and professional services. It has a research and development unit that develops digitalization and digital business capabilities. MPY Palvelut has developed its service offerings based on the technologies provided by its partners. It has combined different platforms and service modules to provide an all-around portfolio of business software and services. APIs are in a prominent position in enabling service development and the configuration of modular services.

6.3.6 Platform of Trust

Platform of Trust (PoT) is a software startup company founded in 2019. It employs approximately 15 people. PoT is a part of Vastuu Group, a well-established software and service company operating in constructed environment industry. The business model is based on the logics of platform economy and network effects. Therefore, the business model is dependent on platform growth and scale. It needs large volumes and a constant flow of data and a solid customer base. In addition, the name Platform of Trust refers to an API-based platform for data interoperability, harmonization, and trust. Organizations can have different data-related roles in PoT. Data producers make data available as data products for enrichers and consumers. Data can be consumed and utilized, and the platform ensures interoperability and trust between platform actors. The objective is to enable co-creation and catalyst business and service innovations. The company has emphasized developer experience in its platform as part of platform growth strategy.

6.3.7 Tapio

Tapio is a private professional services company operating in forestry and bio economy domain. It was originally founded in 1907 and has since undergone multiple transformations and name changes. Currently the group includes two companies, Tapio oy and Tapio Palvelut oy. Tapio group employs over 70 people. Unlike most private companies it has a public function. Tapio produces professional services, such as best practice guidelines for sustainable forest management, for the Ministry of Agriculture and Forestry. The company is also owned by the government. Tapio Palvelut is a subsidiary company that provides additional commercial services as a traditional private company. In the past, Tapio has provided the best practice guidelines as printed books and as downloadable PDF files. However, it has initiated an extensive digitalization project in 2019 to transform the analog best practices data into structured digital form and provide it through APIs by 2021. Moreover, the project includes the development of other tools and services related to the data, its management, and new business opportunities.

6.4 Data analysis

The primary data analysis method is qualitative content analysis. In addition, simple quantitative analysis is used to provide a complementary viewpoint. The analysis methods were chosen based on the research objective: to explore and describe the phenomenon of interest and its organizational context. The objective does not include theory building or hypothesis testing. The analysis methods are based on the post-positivist approach that combines interpretivist and positivist philosophies. Interpretation is done carefully and guided by theory. It is recognized that interpretation is always subjective and based on the views, knowledge, and experiences of the researcher albeit a neutral approach is pursued. Moreover, a detailed and in-depth interpretation is not the purpose of the study.

Content analysis is commonly used analysis method in qualitative research (Ponelis, 2015). It is a loose framework that can include various methods (Sarker et al., 2013; Tuomi & Sarajärvi, 2018; Garcia & Quek, 1997). Ponelis (2015) recommends a four-step analysis process: 1) transcription and capture of notes, 2) development of case narratives and within-case analysis, 3) determination of findings and cross-case analysis, and 4) interpretation and enfolding findings in literature. The approach is acknowledged and utilized as a starting point but scaled down to match the level and scope of a master's thesis. Descriptive case narratives and analysis were done but cross-case analysis was considered out of scope for this study and research strategy.

Tuomi and Sarajärvi (2018) describe another approach for content analysis. The steps are as follows: transcription, reduction, clustering and grouping, classification, and finally theming and typing. Interesting data from the interviews need be identified and reduced guided by the research questions and objective. Similar contents are grouped to create a classification. The classes are described and named. Next, classes are grouped together to create high-level classes which are again described. Finally, a top-level class is created. The tree of classes enables answering the research questions with help of the literature. During the analysis it is important to determine what is interesting in the data and continuously reduce it to narrow down and focus the analysis. Research problem and the related research questions act as a common thread for the analysis phase. (Tuomi & Sarajärvi, 2018). This approach provided a more detailed approach into content analysis and was utilized to define the analysis process in this study.

Sarker et al. (2013) describe qualitative data analysis as processing of collected data to make contribution claims. Similar definition is used by Garcia and Quek (1997). They write that claims based on the data and findings must be accompanied by a description of the logic for research and its thought processes (Garcia & Quek, 1997). Positivist approach can be also utilized in qualitative analysis of case studies. The approach includes discovery of patterns and regularities within the data. Coding and theming are based on selected units. Findings can be categorized and investigated through theory. (Darke et al., 1998). The approach to data analysis in this study is post-positivist. Thus, the positivist approach is used to provide guidance and additional viewpoints for exploring the data. The primary approach is interpretative.

According to Alhojailan (2012), qualitative data collection and analysis are tightly connected processes. Qualitative data processing is both analysis and synthesis. The analysis includes classifying, structuring, and theming. The purpose of synthesis is theoretical framing, sense-making, and building a credible understanding of the phenomena. Analysis is built around three core activities: 1) description, 2) classification, and 3) synthesis. Description is a crucial step in exploring and describing the phenomenon and its characteristics. However, as such it is not an adequate end-result for qualitative analysis. Moreover, the resulting descriptions are not the data speaking but the researcher. (Hirsjärvi & Hurme, 2015). Sense-making and interpretation in qualitative data analysis are emphasized also by Ponelis (2015). Qualitative data analysis does not require or impose a restrictive predefined framework or methodology. The focus is on idiographic description, exploration, and discussion instead of experiments or hypothesis testing. (Garcia & Quek, 1997).

The role of theory is to guide the analysis and drawing of conclusions. According to Tuomi and Sarajärvi (2018), theory-guided approach is a middle ground between data-based and theory-based approaches. Theory has a strong influence on analysis and findings are connected with literature. However, the analysis is not exclusively based only on theory and literature. The unit of analysis and research framework are based on literature but there is room for data-based findings, interpretations, and conclusions. The role of existing knowledge is to guide the research process and open new avenues for research instead of only analysis-based validation. Data analysis in theory-guided approach is a mix of data and theory-based interpretations and findings. Results of the analysis are often compared with and fitted to theory. (Tuomi & Sarajärvi, 2018).

Ponelis (2015) recommends utilizing literature according to the chosen research strategy. New researchers should base their research on prior literature. *A priori* coding can be used to base initial coding and themes in literature. The findings are based on data, but literature-based theming is applied to it. For exploratory case studies, a literature-based research framework should be built and utilized throughout the study. (Ponelis, 2015). Based on Sarker et al., (2013) and Walsham (2006), theory has distinct roles, such as guidance, lens, or scaffolding, in qualitative studies. Furthermore, theoretical engagement is important. Up-front theory should be integrated and utilized in the development of theoretical contributions. (Sarker et al., 2013). Directed content analysis is a type of qualitative analysis that starts with theory and literature. Coding is developed both before and during the data analysis and based on both theory and research findings. During analysis coding scheme is further developed and refined. The findings can provide support, extend, or oppose the existing theory. Also, theory and literature guide the discussion of findings. However, the data collection might influence the answers and it is more likely to discover supporting than opposing evidence. (Hsieh & Shannon, 2005).

Based on the above suggestions and guidelines, the analysis started with literature-based classification scheme and initial themes that were derived from interview themes which were in turn literature-based. Classification and themes were iteratively developed and modified based on the data and findings. Literature had a strong influence on the analysis but did not limit the interesting findings. Themes and typology were again connected and enfolded with literature in the interpretation and discussion of the findings and their implications.

The need for transcription is heavily influenced by the selected analysis methods. The selected research approach is focused on facts and not on the expression or context of the interview situation. Therefore, analysis was done based on direct observations from the recordings. Darke et al. (1998) call the approach as interpreting the interpretations of the interviewees. Walsham (2006) mentions transcription as a time-consuming process. The time spent on it could be better invested in developing themes and carrying out the actual analysis. (Walsham, 2006). Content analysis in this study was not based on text analysis. Therefore, a detailed transcription was not required. Non-factual data, such as filler words, interview feedback, and the actual language used by interviewees were not important in the selected approach and utilized methods. Qualitative analysis is possible with only partial or no transcription, but it should be a reasoned decision (Sarker et al., 2013; Ruusuvuori & Nikander, 2007; Hirsjärvi & Hurme, 2015). Depending on the needs, transcription can be done for the whole interview, interesting themes only, or the analysis can be based completely on the interview data. In the latter case, reduction and analysis are based directly on the recordings. This approach can be used for a small set of research data. In all cases, the level and detail of transcription should be based on the research approach and objective. (Hirsjärvi & Hurme, 2015). Based on the above reasoning, transcription was done only for the selected parts of recordings to provide evidence and examples of the data. Also, the chronological order of the interview was not considered important or to provide meaningful information.

The analysis was based directly on the ten interview recordings. The recordings were listened multiple times to familiarize the researcher with the data as suggested by Ponelis, (2015). Text and spreadsheet editors were used for making case notes and observations that were later processed for analysis. A total of 565 initial observations was made. Each observation included a key point and more detailed notes. Next, the observations were translated into English and reduced to reach a useable abstraction level for the next steps. Finally, each observation (that included a translated code, the original observation, and its description) were assigned a reference code to retain a trace throughout the analysis. According to Hirsjärvi and Hurme (2015), a text analysis software is not required for data analysis. The decision was also supported by the scope of the study and lack of available time and resources for a complete and detailed transcription.

The next step of the analysis were reduction, clustering, and classification. According to Alhojailan (2012), compacting extensive data is a key step in qualitative data analysis and will likely increase efficiency later in the analysis process. However, the richness of the data was also reduced as the result of reduction. Data reduction is about selecting, simplifying, and abstracting raw data to focus and analyze it for drawing conclusions (Darke et al., 1998; Alhojailan, 2012). Data display is used to organize, visually inspect, and make sense of the data and to present the findings in the different phases of analysis, and finally draw conclusions. Data can be displayed in multiple ways, such as tables and figures. (Alhojailan, 2012; Darke et al., 1998).

The observations were translated, coded, clustered, and classified. Each step was done in a tabular format in Microsoft Excel. Visual data displays helped in understanding the data as a whole and enabled the comparison of different classes and themes. Also, interesting findings were marked for potential use as evidence during reporting of the findings. The primary objective of reduction and clustering is to help in structuring of the data and preparing it for further analysis (Tuomi & Sarajärvi, 2018). Case data can be arranged and presented chronologically, thematically, or both (Ponelis, 2015). Thematic presentation was used to pre-process the data for further analysis. Chronological overview was based on re-listening the recordings as needed and by retaining chronological references to the data. Case narratives were loosely based on the chronological order of the interview, but their purpose was to provide a context for the data, analysis, and findings. Furthermore, interpretation and discussion greatly benefited from the case narratives.

Data clustering is based on similar features and characteristics and is utilized to develop themes and groups. Abstraction is needed to transform the interesting and meaningful parts of data into concepts and constructs based on theory and literature (Sarker et al., 2013; Ponelis, 2015; Tuomi & Sarajärvi, 2018). The first level of clustering should be done without the use of literature and then enfold it with literature in later stages (Ponelis, 2015). Abstraction can be done multiple times to reach higher level classes, themes, and concepts (Ponelis, 2015; Tuomi & Sarajärvi, 2018). However, a trace must be retained from the data to the derived concepts. The findings need to be discussed with the help of literature. (Darke et al., 1998; Sarker et al., 2013). Coding and classification systems are up to the researcher but should be described to increase transparency (Tuomi & Sarajärvi, 2018; Sarker et al., 2013; Ponelis, 2015). Interpretative case studies do not require an explicit coding system (Sarker et al., 2013). Classification is typical analysis method for thematic interview data (Hirsjärvi & Hurme, 2015).

In this phase of the analysis, the initial codes were inspected and clustered based on common topics, characteristics, and emerging themes. A theory-guided approach was utilized as described earlier in this section. Grouping and clustering the codes into classification did not reduce any details. However, some codes were included in multiple classes. As new topics and groups emerged, the classification was extended. A total of 593 codes were grouped in a total of 19 classes. The classification scheme is presented in the table 2. The references to the original interviews and observations were carried over throughout the analysis.

TABLE 2 Classification scheme

Class	Number of codes	Description
Interviewee	18	Observations describing the role, background, and work of the interviewee. Class was used to provide a context for the interview.
Organization	15	Observations describing the case organization and its activities in general. Class included observations that did not fit into other categories and was used to provide a context for the interview.
Innovation activities and management	48	Observations describing what kind of innovation activities the case organization does, what are the high-level objectives and processes, and realized and expected benefits.
Open innovation	19	Observations describing types of open innovation, knowledge flows, and related objectives and activities by the case organization.
Innovation and business ecosystems	20	Observations describing the overall business and innovation ecosystem. Initially, the two were separate classes but observations included both topics and were tightly connected. Thus, classes were grouped together.
Digital platform characteristics and use cases	93	Observations describing the platform in general, its use cases, features, and characteristics. Initially, use cases and characteristics were separate classes grouped together because of similarity in codes.
Digital platform ecosystem and users	73	Observations describing ecosystem focused on the platform and its target audiences, market, and user profiles.
Digital platform and service innovation and development	33	Observations describing service innovation and development activities related to the platform. The class also included observations related to the development of the platform itself.
Social boundary resources	21	Observations describing the different types and roles of social boundary resources included in the platform.
Technical boundary resources	12	Observations describing the different types and roles of technical boundary resources included in the platform.
Boundary resource targets and objectives	20	Observations describing target audiences and users of the boundary resources. The class also included objectives related to unspecified boundary resources. Initially, objectives and target audiences were distinct groups but remarkably similar in content.
Challenges and requirements in APIs and	24	Observations describing challenges in the use and/or development of boundary resources and their man-

boundary resources		agement. API-related observations were included due to them being technical boundary resources.
API characteristics	45	Observations describing the features and characteristics of APIs (in digital platforms).
API ecosystem and economy	22	Observations describing API economy and ecosystem. The distinction between platform and API ecosystems were at times ambiguous.
API roles and impacts	62	Observations describing the roles and use cases of APIs and impact of APIs. Initially, roles and impacts were separate classes, but the roles and impacts of APIs appeared to be connected in the observations.
API and boundary resource management and business models	32	Observations describing business models and management related to APIs and other boundary resources.
API and boundary resource design and development	27	Observations describing how and why APIs and other boundary resources are designed and developed.
API expectations and future	9	Observations describing expectations related to the use of APIs in near future and comments describing APIs in future.

Themes represent the high-level classes and concepts. They were developed based on the classification of codes. Walsham (2006) points out that developing themes is always subjective and interpretive. The themes were described in more detail than the low-level classes as suggested by Tuomi and Sarajärvi (2018). Themes represent important and coherent patterns in the data (Ponelis, 2015). In addition, theming can be used to further structure and classify the data as the analysis proceeds. The objective of theming is to further reduce the data but also to retain the facts and other key details. The higher-level themes are often more interesting than the initial low-level themes. Theming is typically based on inference, intuition, and theory. Thus, themes are interpretations of the researcher. There are no universal rules for generating themes, but the research problem and selected approach provide guidance for it. (Hirsjärvi & Hurme, 2015). The themes were built based on the findings from data and the literature. The approach has some similarities with grounded theory and thematic analysis but is not exclusively based on them. However, these methods could provide useful insights and viewpoints in future studies as suggested by Alhojailan (2012) and Walsham (2006).

Examples of the analysis process are provided in the table 3. Observations are translations of the original Finnish observations and notes. The interviews were carried out in Finnish but for the sake of understandability translations are used throughout this report. Next, the observations were abstracted and reduced into more generic codes. The codes included a lot of details during this phase. Coding also included anonymization and reduction of information that specifically identified the case organization. For internal research materials, a reference code enabled the tracing of the evidence and the development of case narratives. However, the published version of the data did not include this information. The case narratives and the findings can still be utilized to connect the data with the organizations. However, it was not considered problematic as no commercial secrets or sensitive information was included.

The codes were listed across all interviews and clustered to develop the initial classification. Each code was assigned to one or more class based on its related topic and characteristic. The decision was based on intuition, interpretation, and the context of observation in the flow of the interview. For instance, codes created from observations on discussion regarding the platform were more likely to be classified in platform-related classes. However, the discussion often included topics different from the current theme and the approach enabled more natural classification. The initial classification scheme was theory-based but evolved during the process based on the data and its interpretations.

The classification was used to develop themes and their subthemes. High-level themes were based on the interview themes, but their subthemes were deduced from the classified codes. Theme development further reduced the level of detail and created abstraction. Each code was assigned to a theme, guided by the classification. Additional clustering was done to develop common characteristics and reduce the amount of codes. The references were grouped with the codes to retain a trace from themes and subthemes to codes, observations, and interviews. Theme development was done in two iterative phases. The first round of theming did not provide satisfactory level of abstraction and the number of defining characteristics for each theme was relatively high. The first iteration of themes included six top-level themes and 17 subthemes. Each theme had from two to three subthemes. The themes had a total of 284 characteristics and features associated with them. For instance, a subtheme describing the target audiences and objectives of boundary resources only had seven defining features, while the subtheme of platform business and use cases included 33. The second round of theming further developed the themes. It resulted in five themes and 13 subthemes with a total of 172 defining features. The top-level theme *APIs* contained the most detailed description, including 55 features in three subthemes. This was a reasoned choice since the theme was further analyzed and processed into a typology for the roles of APIs in digital platform innovation. Other themes were not processed further. The description of themes is presented in the findings section. Themes are interpreted and discussed in the discussion section.

TABLE 3 Examples of theme development

Observation (translated)	Code (abstraction)	Class	Subtheme	Theme
Developer market is underutilized in Finland. Globally it is ongoing and exists. APIs are targeted as products for software developer.	APIs are products for developers in the developer market.	API ecosystem and economy	**Roles and use cases** **Description:** APIs attract and are targeted for external developers.	APIs

The company develops, publishes, and utilized many APIs which have critical roles in business cases, software development, and new service creation.	APIs are in a critical role in service development and innovation	APIs are in a critical role in service development and innovation	**Roles and use cases** **Description:** APIs enable and boost service innovation and development.	APIs
There is a website that introduces and describes APIs and how to use them. It includes API descriptions and enables test use. The website is bundled with the platform.	APIs are bundled with documentation and test environment through a website	Social boundary resources	**Technical resources** **Description:** APIs are bundled with social boundary resources.	Boundary resources
The platform's technical objectives are to enable creation of new services, content, and their combinations and to deliver them to market.	Platform objective is to enable new service development, content creation, and new market entries.	Platform characteristics and use cases	**Business and use cases** **Description:** Platform is utilized as a delivery channel.	Digital platform

A typology was developed based on the themes. Alasuutari (2011) defines building typologies as a common method for advanced data analysis in the facts-based approach. It is often used to analyze interview data, even if it decreases the richness of the data. (Alasuutari, 2011). Typology is a generalization and reduction method that can be used to build a system of common types from themes. A typology provides description of types and is built based on the underlying themes and classes. (Tuomi & Sarajärvi, 2018).

The phase of typology development continued to cluster and generalize the subtheme of *API roles and use cases*. Two very high-level types, resourcing and securing, were identified. However, they were considered non-informative as such. The 23 features of the selected subtheme were interpreted for their meanings and clustered into 12 types. In many cases, a feature was included in multiple types as the roles and use cases overlapped with each other. As the description of each type was developed some features were removed and relocated to better fitting types. Typology development produced three high-level types, or aggregations, each including three to five types. Each type included references to the underlying theme features which in turn included references to the codes. Thus, a trace from the typology was retained to individual observations and interviews. The typology is presented in the findings section.

In addition, some simple and precursory quantitative methods were used to supplement qualitative analysis and support the drawing of conclusions. The codes, classes and themes were counted to gain insights into the data. This was done based on the reduced data. Analysis of the interview transcriptions might have unfolded a more detailed analysis. However, the role of quantitative analysis was not enough to justify the transcription. The objective was simply to explore the data and findings without widening the scope of the study.

Conclusions can be drawn from the data displays that represent and provide structure to the developed themes and typology. The findings can include such as patterns and overarching themes and their connections with the literature, established categories, and the relationships between themes. Ultimately, they lead to the development of coherent answer to the research question and are aligned with the research framework. (Alhojailan, 2012). A typology was chosen as the final level of analysis. The decision was supported by literature and the fact it enables answering the research question. Furthermore, the mid-level results included themes and their descriptions that further elaborate the answer and provide it a context. As recommended by Sarker et al. (2013) and Ponelis (2015), the findings were enfolded and compared with literature in the discussion section. Abductive reasoning was used to interpret the findings and draw conclusions. As mentioned by Shanks (2002), a post-positivist researcher can draw only subjective, fuzzy, and probable conclusions. Sarker et al. (2013) mention abductive reasoning is used in qualitative IS research but is less frequent than inductive reasoning. The generalization of findings can be problematic in qualitative research (Sarker et al., 2013; Alasuutari, 2011). However, the basic assumption is that there is at least some level of generalization or applicability to other settings. There is no point in studying a single unique phenomenon. Furthermore, the research objective sets the required level of generalization. (Alasuutari, 2011; Sarker et al., 2013). However, Conboy et al. (2012) argue qualitative analysis is a form of generalization per se. Raw data is processed and generalized into descriptions, classes, types, concepts, and such. The findings can be used for theory building or to contribute to existing theories. (Conboy et al., 2012).

6.5 Relevance and credibility

Qualitative research and data cannot be evaluated for reliability and validity like quantitative research. Reliability and validity assume the researcher can gain access to objective reality and measures. The concepts are rooted in quantitative research and are problematic in qualitative studies. (Hirsjärvi & Hurme, 2015). Sarker et al. (2013) emphasize transparency and the description of research methods, data collection, and analysis in an adequate detail. Furthermore, accountability and auditability should be maintained throughout the study. (Sarker et al., 2013). The objective of this section is to establish trust and transparency in the methods and findings of this study. However, the scope of the study sets some limitations.

Rigor is often used in research to determine its quality. However, it is also problematic in qualitative research. Instead of rigor, interpretive approach is interested in relevance (Ponelis, 2015). An interesting approach to relevance is provided by Lee (2010). He argues relevance in IS research is how applicable research and its results are as theory-in-use, i.e. practice. However, it is not necessarily generally agreed or complete definition for relevance. The approach to relevance is like that of the nature of knowledge in professions, such as engineering and architecture. (Lee, 2010). Following the argumentation by Lee (1999) this definition and approach to relevance is suited for post-positivist approach. Moreover, Lee (1999) criticizes the traditional positivist approach to IS research and its definition of rigor and relevance.

Some papers (e.g. Gordon, 2008; Darke et al., 1998) on qualitative and case-based research discuss rigor. The definitions are often based on physical sciences. Rigorous research is about what is intends to be and is described in a detail that enables repeating it (Gordon, 2008). Case-based qualitative research can achieve rigor with clear and unambiguous description and research questions. Repeatability is achieved through systematic and detailed description of case selection, data collection and analysis methods and their justification, and the review of related and relevant literature. Evidence should be provided from data to conclusions. Relevance is still strongly connected with the context and setting. Findings and conclusions might not be applicable across different organizational structures, cultures, locations, and profiles. The selected stance and research approach also influence the concept of reality and therefore rigor. (Gordon, 2008).

Hirsjärvi and Hurme (2015) recommend focusing on the actions of the researcher not on the data itself. Triangulation could also be utilized to increase credibility but is unfortunately out of the scope of this study. Lack of time eliminates the possibility of utilizing the expert interviewees to review and validate the results. Tuomi and Sarajärvi (2018) suggest concepts of credibility, transferability, dependability, and confirmability as replacements for quantitative research-based concepts. Credibility is about the trustworthiness of the research and its results and the truthful description of data and methods. Transferability is close to generalizability. It asks if the results can be applied in a similar context and environment. Dependability is about how much of the research process is dependent on the researcher and the environment of the research and if the research is done according to the scientific principles. Confirmability requires an external researcher to be able to confirm the research findings and outcomes. (Tuomi & Sarajärvi, 2018).

A systematic literature review was conducted before the empirical research to establish a justifiable and theory-based research framework. The research problem and questions were based on the literature and relevant to the IS domain. Data collection and analysis methods were based on the suggestions and practices from IS and method literature. Data analysis was done during and immediately after data collection to minimize memory-based errors. The technical quality of the recordings was as high as possible with the tools available to avoid any technical errors. The research process was described in detail to increase transparency and traceability. In addition, the limitations of the research are discussed in more detail later sections.

7 FINDINGS

This section describes the findings of the data collection and analysis. The reporting follows advice by Reay et al. (2019), Ponelis (2015) and Hirsjärvi and Hurme (2015). The level of detail and the style of narrative and descriptions should match the type, strategy, and objectives of the research (Ponelis, 2015). Furthermore, the level of detail in reporting qualitative studies should not be too high. Each detail needs to be carefully evaluated for importance and report kept compact and readable (Hirsjärvi & Hurme, 2015). Reay et al. (2019) describe the style used in this report as the Gioia approach. It focuses on the descriptions of coding structure and data displays and snippets as evidence. The advantages of this style include analytical pathways that help in reading and evaluating the research, suitability for interview data analysis and display, and the level of rigor. However, the richness of the data is reduced, and the data structures tend to be linear. (Reay et al., 2019). The reporting focuses on describing the themes and typology based on the prior analysis. Simple quantitative analysis is provided to give an overview of the data. In addition, case descriptions are included to provide context for the findings and their discussion.

7.1 Case descriptions

7.1.1 Active Life Lab

Two cases from Active Life Lab were covered in this study: 1) a smart gym service platform, and 2) a research data collection platform. The cases and their use of APIs were different from each other. However, both cases were based on publicly funded research and development projects and were in a limited pilot readiness during the research. Furthermore, both cases utilized open innovation in form of inbound knowledge flows, e.g. knowledge absorption, technology insourcing, and ecosystem interaction.

The smart gym platform was focused on connecting smart gym device manufacturers with software and game developers. On a technological level, it was focused on integrations and interoperability. The long-term objective was to standardize and harmonize data transfer between gym devices and software platforms – i.e. to create an IoT platform for smart gyms. The idea was that gym devices could be used as game controllers and data input devices for gamified training and wellbeing exercises. The exercising experience would become interactive and the device could display different kinds of contents, such as games. The platform would aim to establish a three-sided IoT platform and market. Furthermore, the objective was to enable both internal and external service innovation and create a new kind of market for IoT-based games. Internal use cases were related to Active Life Lab' role as a platform provider and data mediator and fostering the ecosystem collaboration. The ecosystem was collaborative and open but in early stage and strongly connected with the ongoing R&D projects and their networks. The external use cases were related to the needs of device manufacturers and game developers. In future, it was planned to be expanded to include such as health and wellbeing companies, gyms, researchers etc. But for now, the focus was on the manufacturers and game developers to validate the operating model and develop the basic components.

The development was focused primarily on technical development of the platform. APIs were critical in the integration of devices and game development tools and enabling data access to external services and applications. Games were utilized in data collection and service innovation and configurations. The platform enabled data to be used for other purposes as well and exposed it via APIs. The platform included mostly technical boundary resources. The two most important were a REST API for platform data access and a software library to be embedded in games to enable connectivity with the gym devices. The platform strategy was focused on technical development and quality and establishing a developer ecosystem. The APIs and data were targeted for software developers who would use them to create applications and contents for the devices and utilize their data collection capabilities. However, software developers are a demanding target audience. The role of APIs was focused on integration and data transfer from the devices to the platform and from the platform to external use. In future, the platform could include capabilities, such as pre-processing and analytics, which could be exposed via APIs as well. Initially, APIs were open, but data was pseudonymized as a securing measure. In future, there is likely to be more need for platform securing through APIs.

The second case by Active Life Lab was related to a research data collection platform. The platform development was driven by internal and external research objectives and needs. The ecosystem was connected with national and international research networks that indirectly influence the platform development. In addition, the platform had a connection to the previously discussed smart gym platform. The objective was to collect data via different means, e.g. digital forms and mobile apps and transfer it to the platform via internal APIs. The research objective was to study and increase the efficacy of wellbeing services. Research publications and openly sharing the development outcomes were considered as a kind of outbound knowledge flow in relation to open innovation. It could enable knowledge spillover and attract partners to the innovation ecosystem. However, service innovation was not the primary objective and would require external innovation mechanisms. Thus, the platform provided only few boundary resources as the use cases for APIs were mostly internal.

The role of APIs was to integrate data collection tools with the database in the platform core. Internal use case for APIs was the primary driver for their development. APIs were considered important in future to increase the reach of the platform and enable new opportunities for service creation and research by providing alternative distribution channels and means to access the data. However, at the time of this research there were no use case that required external APIs. It was considered likely that future development of commercial services, e.g. analytics, data bundles, and interpretations of data, would require APIs as service delivery channels.

The role and influence of APIs in securing was two-fold. First, APIs were considered as service delivery and data distribution channels that would need to be secured. There were inadequate resources to do so which drove the decision not to implement external APIs at the stage of the development of that time.

However, the research data could be sensitive and, in any case, required a research permit. Thus, the second approach to APIs was that they could enforce securing and increase efficiency and the level of automation. The securing at the time of the research was trust-based, like contracts and permits commonly are. In future, should the ecosystem grow, and more data providers and consumers would join the platform, a new need for securing was anticipated to emerge. The manual securing processes would become too time consuming as would current distribution and delivery methods.

7.1.2 Forum Virium Helsinki

The Forum Virium Helsinki case was related to its Internet of Things and data thematic program and Urban Platform innovation platform. Forum Virium Helsinki operates on public funding and does a lot of research and development projects. Due to its nature and ownership, its innovation ecosystem includes the City of Helsinki and its citizens, companies, and public organizations. Forum Virium Helsinki aims to develop city as an open innovation platform and improve city processes and life of the citizens. Open innovation was utilized in a large scale and in the coupled mode of open innovation. The city of Helsinki has opened its resources, such as data and physical premises, through APIs for external use free of charge. The decision has generated a strong outbound knowledge flow that can be and has been be utilized for service innovations and service co-creation.

Urban Platform was defined as a socio-technical structure as a contrast to the technology-centric definition of a platform. Its ecosystem included both collaboration and competition. Platform actors can be competitors, but the platform strategy and governance model encourage collaboration. The use of platform resources is unrestricted and open by default which was a strategic and ideological decision. Urban Platform is based on the idea of interoperability and the flow of data. Those principles have proven its ability to enable and foster service innovation. In addition, the platform and its APIs were utilized to manage the complexity of different data formats and sources. Use cases of the platform included data harmonization and interoperability, fostering generativity and external innovation, supporting agile experiments and internal project activities, the transparency of public processes, and the management of complexity. Urban Platform has managed to attract software developers, companies, and research partners into its ecosystem. Furthermore, it has succeeded in encouraging cooperation between the different ecosystem actors. It has also influenced the development and operations of other regional platforms. Forum Virium Helsinki had developed and fostered models of co-creation and developer communities to carry out agile experiments and accelerate innovation outcomes.

Urban Platform provided multiple types of boundary resources that were often bundled with each other. Social boundary resources were considered more important than technical resources. Technology was seen more often as trivial to implement in comparison to knowledge sharing and contextual knowledge that social resources provide. Urban Platform used social boundary resources to decrease the barrier to use APIs and increase the pace and potential of innovation. Geographic information and metadata were often bundled with other resources exposed by the platform. The APIs were both functional and data APIs and had been designed for specific and defined purposes. The data formats were based on use cases and user needs while APIs were based on modern standards and technologies. In Urban Platform ecosystem APIs created and enabled larger multi-platform service systems and structures. They were also utilized in managing the complexity of the City of Helsinki's multiple information systems and to increase interoperability. Most of the APIs were open and used only for resourcing. However, some functional APIs did require securing for inputting data to the platform and carrying out internal operations.

7.1.3 Helsinki Region Infoshare

Helsinki Region Infoshare (HRI) is the name of both an open data platform and an open data agency operating it. The term HRI is used to refer to the agency, and the term platform is explicitly mentioned when referring to it. HRI maintains an open data catalogue, markets open data, and provides support for using open data. The data catalogue and website were considered boundary resources for other platforms of which resources they share. HRI platform does not host data. Instead it has a collection of metadata and other useful information on how to use and access open data. In many cases, an open API is utilized for data access. The HRI catalogue contains more than 140 open APIs.

HRI's mission is related to the maintenance of its platform and data catalogue. It does not carry out innovation activities of its own. Instead, its role is to support the use of open data for its owner cities but also for other external users. Combinatorial service innovation is a common use case for open data APIs and datasets. HRI pursues to lower the barrier to use open data and open data APIs. The use of APIs, and opening data in the first place, is based on the city of Helsinki's data strategy and the open-by-default principle of the owner cities. The objective of HRI includes to encourage and foster innovation potential and use of data for that purpose. However, available resources limit the ability and services it can provide. The platform ecosystem includes the capital region cities and organizations, software developers, open data activists, data hobbyists, and an open-ended user community operating within the region and Finland.

The HRI platform is based on open source CKAN software. It includes both inbound and outbound APIs. HRI had only one major use case related to the use of APIs. The outbound data API is used by opendata.fi platform to periodically harvest metadata. The inbound API was mainly used for mass updates and imports, but it was not in active use. However, in future APIs could have more use but it is not planned development at this point. Instead, the HRI platform includes a collection of social boundary resources regarding other platforms. For instance, the metadata and example applications share knowledge on how to use open data and what it can be used for. It was mentioned that open data is increasingly provided and accessed via open APIs. In addition, it was discovered that APIs attract developers and are the preferred access method by them. APIs help to automate data access, keep data up to date, and make the integrations and utilization of data easier. However, APIs also increase the barrier to use data for non-technical audiences. The importance of APIs was expected to increase as the city of Helsinki publishes its new data strategy in the late spring 2020.

7.1.4 Metatavu

This study covered two cases regarding Metatavu: 1) Open Trip Planner and 2) KuntaAPI. The cases were quite different from each other but related to the company's business model and strategic decision to utilize APIs and open source in software business. Company's innovation activities were closely related to software development processes, technologies, and business models. Innovation outcomes were realized as commercial benefits and customer value. Typical outcomes were new or improved processes and tools. Open innovation was utilized in the coupled mode of open innovation and related to open source development. Inbound knowledge flows were utilized in technology and knowledge insourcing. Open source enables the use of technology without developing it or paying for it in the traditional sense. In addition, it provided new software modules and capabilities for service development and innovation. Furthermore, Metatavu publishes its software as open source to enable outbound knowledge flows and novel business benefits. Its innovation ecosystems pertain to and are based on open source developer communities and technology partnerships. Joining existing ecosystems was found more beneficial and preferable than establishing own ecosystems around platforms and APIs.

Open Trip Planner (OTP) is an external open source-based platform utilized in complex route planning and navigation. It is developed by an international developer community and used by multiple cities and public sector actors worldwide. OTP was utilized as a module in service and information system development. It illustrated the use of inbound knowledge flows for technology insourcing. Additional benefits from the use of well-established external technology included brand and credibility benefits that would have been otherwise difficult to achieve for a startup company. Metatavu has planned to further develop and extend OTP and contribute back to the developer community. The objective was to enforce the coupled mode of innovation and increase the inbound innovation benefits.

The decision to use of OTP was based on the motivation to scale up the business and partially on identified customer needs. However, it also meant investments on service innovation and software development. The decision was also positively influenced by its open source licensing. As a boundary resource, terms of use and licensing were identified to influence technology and platform adoption and their use in service development. Other important social boundary resources were technical documentation and API descriptions. The mentioned resources were targeted to software developers and aimed to decrease the barrier to use and develop services based on it. Communication channels, e.g. discussion forums, were mentioned as relevant social resources in distributed and decentralized innovation environment. APIs were considered both technical and social boundary resources. In addition, APIs were typically bundled with descriptions and documentation. Ultimately, the usefulness of a platform was determined by the APIs it provides. Other types of boundary resources were significant but not critical and could tip the balance between otherwise equal technology options. Modern software and digital service development would not be possible without the integrative and combinatorial capabilities of APIs. The challenges with APIs were often focused on the social resources, e.g. licensing, terms of use, and not being configured to target a segment like Metatavu represents.

The second research case was KuntaAPI, a software as a service data integration platform for municipalities and cities. It is an open source-based product that Metatavu adopted and utilized in its business. Its original use case was based on public sector legislation and mandatory integration with the PTV, the Finnish service catalogue. KuntaAPI utilizes APIs as means to integrate a wide variety of data sources and information systems. It operated as a data harmonization and mediation layer and provided modern standard-based APIs for internal use and for external service integrators and developers. In addition, APIs were also used to secure PTV data management. However, there was no need to secure read-only data access. Resourcing was considered more than securing which was only included in for CRUD (create, update, and delete) operations in PTV. Additional objective included the creation of local ecosystems and multisided market around KuntaAPI implementations in different municipalities and cities. However, the objective was not successful due to its costs and the fact most customers were more interested in point-to-point integrations and their cost-saving benefits than service innovation and ecosystem benefits. At that time, there was no major competition by other platforms.

The design goals for KuntaAPI platform and its APIs were technical. Only few social boundary resources were developed, and they were very technical by nature and targeted to software developers. The decision was based on the business cases of the time and the lack of resources to develop additional resources based on speculative and future cases. The platform did not fail entirely. It is still in use and critical for its users. In addition, it provides a minor but steady cash flow. However, it did fail to generate the anticipated innovation outcomes and establish local platform and API ecosystems. The future of the platform is likely to include a complete redesign to fit the modern platform landscape and a new attempt to reach the original goals. Today, more services are based on APIs than several years back and modern software development and architectures depend on APIs. The role of APIs would remain as means for integrations and data harmonization. However, it was anticipated that more social boundary resources and resource bundles would be needed to be provided with APIs.

7.1.5 MPY Palvelut

The case of MPY Palvelut (MPY) is focused on the use of external Microsoft Azure platform and its influence on business ecosystems and service innovation. Azure was often used in tandem with Microsoft 365 services. MPY provides IT and infrastructure services that are based on external technologies and service platforms. Its innovation activities are based on developing service offerings and providing value for its customers with a B2B business model. The innovation outcomes were typically improved and more efficient processes that provided productivity and cost-savings through automation, integration, and new business management capabilities. The processes were often cross-cutting multiple information systems and Azure services.

MPY has an established market position and customer base. Its innovation ecosystems are based on partnerships and customer relations and are often specific to customers. The ecosystems were more closed than in many other cases in this study due to the nature of their business and the commercial platform. Moreover, the business data typically included business secrets and sensitive information that needed to be secured. However, MPY did carry out open innovation and utilized its knowledge flows. Inbound knowledge flows were most utilized through technology insourcing and partnerships. Microsoft's ecosystem provided added value through numerous partnerships and service co-creation opportunities based on commercial activities. MPY is both a platform user and a mediator for Microsoft's services. Other reasons to choose an external platform included its established position in the market, brand, conspicuousness, and readiness for service innovation. Platform's capabilities and resources were easy to combine and configure as customized service offerings. Its APIs provided competitive advantage in service innovation through the ability to integrate the platform with the customers' business systems and processes. However, technology per se was not considered valuable for business. A solid business case was a requirement for value creation. It was mentioned service innovation is strongly business driven.

The azure platform is used to both create new service configurations and resell its built-in features directly. Platform capabilities and services are important modules for service innovation and development. Azure services and their APIs were described as service skeletons that needs to be configured and integrated with each other and fitted to business processes to create value. APIs are important tools for service integration and data transfer. They connect both internal and external services and enable modular service creation. The roles of APIs were mostly mentioned in context of benefits such as cost-savings, automation, and profitability. In addition, it was mentioned APIs enable the combinatorial creation of specialized and interoperable services based on the existing standard modules. The services could easily be integrated with standard and widely used productivity tools provided by Microsoft. Azure platform provided a wide range of boundary resources for software developers and other technical audiences. APIs were included as part of the services and bundled with adequate social resources. They had both resourcing and securing roles. Resourcing was discussed and perceived through the customer needs and securing mostly from the perspective of the ecosystem roles and privileges. APIs increased the complexity of service systems but also provided means to manage the complexity by harmonizing technologies and information flows. However, the use of APIs required digital capabilities that combine business and technology knowledge which need to be aligned with each other.

7.1.6 Platform of Trust

Platform of Trust (PoT) is both the name of the company and its signature platform. It is a new company in platform business. However, it has invested in development of its own platform and a novel business model. The platform was described as a data mediator and integrator. Data from a variety of sources is pushed to the platform. It enables agile integration and development of new data inputs via its partner network. PoT harmonizes the data and provides a range of data products that include capabilities and an ontology for the data. PoT incudes several outbound APIs for data consumers. Typical use cases for PoT included combinatorial service development and automation. Furthermore, the data flows were used for other purposes, such as decision making. Platforms value proposition was said to be unique on the market and based on data trustworthiness and reliability and a novel production chain.

The innovation activities by PoT were often started as internal development of tools and processes that were later exposed, first to partners and then to the public, and commercialized. The lack of suitable tools and processes influenced the need for internal innovation. Adopted innovation and development strategy had enabled the coupled mode of open innovation that helped in market validation, creation of customer feedback loops, and incremental co-design of the platform. Most of the innovation activities were driven by need for scaling. Automation was used to decrease the amount of non-scalable manual work. In addition, self-service model and tools were developed and provided for the platform users. PoT utilized and combined market knowledge, stakeholder interaction, and academic knowledge in its innovation activities.

PoT had positioned itself as a platform provider and a mediator for data and services in a multisided market. Other external roles in the ecosystem included data producers and consumers. The roles were not exclusive, and an actor could be associated with one or more roles. Data producers were typically software developers and data integrators creating applications and services. Data producers were providers of information system and APIs. The PoT ecosystem was designed layered with different levels of partnerships. Each layer included increased commitment, interaction, and shared co-design opportunities. Ecosystem was at the same time competitive and collaborative. Collaboration was strengthened by increased data harmonization and interoperability, but also enabled competition. However, competition was perceived useful and innovation accelerating phenomenon. The platform had already started to enjoy positive network effects that in part explained increased competition and its influence on the ecosystem. Platform strategy was first to develop the platform and its ecosystem including onboarding and service co-design models with strategic partners before scaling the business.

Several platform boundary resources were developed to support the platform strategy and objectives. In addition, the purpose of boundary resources was to support customer self-service, provide good developer experience, and enable service co-design. Software developers were considered as gatekeepers in API adoption and platform onboarding. However, it was emphasized that developer market has not been fully utilized in Finland. In global scale the market was more mature. Boundary resources were bundled and structured in a developer portal that also included a sandbox environment to decrease the barrier to onboard. It was designed for two identified user groups within the developer audience. Moreover, APIs were designed for specific purposes and bundled with instructional documents, code examples etc. to speed up onboarding and development. The use of APIs was unrestricted to enable unexpected innovation outcomes and value creation. Moreover, APIs were considered core platform functionalities not a separate addon feature. Most read-only, i.e. data APIs, were open APIs but inbound functional APIs required securing. Data producers could define securing in a self-service manner. The overall design goal for APIs and bundled resources was to create and provide a one-stop-shop service model. The design was business case-driven but included iterative rounds of service design and technical design. The use of APIs was measured and monitored to collect feedback and market knowledge.

7.1.7 Tapio

Tapio case is about an in-development data platform that responds to internal and external use cases and needs. The development project was based on public funding and a mandate set by the Ministry of Agriculture and Forestry. Tapio has traditionally created and published best practices and guidelines for sustainable forest management. The guidelines were being provided free of charge. The platform in development had an objective of transforming the best practices and guidelines into digital, structured format and providing them via APIs and other digital user interfaces. The practices and guidelines have had a huge influence on the Finnish forest industry and forest management in general. They were used and embedded in a multitude of internal and external services, both digital and non-digital. The objective of platform development was to provide easier and more flexible data access and make its use easier. Furthermore, it pursued to catalyst digital transformation of the entire forest domain in Finland. The impact was compared to the opening of public geospatial information in the past. Forest data was anticipated to be used in service innovation and development of new software and tools. It was anticipated that platform and its APIs would increase the use of the data and thus increase harmonization and interoperability on the field. Moreover, alternative distribution channels and other services based on the data were expected to increase knowledge absorption.

The traditional ecosystems and innovation models in the forest domain have been closed. However, the development of Tapio platform was based on open source, open innovation, and such. The decision was both strategic and dictated by the public funding conditions. Inbound knowledge flows were utilized to increase ecosystem interaction and participation in co-design of the platform. Other benefits included market validation and feedback loops. Outbound knowledge flows were based on the exposed platform resources and open APIs. Openness acts also as a justification for the platform. It was developed with public funding and some of the data can be considered public as well. In addition, the development model was based on open source. Platform resourcing was carried out by open APIs. The platform ecosystem was both collaborative and competitive. There are well-established roles for forest companies. Competition might emerge between software companies in the sector. However, there are synergies and cooperation between the public sector organizations that provide data and services to forest domain. Tapio pursues a role where it would be a non-profit platform provider and data mediator, but it can also provide commercial services and do business with the help of the platform.

The platform includes a set of features to create, manage, and publish the forest management guidelines. Securing was an important aspect in these functionalities. The access to data was provided through the same APIs regardless of internal or external use or the interaction channel, such as web user interface. APIs ere designed to be used by information systems. A typical use case was anticipated to be a scenario where data from multiple sources was combined and enriched for third-party service offerings. Thus, APIs functioned primarily as data integration and distribution channels. Moreover, they were hoped to act as catalysts for internal and external digital transformation. For example, APIs provide an alternative distribution channel to the guidelines, in addition to the printed and PDF books. The API-based distribution could enable new kinds of business models and services in future. They enable a contextual use of the data through structured format and embedding it into services.

A set of social boundary resources were created to support the use and adoption of APIs. Resources were bundled and provided in a developer portal. Furthermore, APIs were provided in two alternative technologies to make their use easier for software developers. Early access to the platform and its boundary resources was provided to planning of IT budgets and investments. It was considered important to avoid challenges in onboarding and adoption due to incompatible and legacy information systems. Moreover, the use of APIs requires new kind of digital capabilities that might take time to acquire. The use of APIs was moderated by social boundary resources, such as content licenses. The data was provided with a Creative Commons (*CC-BY-ND*) license that would enable its use for service innovations. The data itself could not be modified to maintain its trustworthiness.

The design of APIs and other boundary resources were based on internal needs, defined use cases, and early stakeholder and ecosystem interaction and feedback. General and specific design were balanced and had an initial conflict that needed to be sorted out. The design was to enable answering the busines needs but enable both anticipated and unexpected innovation outcomes. It was important that the terms of use and licensing do not hinder external innovation potential but increase the trust and usefulness of the data. APIs (and the platform) are planned to be measured for their use and impact. The premise was that high resourcing with minimal securing would positively influence service innovation and the use of forest data for the benefit of the whole forest industry.

7.2 Themes

Five themes and 13 subthemes were developed during the data analysis. A total of 172 features were used to describe the themes. The five themes are 1) ecosystems, 2) digital innovation, 3) digital platform, 4) boundary resources, and 5) APIs. The table 4 provides a summary of the themes and their descriptions. The level of detail was purposely deeper in API theme and its subthemes. Those were further analyzed and developed into a typology that was used to answer the research question.

TABLE 4 Theme definitions.

Theme	Subtheme	Number of features	Description
Ecosystems	Characteristics	12	Characteristics of business and innovation ecosystems focused in and around digital platforms. Includes topics such as ecosystem dynamics, roles, and development.
	Objectives	10	Objectives and goals related to the use and development of ecosystems in digital platform innovation and economy.
Digital innovation	Activities and objectives	14	Innovation drivers, activities, objectives, and desired and realized outcomes.
	Open innovation	8	How case organizations utilize open innovation and what role it has in innovation.
Digital platform	Features and characteristics	13	Platform descriptions including the defining characteristics, features, and functionalities.
	Business and use cases	15	Business cases and use cases of platforms, i.e. how and for what platforms are used.
	Design and management issues	14	Platform design, development, and management related topics and issues, i.e. how platforms are designed and managed.
Boundary resources	Social resources	14	Descriptions of social boundary resources, their use cases, objectives, and roles in digital platforms.
	Technical resources	5	Descriptions of technical boundary resources, their use cases, objectives, and roles in digital platforms.
	Design and management issues	12	Design, development, and management related topics and issues, i.e. how boundary resources are designed and managed, and identified challenges.
APIs	Characteristics	12	Description of defining characteristics and features of APIs.
	Roles and use cases	23	API roles and use cases in digital platforms and the related outcomes and expectations.

	Design and management issues	20	Design, development, and management related topics and issues, i.e. how APIs are designed and managed, and the identified challenges.

The *Ecosystem* theme is divided into two subthemes: 1) *characteristics*, and 2) *objectives*. It includes codes covering platform, business, and innovation ecosystems. In many observations different ecosystem types were overlapping and interconnected and the boundaries of ecosystem types could not be defined unambiguously. Ecosystems were typically but not always distributed and decentralized. Commercial and proprietary ecosystems tended to be more centralized, closed, and structured than non-commercial and open ecosystems. Development projects and developer communities provided structure and influenced the ecosystem dynamics. However, the openness and decentralization introduced challenges in decision-making and governance. An ecosystem could include both competition and collaboration. Typically, the platform owner was not challenged but other actors and roles could face competition. However, competition was usually perceived to increase creativeness and innovation. Innovation-based ecosystems were typically lightly controlled to support innovation and co-creation. Innovation processes often utilized experimenting and market validation based on ecosystem interaction. Moreover, ecosystem had an enabling and strengthening influence on the innovation mechanisms.

Ecosystems were of different shapes and sizes and were based on different models. The most typical ecosystems were n-sided markets and included the roles of platform owner, service and data providers, and service and data consumers. Most of the ecosystems were business to business but some included business to consumers relationship as well. The roles of consumers and providers could sometimes overlap and were not mutually exclusive. In addition, the boundaries of ecosystems were fuzzy and often included internal and external users. Typically, the ecosystem roles were defined but some were open to undefined audiences. Joining existing ecosystems was in many cases perceived more attractive than founding and nurturing a new ecosystem. Already established ecosystems provided benefits, such as increased collaboration and access to developer communities, faster and cheaper. One interviewee especially emphasized the importance of developer communities in ecosystem growth and knowledge sharing.

Ecosystem objectives were dependent on the role of the case organization. Attracting external developers and onboarding activities were perceived important by many interviewees. They contributed towards ecosystem growth, positive competition, building dependencies between ecosystem actors, and provided positive network effects. In emerging platforms, the platform owners typically wanted to establish new business models and even markets while increasing their influence in the ecosystem. Partnerships, collaboration, and synergies were pursued within ecosystems and by connecting with other ecosystems and networks. Partnerships and collaboration were highlighted as the most important ecosystem objective in studied cases. Also, service innovation and development through combinatorial and distributed innovation were considered important objectives. Some organizations were more focused on supporting and enabling external innovation while others pursued innovation by themselves. However, none of the objectives excluded each other by default. Service innovation also included the co-design and evolution of the platform.

The theme of *Digital innovation* includes 1) *innovation objectives and activities*, and 2) *open innovation*. The objectives and activities were mostly related to technologies, tools, internal development processes, cooperation, and interoperability. Activities included new service and product innovation that was often mixed with other development activities. Experiments and problem-driven approaches were utilized to pursue innovations. Combinatorial innovation and modular service development were utilized for platform and service innovation. Most often innovation was business-driven and carried out to reach other business objectives. Cost-savings, productivity, and efficiency were economy-related objectives. However, some interviewees highlighted innovation as a primary objective. The type of funding had a major influence on how innovation was perceived and how it was driven forward.

Open innovation subtheme is focused on inbound and outbound knowledge flows. The most typical use of open innovation was ecosystem interaction in pursue of market validation, knowledge absorption, and increased stakeholder commitment. The coupled mode of open innovation was utilized by some case organizations. Often it was carried out iteratively in cycles of knowledge and technology insourcing, co-design of the platform resources, and exploiting shared resources. In a few cases, open innovation was related to the use of open source and open data. Technology insourcing and knowledge absorption were the most common inbound knowledge flows. Outbound knowledge flows were a less frequent but included e.g. the utilization of spinoffs, knowledge spillover and external innovation mechanisms. In three cases unbound and uncontrolled outbound knowledge flows were highlighted. Their objective was to enable and support the emergence of diverse and unexpected innovation outcomes. Moreover, corporate environments were more likely to combine closed and open innovation processes.

The *Digital platform* theme was interconnected to the themes of ecosystem and innovation. Some observations and codes were included in multiple themes as interviewees discussed the topics in the same context. The theme included three subthemes: 1) *features and characteristics*, 2) *business and use cases*, and 3) *design and management issues*. Only one of the case platforms was closed and primarily based on commercial partnerships. All the nine other platforms were considered open platforms or included many open elements, such as open APIs. Many platforms faced little or no competition due to their first-mover position or specialization. Some interviewees defined platforms as complex socio-technical structures that are a combination of technology, processes, and social structures. Others referred to platforms more as a technological concept. However, platforms were considered by many as strategic components in service innovation and creation of service offerings. Almost all interviewees mentioned platform as a data sharing and integration tool and a few also as a data collection and processing platform. Automation and self-service were mentioned by two interviewees as platform features. All platforms provided APIs, but some also included user interfaces and additional interaction channels.

Platform business and use cases were had similar codes and a relation to the subtheme of features and characteristics. Three use cases were prominent: 1) delivery and distribution channel for data and services, 2) integrations and complexity management, interoperability, and harmonization, and 3) service innovation. In most cases, the platform had a defined market and target audience. Furthermore, most platforms had both internal and external use cases as suggested by the findings based on the ecosystem theme. Internal use cases were more common than external. In addition, business cases had a strong customer and/or user-orientation and they focused on partnerships and value co-creation. New market entries and business innovation were pursued through service innovation and development and creation of new service offerings. Use cases focused equally on technical and non-technical target audiences. The less frequent use cases included brand and reputation building, increasing transparency and openness, and supporting business management and governance.

Design and management issues in platforms included both identified challenges and actions taken to mitigate them. Most platforms were strategically managed and had a long-term vision that guided its use and development. However, not all interviewees mentioned strategic management and platform leadership. In fact, few specifically mentioned a lack of strategic management and platform strategy. The lack of defined strategy was often related to new and emerging platforms that were still in development or linked to the nature of business case. Co-design and shared resources were mentioned as a platform development strategy by half of the interviewees. Platforms were both business-driven and based on public funding. However, the research site selection had a decisive role in the close to equal share between public and private platforms. Business case and technology were both equally popular drivers in platform development and design choices. However, in case of external platforms, the selection was primarily based on business case and needs rather than technology. Typically, the use of the platform was measured and monitored but not in all the cases. Less mentioned topics in the subtheme included open source-based development, developer orientation, and API-first platform design.

Boundary resources theme includes a division into social and technical boundary resources and their design and management issues. Social boundary resources were most often bundled together, structured, and exposed through a developer portal, website, or a resource catalogue. Their most important purpose was knowledge sharing. Furthermore, social resources were bundled with technical resources to decrease barrier to use and attract external developers. *Social boundary resources* were used for sharing knowledge and securing. However, one interviewee mentioned securing that was based only on social resources is trust-based and could require additional technical enforcing. Social boundary resources used for securing included contracts, licenses, and directives and standards that moderate the use of data and technology. Less common boundary resource types were communication channels and research and development publications, such as articles. However, they did carry out a similar function of knowledge sharing. Communication channels enable communication and knowledge sharing with developer communities and decrease the barrier to use. Publications share knowledge on the benefits and use cases of the platform and its resources. Some platforms did not include any or only very few social boundary resources. However, one interviewee argued social boundary resources are more important than technical resources, which are often trivial to use and just needs to be implemented with modern technology. Social boundary resources were primarily targeted to software and content developers and other technical audiences but also in a couple of cases to decision-makers, managers, and even to the public audience.

Technical boundary resources were primarily APIs, but one interviewee also mentioned software libraries, such as DLLs. The primary use for APIs was to expose and enable the use of bundled platform resources. Bundling included internal platform resources and related social boundary resources. One interviewee argued technical resources are prioritized in platform development. Another interviewee mentioned the platform did not at the time being provide any exposed technical boundary resources.

As with previous *design and management issues* subthemes, the subtheme includes identified challenges and design actions and considerations. Most platforms had a well-defined target audience for their boundary resources. The interviewees also recognized the use of technical resources, i.e. APIs, require knowledge and capabilities that the social resources provide. The use of APIs also requires IT investments because typical API users are information systems, not humans. The design of technical resources was based on technical quality, standards, and open technologies. Several interviewees mentioned that finding a balance between securing and resources was perceived a challenge. They recognized the importance of platform resourcing to be useful and that it created value. However, there were identified issues such as privacy, GDPR, and commercial secrets that required securing. Furthermore, openness included a risk of abuse of resources or economic losses due to unregulated API requests or heavy use. In few cases the definition of open resources in context of commercial services was perceived fuzzy. Another perceived challenge was to design and manage up-to-date boundary resources due to limitations in available time and resources. In case the platform boundary resources were related to an external platform there were perceived challenges their design and fit. In one case, the platform boundary resources were designed to a different target audience. Two interviewees mentioned software developers are a demanding audience but also act as gatekeepers for API adoption and use.

APIs is the most important theme and includes three subthemes: 1) *characteristics*, 2) *roles and use cases*, and 3) *design and management issues*. Nine out of ten platforms included open APIs. One did not provide any APIs at the time being and one provided both closed and open APIs. Platforms typically included both functional and data APIs. Data APIs were slightly more frequent than functional APIs in the studied platforms. APIs were typically used also internally. In some cases, an internal API was later published as an open API. Inbound APIs were functional and used for CRUD (i.e. create, update, delete) data functions or to perform other exposed functionalities. Outbound APIs were primarily data APIs that exposed platform resources and sometimes capabilities. Three platforms exposed experimental APIs or considered APIs as tools for conducting experiments. Those APIs were not designed for production use and were published in an early stage. They were used to validate business cases, use cases, and hypothesis. APIs were defined as technological artifacts that undergo fast development cycles. The usefulness of an API was not determined only by its technical qualities and such but also by its payload, i.e. what resources it exposes and how useful they were to the target audiences.

The roles and use cases are the most important (sub)theme in this study. Therefore, its abstraction level is not as high as with the other themes and subthemes. Instead, the typology is used to develop the subtheme further. The most common use case for APIs was service and content delivery and distribution channel. The role was highlighted in one way or another in all interviews and emerged in different parts of the interviews. The high-level role for APIs was primarily resourcing. The role of securing was dependent on resourcing and was utilized to moderate it. There were some cases where the use of APIs was not regulated, i.e. secured. However, it was emphasized it does not mean the APIs were insecure. The second most frequent role was to enable and boost service innovation and service development. The role of securing and cost-savings were close to each other as the third most discussed role. Cost savings included e.g. automation that increases efficiency and productivity. Interoperability and the harmonization of services and data were prominent in multiple cases as well. Moreover, the design and development of service offerings based on modular components and combinatorial innovation were mentioned in almost all cases. Other roles were API-based partnerships and service co-creation, the modularization and standardization of data and functionalities, enabling API-based business models, developer attraction, supporting digital transformation, and the abstraction of low-level technical implementations. However, not all platforms had a business or use case-driven APIs. Some platforms exposed data or functionalities because openness was a justification for the platform development and existence due to public funding requirements. In addition, some case organizations wanted to observe what kind of innovations would emerge by opening the platform resources. The clear consensus was that the supply and use of APIs provides competitive advantage to both the users and the API providers.

API design and management issues are a collection of topics related to identified challenges and design and management choices. API design and management were based on high-level business and ecosystem objectives and the platform strategy instead of dedicated API strategy. However, API strategy was in many cases deducted from these high-level objectives. Ecosystem interaction was a strategic choice adopted by many organizations. It enabled inbound knowledge flows that provided ideas, market validation, and feedback. The findings are strongly connected with the subtheme of open innovation. Most organizations measured the platform, but APIs were not measured and monitored by the majority. However, few organizations paid close attention to the use of APIs and their external use cases. Anonymous API use made detailed measuring difficult. In those cases, it was possible only to measure the amount of use, not use cases nor the impact of use.

Public funding and initiatives influenced the design and management in many cases. Funding conditions and policies had a major say in openness, use cases, and ecosystem interaction. The technical design of APIs was based on modern standards and developer preferences. The speed of development was commonly rapid and aimed to respond to the needs emerging from the developer market and communities. The design of data formats was based on established standards and use cases. In one case it was mentioned that data formats would need to support legacy systems and use but API design was modern. The design and development of APIs was business or customer-driven in a few cases but not in the majority. In three cases the development of APIs was purely technology driven. Two interviewees claimed the use and design of APIs was based primarily on internal needs. The role of social boundary resources was also small in the above-mentioned cases. API governance was influenced by strategic leadership, such as boards and steering groups but in some cases, API governance was limited or almost non-existent. API design and development were strongly influenced by platform and ecosystem strategies. It was identified that the design should balance between specific and generic API design. Two interviewees mentioned the use of APIs increased complexity. Only one or two interviewees highlighted the importance to secure even open APIs. Other design and management issues were how to mitigate the barrier to use APIs by non-technical audiences, how to keep API design malleable and adopt an API-first approach in platform development and strategy.

7.3 Typology of API roles in digital platform innovation

A typology of API roles in digital platform innovation was developed based on the previously described *APIs* theme and its subtheme of *roles and use cases*. The purpose of the typology is to provide a data-based and theory-bounded answer to the research question. The typology contains three high-level aggregations: 1) service and business innovation, 2) development and operations, and 3) ecosystem and collaboration. Furthermore, it should be noted that there are many connections and dependencies between the roles. The typology is presented in the table 5. Its connection with literature is discussed in detail in the next section.

TABLE 5 The typology of API roles in digital platform innovation

High-level role	Role	Description
Service and business innovation	Enable and support innovation	Resourcing is done to enable open and distributed digital innovation and foster generativity. Includes decreasing barriers to use APIs in service innovation.
	Exploit combinatorial innovation and generativity	APIs enable exploiting the potential of combinatorial innovation, enable wakes of innovation, and the creation of new service configurations and systems through generativity.
	Creation of new service offerings, business models, and markets	APIs enable the creation of new service offerings and business models. They enable and create new markets (i.e. API economy) and enable the productization of new kinds of services and products and disseminating them to market.
	Service delivery and distribution channel	APIs are used to deliver services and operate as data distribution channels. They enable machine-to-machine services and use cases. APIs influence innovation potential by operating as additional and alternative channels.
	Service specialization	APIs enable the creation of specialized services based on standard modules. Specialization enables niche players to differentiate and position themselves in API and platform economy and ecosystems.
Development and operations	Integration and interoperability	APIs are used to integrate systems, processes, services, and data. They are used for interoperability, harmonization, and standardization. APIs are used to remove silos and manage complexity.
	Automation and cost-savings	APIs enable automation and scalability that provide cost-savings, decrease the need for manual work, and increase cost-efficiency.
	Modular service development	APIs enable the creation of modular service configurations. Other systems and services use internal and external APIs for capabilities and resources they provide. Modern web-based applications are based on and built with APIs.
Ecosystem and collaboration	Ecosystem development	APIs are used to develop platform ecosystems and build it around themselves. They support ecosystem activities and growth and provide means for ecosystem interaction. APIs increase positive dependencies and commitment and attract external developers.
	Creation of new kinds of partnerships and service co-creation	APIs enable service co-creation based on new kinds of partnerships. Positive dependencies are created between API ecosystem actors.
	Brand building and marketing	APIs are used in platform brand building and marketing. They contribute towards ecosystem development and developer attraction.

Service and business innovation cover the roles related to the design and creation of new service concepts, business models, and markets. It is further divided into five types that provide more details on the findings. APIs are used to *enable and support innovation*. Platform resourcing is done to enable and foster internal and external innovation possibilities and mechanisms. The role is related to the mechanisms of open and distributed innovation. The scope of innovation varies a lot depending on its context. For example, it can be related to digital transformation of an industry or market disruptions. On the other hand, it can be about innovations related to specific digital resources and capabilities. The purpose of platform resourcing through APIs is to decrease the barrier to innovate. APIs operating in this role are often bundled with other APIs and knowledge sharing resources. For example, data exposed by APIs can be embedded in an external information system or used in the development of new kinds of services that would not be possible without the data APIs.

Exploit combinatorial innovation and generativity is interconnected with the above-mentioned role. However, instead of enabling and supporting innovation it is about first-hand innovation activities that seek to exploit the innovation potential and generativity. Modern web-based applications are based on APIs. Many platforms provide APIs as service skeletons that can be combined and configured to create complex and customized service systems that are based on standard technologies and modules. For instance, modern data APIs enable subscription type use and embedding real-time data with application business logic. Existing service modules, data sources, and other functionalities exposed via APIs enable continuous wakes of innovation and decrease the time to develop solutions. The impact is like how open source transformed software development and service innovation in the past. Modular service architectures are based on internal and external APIs, and the Internet-connected APIs have become de facto building block in development of hyperconnected services.

Creation of new service offerings is connected with the business aspects of service innovation. The combinatorial and modular nature of API-based service innovation enables agile creation of service offerings and service concepts. Cloud-based solutions enable new kinds of business models and the creation of completely new markets. For instance, data can be productized and published through bundles of APIs and supporting boundary resources. The business side of innovation includes utilizing APIs in monetization and business model innovation. For example, new kinds of cash flows can be created by subscription-based payment models for data. Furthermore, APIs can be used in market-fit and demand validation. They enable the creation of alternative services and offerings based on the existing resources and enable targeting new target audiences or markets. Inbound knowledge flows include feedback loops that provide valuable market information.

Service delivery and distribution channel is a very typical role for APIs. They are used as a primary or secondary distribution or service delivery channel for data or functionalities. Most modern user interfaces are based on APIs that provide access to data and capabilities. Moreover, APIs are primarily used for machine-to-machine communications, even if they can technically be accessed directly. However, the efficient and large-scale use of APIs requires software. APIs are used both as internal and external delivery and distribution channels. It is typical to use the same APIs internally that are exposed for external use for partners or the public. API design is malleable so that the decision can be made virtually any time. The role and position of platform owner influences the use of APIs in this role. Many platform owners implied the objective to operate as a mediator, data broker, and data provider in their respective platform ecosystem or n-sided market.

The *Service specialization* role enables the creation of specialized and customized digital services that are based on standard modules and components. API-based services can be a mix of multiple data sources, capabilities, and custom developed modules. They can be used to create boundary crossing services and processes that are specialized to a specific need. Moreover, the use of APIs decreases the need for custom software development. Instead services are configured and embedded into service-based architectures. Service specialization enables niche roles in platform ecosystems and specialized offerings that have a well-defined position and validated market-fit. It opens also new business and innovation avenues for API providers that can design their offerings for specific niches and use cases. There is a demand for both specialized and generic APIs.

Development and operations are the second high-level role aggregate. It is related to service engineering, software engineering, and the operational benefits of the use of APIs but also to service and platform innovation. It is more technically oriented category of roles than the first aggregation. The role of *Integration and interoperability* is thematically related to the use of APIs as service and distribution channels. However, from the technical point of view, it is about integrating data sources and capabilities not the ability to provide such capability per se. Integrations increase the interoperability and harmonization of resources and remove silos within organizations and information systems. APIs both increase complexity and help to mitigate it via interoperability and harmonization. Integrations can be internal and external. Most API-enabled benefits can be connected to the integration role and most use cases are about integrating resources and capabilities. APIs effectively create larger structures and service systems from the connected systems. For example, APIs enable the integration of subscription-based data APIs, the creation of service-spanning processes, and the creation of complementary integrations in the existing platform ecosystems.

Automation and cost-savings is a role related to the impact of many resourcing-based roles. However, it was prominent in the research data and was highlighted as both a benefit and a role that APIs operate in. APIs are often designed to automate routines and decrease the need for manual work. The role is associated with benefits like scalability, productivity, and cost-efficiency. Examples include the automation of data transfer and data collection for reporting and for use by other information systems. Automation is often a requirement for feasibility and scaling digital services. The benefits of the role are visible by comparing a process before and after automating it or its parts.

Modular service development role is connected with integrations and combinatorial innovation. It is a technical role and related to software engineering. Modern software development is based on modular architectures and software components that are connected through APIs. In addition, APIs provided the needed abstraction in complex software systems and hide the underlying technical details. APIs operating in this role both enable service development and help to manage the complexity of service systems. The role is also related to the development style of modern services and the feasibility to develop them in the first place. In a sense, the role is a technical counterpart to e*xploit combinatorial innovation and generativity* role mentioned in the service innovation aggregation.

The third high-level aggregation is *Ecosystem and collaboration*. It includes four types of roles. *Ecosystem development* role is related to how APIs are used to contribute towards platform ecosystem growth and development. In addition, APIs can have their own ecosystems. APIs enable ecosystem interaction and the development of positive dependencies within the ecosystem. They can also attract external developers and increase commitment to the API and platform provider through interaction and exposed resources. APIs contribute towards positive network effects the platform might enjoy. However, APIs operating in this role need to be supplemented by and bundled with social boundary resources that support their use and decrease the barriers to use.

Creation of new kinds of partnerships and service co-creation role is related to API and platform ecosystems and dependencies between their actors. New kinds of use-based partnerships can be founded around APIs. The partnerships might be informal and based on a publicly available API or it can be contract or subscription based commercial partnership. For example, a platform can exploit a data API to fetch external data as part of its value creation process. Another example could be that a cloud infrastructure provider has exposed capabilities through APIs to be embedded into other software. The value they provide is the basis for the partnership. API providers often provide a sandbox or evaluation version for service development purposes. The commercial version could be provided as self-service. These partnerships and service co-creation models enable new kinds of monetization and innovation opportunities based on moderating and mediating APIs and exposed resources. At the same time, they decrease the financial barrier to use external resources in service innovation.

Brand building and marketing role is related to ecosystem development but is focused on using APIs as marketing tools. APIs not only market the platform and its offerings but also the embedded knowledge and the providing organization. Therefore, APIs influence the reputation and attractiveness of the API provider. Software developers are common gatekeepers for API adoption. APIs and their bundled social boundary resources can be used to influence their decision making and increase the attractiveness of the platform. API-based marketing is important in increasing platform stickiness and loyalty even if the switching cost for APIs is relatively low. Furthermore, APIs can be utilized for market validation, scouting, and other marketing activities in the platform economy.

8 DISCUSSION

This section discusses and interprets the findings of the empirical research and the synthesis of the literature review. It is structured based on the primary research question and the two supporting secondary research questions. The primary research question for this study was *how web-based APIs are used in digital platform innovation?* The two secondary supporting questions are as follows:

1. What is a web-based API as an IS concept?
2. What is digital platform innovation?

First, each research question is reviewed, discussed, and answered starting with the two supporting questions and concluding with the primary research question. The answers are composed based on the findings and literature. The answers are discussed and interpreted to understand their meaning and implications. Finally, the contributions for research and practice are discussed and presented.

8.1 What is a web-based API as an IS concept?

The first of the supporting research questions explores the definition of web-based API as an IS concept and compares it with the empirical research findings. IS literature (e.g. Wulf & Blohm, 2017; Aitamurto & Lewis, 2012) defines API as a machine-readable software that enables interaction, interoperability, and abstraction between information systems. An API includes both technical and social aspects. They are used as technological artifacts that provide specific functionalities but also include a set of rules or a contract as the terms of use. (Huhtamäki et al., 2017; Aitamurto & Lewis, 2012). APIs are defined as building blocks of modern web-based service systems and control points (Basole, 2016; Evans & Basole, 2016; Tilson et al., 2010). APIs enable value creation in the Internet economy (Huhtamäki et al., 2017). Furthermore, APIs are conceptualized as platform boundary resources that facilitate the relationship between the platform and its users (dal Bianco et al., 2014; Ghazawneh & Henfridsson, 2013; Wulf & Blohm, 2017; Eaton et al., 2015).

As expected, the empirical findings were well aligned with the literature definition. The empirical findings were more practically oriented but matched the literature. Interestingly, APIs were considered by many of the interviewees more than just technical artifacts. It seems they are not perceived anymore only as a software engineering topic like they used to be in the past. However, the technical use cases and benefits of APIs were often mentioned first by the interviewees. Also, functions, benefits, and roles related to resourcing theme were the most highlighted. Typical functions and benefits included integration capabilities, distribution and service delivery, and connectivity. As the discussion proceeded, a wider scope of details, roles, and characteristics were unraveled. They included also the social and organizational aspects of APIs but also more detailed technical roles, such as harmonization and abstraction, and ecosystem related roles, such as interaction and feedback. The distinction between APIs and platform was at times fuzzy. APIs had a role in how the ecosystem interactions and access to platforms were controlled and moderated. Helsinki Region Infoshare mentioned that APIs introduce new kinds of technical challenges and that in fact APIs are used also by human users, not only information systems and software. The observation is likely to be marginal but noteworthy still. However, some technical details were argued to be trivial or self-evident which hinted that there are certain expectations in API design and implementations. A likely explanation is that the platforms were relatively modern or still in development at the time of the interviews. During the research design it was decided that the case selection would not include any legacy platforms but a current and even a future-oriented view into APIs and platform innovation.

Platform of Trust and MPY Palvelut considered APIs as integral part of their service platforms and service offerings. However, they did not highlight APIs as such. Instead it was emphasized that APIs generate benefits, enable operations, and make them viable. The findings imply APIs are strategic assets and have business and ecosystem importance in addition to their technical benefits. APIs were often bundled with other types of resources as described in the boundary resource literature (e.g. dal Bianco et al., 2014). These resource bundles were tuned for a product-market fit based on the needs, available resources, and ecosystem interaction. The findings confirm that there are dependencies and synergies between different kinds of platform boundary resources.

Case organizations had different approaches to API design, use, and governance. For instance, Metatavu, highlighted APIs as a development boundary resources that are used primarily to develop new services based on exposed resources and functionalities. On the other hand, Forum Virium Helsinki had a more complex sociotechnical approach to APIs. The organizational context might explain some of the difference. Metatavu is a private software development company and Forum Virium Helsinki a city owned innovation and development company. APIs seem to have a different meaning and purpose for different organizations.

APIs can be categorized based on their accessibility and use of proprietary software and standards as open, partner, and closed APIs. Closed APIs are typically internal, i.e. available only within a system or an organization boundary, and their use can require use of proprietary software. Access to partner APIs is limited by a contract or another type of regulation. Typically, they are based on partnerships between organizations or a customer relationship. An open API is publicly available, and its use is based on open standards and open technologies. An important distinction is an open data API that, in addition, provides open data. Many of the modern web-based platform provide open APIs. (Wulf & Blohm, 2017; Aitamurto & Lewis, 2012, Moilanen et al., 2018). Another descriptive categorization of APIs is their division into data APIs and functional APIs based on if they are one-way data distribution channels or provide interaction and functionalities (Wulf & Blohm, 2017). These categorizations also emerged from the empirical data. Furthermore, additional characteristics and use cases were able to be paired with the type of API. The open-partner-closed decision was heavily influenced by the business and technical environments. For instance, MPY Palvelut utilized partner APIs due to the commercial nature of the external platform and their own business environment. A typical business case included integrations between Microsoft Azure and customer's information systems. Therefore, APIs and access to the data and functionalities needed to be secured and limited. Another approach to closed APIs was presented by the case of Active Life Lab. They utilized closed internal closed APIs in their infrastructure development. APIs were required for connectivity but there was no business case for opening and publishing the APIs. Security was necessary due to possibly sensitive and personal data. However, open APIs dominated the discussions. Data APIs were more often open unlike functional APIs that exposed interaction and functionalities. Functional APIs were typically more restricted and included technical and social securing elements. Some of the case organizations, e.g. Platform of Trust, hinted that the distinction between data and functional APIs might be fuzzy. Modern APIs often execute a function and provide data. Moreover, modern data APIs push the data directly to subscribed systems. As such, the classification might need a re-evaluation as technology and API use evolve.

API archetypes can be used to categorize APIs based on their strategic purpose. An integrator API is used to enable and stimulate service innovations and integrates resources and functionalities together. API as a free data provider acts as a primary or secondary distribution channel for data and often aims to stimulate external innovation. Mediator APIs are used to establish an ecosystem and support its growth around the platform and its APIs for service co-creation and added value for the platform. (Wulf & Blohm, 2017). Several case organizations, e.g. Active Life Lab, Platform of Trust, and Tapio, mentioned the utilization of mediator strategy with their API initiatives. Metatavu and MPY Palvelut had adopted integrator approach and Tapio utilized it in internal use cases. Helsinki Region Infoshare and Tapio were also utilizing free data provider strategy. Forum Virium Helsinki was a complex case and had elements of each archetype in its definition of APIs and their use cases but could be classified as a mediator considering the big picture. Tapio also utilized multiple archetypes to accomplish different objectives. The findings indicate that more than one archetype is often needed to achieve business goals. The archetypes are not mutually exclusive. Instead utilizing the different archetypes of APIs multiple goals can be pursued. It could be interpreted that the organizational context influences the selected archetype. However, the sample size is likely too low to draw reliable conclusions.

As an IS concept, API includes a variety of dimensions that could be used to describe and define them. The above was mostly based on literature but reflected against the empirical findings. The sociotechnical nature of APIs was confirmed and present in the empirical data and literature. The interviewees were technically oriented but represented diverse roles and backgrounds in digital innovation and business. However, a different kind of results would possibly have emerged if they would have been software developers and engineers. The definition of APIs as platform boundary resources connects it with the concept of digital platform innovation. In this definition, the literature and empirical findings seem aligned. However, some discrepancies were found in API classification due to rapid advances in technology and digital business on the field.

8.2 What is digital platform innovation?

The purpose of the second supporting research question is to define digital platform innovation based on the IS literature and explore how the phenomenon is perceived and described in the field. Both the literature and the empirical findings confirmed that the research question and its answer are complex and multidimensional. However, it is an important question to cover for the purpose of solving the primary research problem at hand. First, the components of the research question need to be defined: what is a digital platform and what is digital innovation? Both concepts are broad and are covered considering the scope and context of this study.

A digital platform is a socio-technical foundation that provides structure and environment for the development of services, processes, and applications (Anttiroiko & Valkama, 2013; Yoo et al., 2010; Smedlund & Fafhankhani, 2015) and its surrounding ecosystem (de Reuver et al., 2017). Digital materiality and the characteristics of digital technology set digital platforms apart from the other types of platform. Digital platforms can influence and interact with physical materiality and social structures and are therefore increasingly complex. (de Reuver et al., 2017; Yoo et al., 2010). Digital technology and modularity are major enablers for digital platform innovation. Software and services can be developed based on the interfaces that expose platform functionalities and resources. The interfaces enable boundary crossing platform expansion and connectivity. (Ghazawneh & Henfridsson, 2013; Tiwana et al. 2010).

The empirical part of this study did not explore the definition of digital platform or digital platform innovation as such. However, some findings emerged from the natural flow of the discussions. For example, Forum Virium Helsinki did define the digital platform as a complex social-technical structure and emphasized it is more than just an information system. Furthermore, some defining characteristics were discovered from the research data. Digital platform was considered a strategic component in service innovation and in the development of digital service offerings. Both internal and external platforms were present in the research data. Most of the studied platforms were internally developed by the case organizations. Only Metatavu and MPY Palvelut discussed externally provided and/or developed platforms. The technology base for other platforms was in many cases was insourced or based on externally developed technologies. However, the interest was in whether the platform was managed and governed externally or not. The distinction might be fuzzy and artificial. Nonetheless, in most cases platform innovation was based on internally controlled and developed digital platforms. In the case of Metatavu, an externally developed open source platform was adopted as an internal service module but still relied on the external developers and community.

Open and distributed innovation need to be defined briefly to understand digital platform innovation and its mechanisms. Innovation is defined as a technologically novel concept that is diffused into a new market (Bogers & West, 2012). Digital innovation refers to the use of digital technology in the innovation process and its outcomes (Nambisan et al., 2017). Digital innovations are generative and convergent by nature (Yoo et al., 2012). Moreover, generativity and combinatorial innovation are the core mechanisms in digital platform innovation (Tilson et al., 2010). Digital platforms, distributed innovation, and combinatorial innovation are the three core traits of digital innovation. Digital platforms have become an important locus in digital innovation. Innovation environments are distributed more than before, and innovation processes have become organizational boundary crossing. (Yoo et al., 2012). Therefore, digital platform innovation is related to the concepts of open and distributed innovation (Chesbrough, 2012; Anttiroiko & Valkama, 2013; West & Bogers, 2017).

The empirical data provided evidence of open and distributed innovation and its intertwining with platform ecosystems. However, the distinction between platform, business, and innovation ecosystems was fuzzy. They were discussed and described similarly and had overlapping themes. The findings implied digital platform related innovation and ecosystems were indeed distributed and involved a lot of interaction between different actors. All cases included elements of open innovation albeit the level of openness varied between the cases. Innovation was explicitly mentioned as a platform objective in two cases. It was at least a secondary objective in other three cases and in five cases the interviewees did not prioritize it over other objectives. Platform innovation was considered important but not the top priority. Huhtamäki et al. (2017) argue API-based innovation is more distributed and diverse than platform-based innovation. The empirical data did not confirm the argument. None of the interviewees mentioned any different between API and platform innovation. Instead, they were seen intertwined and related. The data implies APIs have a significant role in digital platform innovation. However, the conclusion is based on a small sample and the research setting is likely to have influenced the findings.

In most cases innovation objectives and activities were driven by internal needs and the development of tools and processes. External innovation objectives and activities were related to enabling and supporting external innovation mechanism and actors, such as third-party developers, users, partners, and customers. Digital platform innovation pursued new services, products, and processes as the top priority objective. In addition, cost-savings and increased efficiency, productivity, and interoperability were pursued. New market entries were mentioned but less often than the other above-mentioned innovation targets.

Open innovation is based on inbound and outbound knowledge flows. The open innovation process can be visualized as a holey funnel where the knowledge flows may enter and exit the process. The edges of the funnel represent organizational boundaries. Open innovation enables the flow, absorption, and spillover of knowledge, technology insourcing, spin-offs, out-licensing, external innovation and market mechanisms, innovation partnerships, ecosystem interaction, and the utilization of external innovation and commercialization opportunities. (Chesbrough, 2012; West & Bogers, 2017). Utilizing open innovation in digital platform innovation requires relinquishing at least some platform control and exposing platform resources and functionalities (Chesbrough, 2012). Furthermore, the platform must remain incomplete to be able to exploit and absorb external innovations through the knowledge flows (Tilson et al., 2010).

Open platform innovation provides a solution to the question whether to provide scalable and easy to provide standard services or specialized services that create more value. The platform resources can be standardized and exposed, i.e. opened, to enable and stimulate specialized external service innovation. These service offerings increase the value of the platform and are dependent on it. (Chesbrough, 2012). In fact, modern digital service innovations are typically based on digital platforms and the combinatorial innovation potential (Smedlund & Fafhankhani, 2015).

As literature (e.g. West & Bogers, 2017) described, inbound knowledge flows were more utilized in practice. They were typically used for market validation, feedback loops, market knowledge absorption, technology insourcing, ecosystem interaction, and increasing platform commitment. The use of outbound knowledge flows was related to open-by-default principle and open source development model. Especially Metatavu, Forum Virium Helsinki, and Tapio utilized outbound knowledge flows, but also Active Life Lab mentioned it. Interestingly, outbound knowledge flows were less utilized to out-license and commercially benefit from innovations. Instead, the purpose seemed to be the stimulation and utilization of external innovation mechanisms, the attraction of partners and external developers, the enablement of the coupled mode of open innovation, and the discovery of unanticipated serendipities. The coupled mode of open innovation was utilized by Metatavu, Active Life Lab, Platform of Trust, and Forum Virium Helsinki. MPY Palvelut utilized a partnership-centric combination of open and closed innovation models in innovation.

The paradox of openness and control is present in digital platforms. Both sides have positive and negative influence on the digital platform innovation. Openness enables generativity that increases the innovation potential and stimulates combinatorial, distributed, and open innovation. Generativity can lead into continuous wakes of innovation and a positive innovation loop. Nevertheless, it simultaneously increases chaos and the speed of platform evolution and leads to decreased platform control and governance. The instability starts to reduce the usefulness and efficiency of the platform and finally decreases the innovation potential. On the other hand, control increases the stability and reliability of the platform. Both are required to attract users and developers to the platform and generate innovations. However, too much control hinders creativity and decreases the innovation potential. Therefore, a balance must be found between control and openness to achieve both flexibility and stability. The balance must be continuously tuned. Platform boundary resources are tools for solving the paradox. (Tilson et al., 2010; de Reuver et al., 2017; Nylen & Holmström, 2015; Ghazawneh & Henfridsson, 2013; Eaton et al., 2015). The paradox as such was not highlighted in the discussions. However, it could be observed and interpreted in the interviews with Platform of Trust, Tapio, and Forum Virium Helsinki.

Digital innovation happens at the boundaries of platforms and beyond them (Nylen & Holmström, 2015). Platform openness is in a critical position to support and enable boundary crossing innovation processes and benefit from the positive network effects in the innovation ecosystem. Openness is achieved by decreasing platform control and adopting open technologies and standards, and opening platform resources through open APIs. (de Reuver et al., 2017; Parker & Alstyne, 2016). Open innovation requires open business models to co-create and capture value. Platform governance for open innovation includes platform strategies, IPR management, and ecosystem interaction. (Parker & Alstyne, 2016; Chesbrough, 2012). The empirical data indicates that open innovation and the related paradigm shift have been acknowledged and are utilized on the field. Many interviewees emphasized the importance to align platform strategies, design, management, and governance with the logic of open innovation. In addition to innovation objectives, the platform design choices were driven by business needs and strategies and the terms of public funding. Four out of seven case organizations mentioned the co-design of platform resources for a better ecosystem-fit that would generate innovation benefits and monetary value. The logic is related to those of open innovation and open business models.

Platforms form ecosystems around them (de Reuver et al., 2017). Literature (e.g. Han et al., 2017) and the empirical findings both indicate that the different kind of ecosystems (e.g. business, innovation, and platform) are often overlapping and their differences are fuzzy. The interviewees discussed business and innovation related topics when they were asked about platform ecosystems. Moreover, the discussion on innovation activities and processes brought up business and platform ecosystem related topics. The interviewees emphasized the importance of ecosystem in creation of partnerships, synergies, and in fostering collaboration around the platform. The reasoning was that it has led to and/or would lead to the co-creation of new services and service offerings and new market opportunities. The logic of combinatorial and distributed innovation was brought up by multiple interviewees in the context of platform ecosystem benefits. Four platforms pursued to attract external developers and content creators in their ecosystems to increase the positive network benefits. External innovation mechanisms and user innovation were less mentioned but present in the data. Also, a couple of interviewees mentioned and could be interpreted to talk about business model innovation related to their platform objectives.

Orchestration and coordination are important activities to foster digital platform innovation (Han et al., 2017; Smedlund & Faghankhani, 2015). Based on the findings, the less coordinated ecosystems, such as open source communities, were found challenging innovation environments. Defined structure and roles might decrease freedom and flexibility but create stability and make innovation processes easier. The finding is connected with the paradox of openness and control. Interestingly it emerged in the ecosystem-related discussion but was described in platform literature.

Smedlund and Faghankhani (2015) argued the platform owner is the most typical ecosystem orchestrator and that they intentionally assume the role. Similar observation was made based on the empirical data. The case organizations wanted to become the keystone player in the ecosystem, establish a new ecosystem around their platform, or already had a leading role in the ecosystem. Most often the roles associated with the keystone player were mediator, moderator, and orchestrator. However, there was one case where the platform owner did not want to become the active orchestrator or the controlling actor in the ecosystem. Instead, it operated as a provider that enabled external innovation and supported other ecosystems.

There are a range of platform strategies associated with innovation. The strategic fit is dependent on the role of platform and the influence of its owner in the ecosystem. (Smedlund & Faghankhani, 2015). Most of the case organizations did face little to no competition in their ecosystems due to specialization, niche market, or a well-established position. For example, Platform of Trust had entered an early stage market that was still shaping and benefitted from the first-mover advantage. However, successful platforms need to be ambidextrous and evolve over time. Innovation, operations, and business are intertwined. It is perhaps most visible in case of MPY Palvelut that operates in a competed market and has pressure to keep its offerings constantly up to date and relevant. Innovation per se was more prominent in publicly funded platforms. In business-oriented platforms it was more subordinate to business and growth.

8.3 How web-based APIs are used in digital platform innovation

This section composes an answer to the primary research question. It builds on the literature-based concepts of APIs and digital platform innovation and the previously described empirical findings. APIs are defined as platform boundary resources that enable interaction with the platform and the utilization of its resources in service and platform innovation (dal Bianco et al., 2014; Ghazawneh & Henfridsson, 2013; Basole, 2016; Evans & Basole, 2016; Huhtamäki et al., 2017; Weiss & Gangadharan, 2010; Zuccalà & Verga, 2016; Wulf & Bohm, 2017; Yoo et al., 2010; Aitamurto & Lewis, 2012; Bonardi et al., 2016). This conceptualization connects API as an IS concept with digital platform innovation. APIs can have multiple roles in digital platform innovation where they operate in the boundaries of platforms and organizations. Many of the roles have a direct or indirect relation influence or relation to digital platform innovation. The typology of API roles in digital platform innovation presented the findings in the section 7.3. Next, the typology is discussed in more detail and compared with literature. Furthermore, the relation and influence of API use cases and organizational context are explored.

The first level of the typology of API roles in digital platform innovation presents three high-level role aggregations: 1) service and business innovation, 2) development and operations, and 3) ecosystem and collaboration. Resourcing and securing could be considered as the top-level abstraction. Ghazawneh and Henfridsson (2013) are interested in understanding how boundary resources, like APIs, are used in resourcing and securing. However, they abstract a lot of the interesting details and most of the API roles are a mix of both. APIs are always used for platform resourcing in one way or another. It would be pointless to develop an API that would not do anything. Resourcing is moderated through securing. Therefore, APIs operate also as platform control points. The roles of resourcing and securing are intertwined and dynamic by nature. Each of the role aggregations includes a second level of roles that enables better description and exploration of how APIs are used in digital platform innovation. Furthermore, a more detailed role typology provides a ground for discussion, interpretation, and criticism.

8.3.1 Service and business innovation

The role aggregation of *service and business innovation* is most closely related to digital platform innovation. However, the roles are ambidextrous. APIs are used for both innovation and exploitation, i.e. value creation and capture. APIs are used for development and operational purposes and to foster collaboration and ecosystem growth. Each of the objectives and roles are related to innovation but also to other topics. The empirical findings provided evidence that the roles were not exclusive, and their use was connected to different kinds of expectations and outcomes. The interview data implied innovation was often a secondary use case or objective for the use of APIs. Therefore, it was found useful to also explore the roles where innovation outcomes are a side product or a secondary objective. However, the decision led to inclusion of roles related to ecosystems, software development, and operations. Nonetheless, innovation activities and outcomes were perceived important by all the interviewees.

APIs operating in the *enable and support innovation* role use resourcing to enable and support internal and external innovation mechanisms and activities. The objective is to decrease the barrier to innovate and foster the natural generativity of digital technology and platforms. APIs increase the convergence of digital capabilities and resources like Yoo et al. (2012) described in their research. Each interviewee found open innovation relevant and described how it was utilized in their organization. APIs had a pivotal role in enabling the open innovation knowledge flows and providing the means for machine-to-machine platform interaction. Therefore, APIs could be interpreted as a part of architectures that Chesbrough (2012) describes as a necessity for open and boundary crossing innovation. Furthermore, the role can be connected to the mediator API archetype described by Wulf and Blohm (2017).

The ability to integrate external resources and knowledge is particularly important to enable and support distributed innovation and its mechanisms. Prior research (e.g. Lakhani & Panetta, 2007; Sawhney & Prandelli, 2000; Howells, James & Malik, 2003) has provided evidence that innovation and competitiveness benefit from a narrow focus in internal innovation and the supplemental ability to exploit external resources. However, it also increases the need for collaboration and the dependency of external actors and resources. Therefore, to be able to support distributed innovation the role overlaps with themes like ecosystem and collaboration. Moreover, APIs operating in this role enable service specialization and combinatorial innovation in the platform ecosystem.

APIs provide digital capabilities and resources to organizations lacking them. It is acknowledged as a core benefit from the use of APIs (Tan et al., 2016). The research cases of Active Life Lab, Tapio, and Platform of Trust provided evidence that resources and capabilities their platforms exposed provide missing capabilities to their ecosystems. For example, traditional constructed environment and real estate businesses benefit from the data processing and connectivity capabilities Platform of Trust can provide to them through their platform. However, enabling innovation requires APIs to have a low learning curve and barrier to use as described by Weiss and Gangadharan (2010). API design choices and governance are deal breakers for success of the role.

The findings indicated that several innovation objectives of varying size and scope were associated with this role. For example, Tapio targeted digital transformation in the use of data in the Finnish forest industry. Active Life Lab pursued a similar objective, but they wanted to transform the wellbeing services domain. Forum Virium Helsinki had an objective of enabling and stimulating smart city development and related innovation outcomes in the city ecosystem. MPY Palvelut, on the other hand, pursued internal innovation and partnership-based innovation. However, most of the objectives were applicable to both APIs and platforms. The use of APIs was a major enabler in the pursuit of innovation objectives which were often associated with the platform or business instead of the APIs themselves.

APIs are in a vital position to manage the paradox of openness and control in digital platforms. They are the most common platform boundary resource, based on the empirical data. Tilson et al. (2010) and de Reuver et al. (2017) argue platform boundary resources need to be continuously tuned to manage the paradox and moderate generativity. The interviews touched the topic of API management but were not specifically oriented to explore the topic in detail. However, it was clear that APIs were used for both purposes. Openness was observed as the use of open APIs and open standards, exposed open data, and the use of open source. Furthermore, it was present in the platform governance models. However, the design and governance choices were often made on the platform level and reflected to APIs.

Exploit combinatorial innovation and generativity is a role that seeks to benefit from the innovation opportunities created by APIs operating in the previously mentioned role. APIs expose resources and functionalities that can be mixed and matched to create new kinds of applications, systems, and services. The benefits are cumulative and reinforce combinatorial innovation and generativity and can trigger wakes of innovation (Weiss & Gangadharan, 2010; Yoo et al., 2012). Companies need to be able to exploit combinatorial innovation and distributed resources to compete in modern markets (Howells, James & Malik, 2003). Smedlund and Faghankhani (2015) argue that service innovation and the creation of new service offerings is becoming increasingly distributed and difficult without the ability to adapt to the change. APIs that operate in this role are mostly associated with the integrator archetype described by Wulf and Blohm (2017). The creation of service innovation through exploiting APIs is divided into two distinct roles: one technology oriented and the other business oriented. They are interconnected but different enough to justify being divided into two roles that belong to the same role aggregation. The role described here is technology oriented.

Based on the empirical data it was evident that APIs were utilized to configure and reconfigure digital capabilities and resources to create new services. For example, MPY Palvelut used APIs to combine capabilities available in an external platform with resources and capabilities in customers' information systems. These services could be specialized and tailored based on standard service modules. Moreover, the existence of APIs, service configurations, and integrations makes future reconfigurations and platform expansion more desirable. Therefore, exploiting the combinatorial innovation potential decreases the barrier to innovate and stimulates further innovations. The same conclusion was made by Tapio. They said existence of APIs is both requirement and accelerator for future innovations. Furthermore, Forum Virium Helsinki mentioned that they benefit from the combinatorial innovation that is outcome of combining their own research and development efforts, i.e. API development, with the external service innovations. These outcomes can then be combined and reconfigured into more advanced services and completely new boundary crossing services. The results are similar to what Anttiroiko and Valkama (2013) discovered in their research on the innovation impacts of APIs in smart city development.

Mashup applications were often mentioned in API innovation literature (e.g. Weiss & Gangadharan, 2010; Huhtamäki et al., 2017; Evans & Basole, 2016; Basole, 2016). Surprisingly, the term as such did not emerge in the interviews. It might be outdated or replaced by some other term with a similar meaning. Another explanation could be that the studied organizations were mostly platform and API providers. MPY Palvelut and Metatavu described the use of an external platform and service innovations that somewhat fit the description of mashups.

The role is connected to the combinatorial and open innovation but on the opposite side compared to the previous role. Exploiting these mechanisms is a critical requirement for digital platform innovation. Aitamurto and Lewis (2012) mentioned technology insourcing and market knowledge are the most common types of inbound knowledge flows. The empirical findings confirmed the argument. Market knowledge, feedback loops, and ecosystem interaction were indeed common. The knowledge also helped to configure and reconfigure services and could be exploited through other API roles as well.

Successfully exploiting API-based innovation opportunities requires digital capabilities and a matching platform strategy (Basole, 2016; Wulf & Blohm, 2017) which was also confirmed by the empirical findings. Surprisingly, many of the early stage platforms were focused on the technical development to the detriment of governance and strategy development. Nevertheless, all case organization acknowledged their importance.

Creation of new service offerings, business models, and markets is a role related to the business side of platform innovation. A successful exploitation of open and distributed innovation requires aligned business models (Chesbrough, 2012; Lakhani & Panetta, 2007). APIs enable the creation of new kinds of service offerings and business models (Basole, 2016; Evans & Basole, 2016) which was confirmed by the empirical findings. For example, Platform of Trust had created a novel busines model around data products and was working on establishing a new kind of market around the platform and its APIs. However, the creation of new service offerings, business models through APIs requires the ability to generate and exploit open innovation knowledge flows. The empirical findings implied that inbound knowledge flows can be used to detect and respond to market needs and opportunities. The role of APIs in digital platform business innovation is mostly associated with integrator and mediator archetypes by Wulf and Blohm (2017). Tapio and Platform of Trust had created customer and stakeholder feedback loops enabled market validation and the development of API-based business models. Furthermore, Active Life Lab had sought to establish a new kind of market that includes game developers, gym device manufacturers, and wellbeing service providers.

Outbound knowledge flows, on the other hand, enable new ways to react to market and expand possibilities for the creation of boundary crossing service offerings and configurations. For example, Forum Virium Helsinki can indirectly provide a variety of digital services that were created by external companies based on the APIs and resources exposed by them. Metatavu and MPY palvelut exploited external digital platform innovations to create service offerings that match the customer needs. Moreover, the services required a development of fitting business models.

The importance of business innovation (in addition to the technical innovations) was mentioned in one way or another by almost all interviewees. The findings implied both value creation and capture mechanisms were an important part of digital platform innovation and their longevity. In some cases, like the research platform by Active Life Lab, the business model was still taking shape. It was also interesting to include unsuccessful business innovations in the study. Metatavu described KuntaAPI platform was unable to discover a scalable and successful business model even though technically it was successful and created opportunities for service innovation in the municipality sector.

APIs hold a significant importance in the creation of new kinds of revenue streams for digital platforms (Basole, 2016; Vukovic et al., 2016). Business objectives are a strong driver for digital platform and API innovation (Aitamurto & Lewis, 2012). Moreover, the logic of multisided platforms and markets must be understood, and fitting business models needs to be designed to benefit from the API ecosomy (Bonardi et al., 2016). Based on the empirical findings, the business models were defined on the platform level and then had a major influence on the use of APIs in business innovation.

Service delivery and distribution channel is a common role for APIs based on the empirical data and literature. All studied platforms utilized APIs to deliver some services and/or distribute content even though the implantations were case specific. APIs are medium for platform resources and capabilities. Moreover, the role has important impact on digital platform innovation as described by e.g. Aitamurto and Lewis (2012). APIs operating as service delivery and distribution channels are an implementation of platform resourcing. In addition, the role is associated with all API archetypes described by Wulf and Blohm (2017). For example, Helsinki Region Infoshare demonstrated how APIs are used as distribution channels. Furthermore, Tapio utilized APIs as a distribution channel for their data but also as a service delivery channel for value-added services.

Service delivery is one of the four dimensions of service innovation in digital platforms Wulf and Blohm (2017) describe. APIs as such are a service delivery channel. User interfaces are perhaps the most common service delivery channel, and the modern user interfaces are based on the underlying APIs, as described by Metatavu and Tapio. Moreover, the modern API-based architectures are heavily influenced by modularity and loose coupling. APIs are the glue that ties together data, capabilities, and user interfaces. The characteristics of digital technology, e.g. malleability, are observable in API-based services. Wulf and Blohm (2017) argue the availability and diversity of delivery and distribution channels increases the number and variety complementary services

(Wulf & Blohm, 2017). Helsinki Region Infoshare and Tapio confirmed the argument. Helsinki Region Infoshare provides additional channels and means to discover and utilize open data (of which a major part is available through APIs). These possibilities increase the use of data and the beneficial innovations based on them. Aitamurto and Lewis (2012) concluded that open APIs are particularly useful and important to increase the efficiency of digital platform innovation. For example, Metatavu emphasized the importance of open APIs as a criterion to use external digital platforms in service innovation.

Service specialization role is related to the integrator API archetype as described by Wulf & Blohm (2017). APIs enable the configurations of different standardized platform offerings, e.g. modularized resources and capabilities, into services. Typically, the resources and capabilities are based on multiple platforms. The role is related to solving the issue between standardization and specialization as described by Chesbrough (2012). APIs enable the creation of specialized services based on standard modules that are mixed and matched from different sources. In addition, the APIs can be used to solve the paradox of openness and control. The external use of APIs for service innovation ensures the creativity and flexibility but the actual platform resourcing is controlled and internally stabile. However, the solution is imperfect as the ecosystem could still be chaotic. Metatavu described the uncontrolled nature of open source platform development communities, which is a real-world example of excess generativity.

External service specialization can add value to the platform through niche and complementary offerings. In addition, it introduces new market and commercialization opportunities and increases the value and diversity of the platform and its ecosystem. For example, Metatavu exploited the OpenTripPlanner platform to create services for a niche market through narrow specialization. The service provided navigation and route planning for pedestrians and non-motorized travel based on clean air and travel time. Another example is MPY Palvelut that utilizes Microsoft Azure platform to provide specialized services based on its standard offerings. Forum Virium Helsinki represents the different side of service specialization. They seek for niche providers and developers and provide a platform for them to exploit. The idea of service specialization is related to mashup applications (Weiss & Gangadharan, 2010). Service specialization benefits from the inbound knowledge flows that provide market knowledge, validation, and feedback loops. APIs are in a key position to capture that information, enable market interaction, and increase internal and external service specialization.

8.3.2 Development and operations

The role aggregation of *development and operations* is related to how APIs are used and developed. On the surface these roles might appear less relevant to innovation. However, the studied cases revealed that API use cases are multifaceted and non-exclusive. Moreover, the use of APIs and its outcomes are often drivers for innovation. Therefore, it is important to also understand how APIs are developed and used. The development is approached from IS perspective rather than software engineering, but the viewpoint is nevertheless technologically oriented.

The role of *integration and interoperability* is likely the most common use case for APIs. It is associated with the integrator archetype described by Wulf & Blohm (2017). Based on both the empirical findings and literature (e.g. de Reuved et al., 2017), APIs are used to integrate resources and functionalities across the boundaries of information systems and organizations.

For example, MPY Palvelut utilized APIs to integrate systems and processes to create and configure organizational boundary crossing services and processes. Each of the studied cases utilized APIs to either integrate internal and/or external resources or provide external integration opportunities. Interoperability was perceived as a requirement for successful integration of resources and functionalities. Platform of Trust and Forum Virium Helsinki emphasized the importance of interoperability which was a core value in their platforms. Interoperability and harmonization decrease and mitigate complexity. Thus, it effectively decreases the barrier to innovate and increases the opportunities for combinatorial innovation. Similar observations were made by Huhtamäki et al. (2017) and Aitamurto and Lewis (2012).

Distributed and boundary crossing innovation is dependent on the capability to integrate resources and functionalities and make them compatible, i.e. interoperable, with the organizations information systems. It requires both knowledge and technical capabilities. APIs provide the technical means for integration but are also medium for knowledge transfer. In addition, they spread the platform's influence in the ecosystem and contribute towards the convergence of digital technologies. (Yoo et al., 2012; Weiss & Gangadharan, 2010; West & Bogers, 2017). The success of digital platforms is likewise dependent on the above-described ability and innovation outcomes, i.e. boundary crossing processes and operations. The processes are related to the mechanisms of distributed and open innovation (Chesbrough, 2012; West & Bogers, 2017).

Technical quality influence heavily the usability and suitability of APIs for combinatorial innovation and the integration of resources (Weiss & Gangadharan, 2010). Metatavu emphasized the technical quality as a key consideration in API selection and deployments. On the other hand, MPY Palvelut emphasized how APIs align with busines processes and how they fit in the ecosystem. In any case, APIs have a relatively low switching cost and are often replaced to find the best problem-solution fit (Huhtamäki et al., 2017; Parker & Alstyne, 2016).

Platform of Trust, Tapio, and Forum Virium Helsinki focused on the harmonization, i.e. interoperability, of data. They had different approaches to it but nonetheless pursued to increase the integration potential of resources and capabilities exposed by APIs. The expectation was that the convergence of resources would increase the pace and diversity of innovation and increase the positive dependencies in the ecosystem. Some of the expectations had already been realized. Helsinki Region Infoshare is an open data provider that pursues to increase interoperability of open data and especially its metadata by harmonizing knowledge sharing. The research data included numerous use cases related to how APIs are used to in integrate resources and increase the interoperability, and how it influences digital platform innovation.

Automation and cost-savings is a business-driven role. Cost savings are achieved by increasing the level of automation. However, the interview data unfolded multiple paths to cost savings. Machine-readability and scalability were the most often mentioned requirements for automating processes and tasks. Especially Platform of Trust and MPY Palvelut utilized APIs to increase the level of automation and scalability. Moreover, Platform of Trust pursued automation and scalability to make their business model viable in the long term. Based on the research data, companies were more interested in cost savings as an innovation outcome than the public sector organizations. However, the efficiency of the innovation process was likely to provide cost savings as a secondary or indirect outcome. The role is most accurately associated with the integrator API archetype but perhaps also to the mediator.

Automation and cost savings are operational outcomes of successful innovation outcomes. For example, Platform of Trust pursued internal innovation that provided cost savings and especially increases in the level of automation. Those innovations could be first utilized internally but alter commercialized and exposed in their ecosystem. Automation increases productivity. MPY Palvelut and Metatavu had a business objective of increasing the productivity of their customers through new digital services and process improvements. APIs were utilized to automate processes but also to increase interoperability that was considered a requirement for automation. Overall, the empirical findings were in line with the prior research (e.g. Zuccalá & Verga, 2016; Basole, 2016; Evans & Basole, 2016; Aitamurto & Lewis, 2012).

Modular service development is intertwined with both service innovation and service development. It is a technologically oriented role that is associated with integrator and mediator API archetypes described by Wulf and Blohm (2017). Modularity increases the potential for combinatorial innovation. It also decreases the barrier to innovate and increases the speed of service development. Digital service systems are incomplete and thus are open for unanticipated innovation outcomes. (Yoo et al., 2012, Weiss & Gangadharan, 2010). Service modularity is an important to respond to specialized needs and support digital service innovation (Chesbrough, 2012).

Multiple interviewees brought up modularity in different contexts. For example, Metatavu and Platform of Trust discussed modularity in context of software development. Bonardi et al. (2016) and Vukovic et al. (2016) argued APIs have revolutionized software development. The same argument was made by Metatavu and Platform of Trust. MPY Palvelut defined modularity as the modularity of business processes that were enabled by the underlying services. Forum Virium Helsinki described that APIs provide abstraction for the technical details of various modules and thus reduce the complexity of service systems. Furthermore, APIs enable the co-creation of service modules in platform ecosystem. APIs are also used to integrate the co-created modules and provide the connectivity with them. Modern service and platform architectures are service-based and practically built on top of APIs. In addition to service and software development benefits, APIs can be used to increase collaboration in platform ecosystems. Modularity support service specialization and configuration of specialized services based on standard modules that are exposed by APIs. The role of modularity was defined as a requirement, outcome, and benefit depending on the context of the term and the interviewee.

The role of modular service development is related to some of the previously described roles. This observation highlights well the synergies and dependencies different roles have with each other. APIs are connectors between the service and platform building blocks. Platform of Trust described APIs are the modern service-oriented version of open source. They both have a similar role in being building blocks in software development. However, APIs are more refined in their offerings. The use of APIs has increased the speed and efficiency of service development. The benefits are cumulative but increase the complexity of service systems. Literature (e.g. Bonardi et al., 2016) helps to connect software and service development with digital platforms and innovation. API-based service architectures provide foundations to digital platform innovation.

8.3.3 Ecosystems and collaboration

The final aggregated group of roles is *ecosystems and collaboration*. Literature (e.g. Evans & Basole, 2016; Basole, 2016; Huhtamäki et al., 2017; Bonardi et al. 2016; Weiss & Gangadharan, 2010; de Reuver et al., 2017; Han et al., 2017; Smedlund & Faghankhani, 2015) have described how innovation, business, and platform ecosystems are intertwined and overlapping and their distinctions are fuzzy at best. The empirical findings implied the distinction was artificial in practice. APIs used for ecosystem collaboration and interaction might have a less direct influence on digital platform innovation but indirectly they are important. Both literature and empirical findings provide evidence that ecosystems influence digital platform innovation through APIs.

Ecosystem development provides the foundations and means to both exploit and grow innovation, business, and platform ecosystems. It includes the fostering and realization of positive network effects, partnerships, service co-creation, ecosystem interaction, and open innovation knowledge flows. APIs can be designed and used to support ecosystem development. Aitamurto and Lewis (2012) discovered in their study that APIs enable the development of innovation networks. Active Life Lab and Forum Virium Helsinki had established their research, development, and innovation networks around platforms. Forum Virium Helsinki and Platform of Trust had successfully used APIs to develop their platform ecosystems. In addition, Tapio had future platform objectives related to the use of APIs in ecosystem growth. Yoo et al. (2010) provide a literature-based description on the importance of APIs, and other boundary resources, in the coordination and control of distributed innovation ecosystems. The mediator archetype is a best fit for APIs operating in ecosystem development.

In almost all research cases ecosystem related strategies were set on the platform or business level not on API level. APIs are more likely to perceived as tactical tools and means to achieve the strategic ecosystem objectives. Even if the API literature describes them as strategic assets. APIs are used for ecosystem interaction, the creation of positive dependencies, and increasing customer and partner commitment. Furthermore, APIs were found critical in the attraction of external developers. Literature (e.g. Henfridsson & Bygstad, 2013) confirms APIs are used in the creation of architectures for ecosystem development. Moreover, Zuccalá and Verga (2016) concluded that platform innovation ecosystems were often supported by bundles of platform boundary resources, such as APIs. The cases of Platform of Trust, Tapio, and Forum Virium Helsinki provided solid evidence of how APIs were used in platform ecosystem development and how it influenced innovation.

The empirical findings indicated that API-based designs were malleable and could be modified and reconfigured to respond to market and ecosystem needs and changes. Moreover, the APIs themselves could be modified, expanded, and new APIs could be added as required. In fact, many interviewees mentioned ecosystem interaction heavily influenced API design choices and deployments. For instance, Tapio and Platform of Trust had created validation and feedback mechanisms to increase market-fit and ecosystem interaction in the early phases of platform and API development. Forum Virium Helsinki differentiated the payload, i.e. data design, from the API design. The data format and design were much more stable than the technical APIs. Lakhani and Panetta (2007) recommend considering the distributed, decentralized, and self-organizing nature of innovation systems in ecosystem development. Metatavu discussed the open source development ecosystems and its influence on service innovation. The case was a bit different from the others since Metatavu hosted an externally developed digital platform instead of utilizing its APIs as such. Chesbrough (2012) discussed open source innovation but made a clear distinction between the development related open source and innovation related open innovation models. However, the interviewees discussed platform and service development and innovation in the same context and almost interchangeably. In this typology, the innovation and development are differentiated and associated with different role aggregations altogether. The relations, dependencies, and synergies between the two aspects were identified also in literature (e.g. Bonardi et al., 2016). Helsinki Region Infoshare and Forum Virium Helsinki considered developer communities an important part of the innovation ecosystem and an enabler innovation diversity.

The studied ecosystems had a variable level of decentralization. All research cases included some elements of distributed innovation. For example, Forum Virium Helsinki had adopted a more distributed approach and projected only little control on the ecosystem. MPY Palvelut represented almost an opposite. The proprietary ecosystems were very business-driven and thus centralized around their customers and the Azure platform. In all cases, except the OpenTripPlanner described by Metatavu, the platform ownership was well-defined. APIs were used as tools for ecosystem interaction and moderation by the platform owners. Basole (2016) provided a literature-based description that matched the empirical findings. API-based interactions expand the platform and cross organizational boundaries.

Creation of new kinds of partnerships and service co-creation is another role heavily intertwined with the other roles. It is defined as a role of its own to focus on how APIs are used in the formation and enabling of service co-creation, not the actual event of co-creation itself. The role is associated with the mediator API archetype.

API-based partnerships and digital service co-creation are often based on mutual reciprocal benefits rather than traditional contract-based relationships. Howells, James, and Malik (2003) studied the characteristics of distributed innovation and their findings can be used to interpret and discuss API-based innovation partnerships. As such their study is outdated in comparison to the emergence and success of APIs during the last decade. However, their findings and the empirical data provide similar conclusions. The objectives and motivation and the innovation activities carried out by the collaborative actors are different depending on the time horizon. Collaboration can short or long term and based on partnership or technology. For example, Active Life Lab pursued research and development partnership-based ecosystem collaboration. Moreover, they wanted to co-create knowledge in addition to technology and to co-establish a new kind of market. Metatavu, on the other hand, pursued technology-focused partnerships and co-creation of technologies that could be used for service innovation. MPY Palvelut and Platform of Trust had a focus on partnership networks in their ecosystems. APIs were present in the discussion regarding ecosystems and partnerships. Based on the empirical data, the exact role and influence of APIs is hard to pinpoint. However, it was evident that they did have influence.

Partnerships can be formed with the other platforms in ecosystem (Weiss & Gangadharan, 2010). MPY Palvelut and Forum Virium Helsinki described multiplatform partnerships where APIs had a role in co-creating and realizing the benefits from the technical point of view. In other cases, e.g. Tapio and Helsinki Region Infoshare, the relationships with other platforms but their impact on innovation was not that clear or present.

The interviewees discussed partnerships mostly from the platform perspective. APIs were the means to configure services, connect modules, transfer knowledge, expose resources etc. but they did not emerge as the core of partnerships. The discussion on APIs was more detailed and practical than, say, innovation ecosystems and platform objectives. APIs were described more as technical means that were kind of separate from the co-creation processes. For example, Platform of Trust did not want to highlight APIs per se but the capabilities, partnerships, and outcomes they enable and support. Moreover, Basole

(2016) and Huhtamäki et al. (2017) describe APIs as tools for ecosystem interaction and creation of partnerships.

Brand building and marketing is the final role in the typology. It is mostly associated with mediator archetype by Wulf and Blohm (2017). It might be possible to merge the role with ecosystem development. However, the role emerged in the empirical data. APIs are tools for brand building. Positive brand supports the ecosystem growth, attracts external developers and partners, and increases the innovation opportunities. Technically modern, reliable, and high-quality APIs can provide the needed competitive edge in the platform economy. Furthermore, APIs market the platform, its offerings, and resources. For example, Stripe was mentioned by Active Life Lab and Platform of Trust was a global leader in API branding which had helped the company to establish their market position.

Metatavu mentioned APIs enable new market entries and marketing efforts when joining an existing platform ecosystem. Using APIs, a company can specialize in a niche market and provide complementary services to the ecosystem. By connecting to the APIs, the niche provider can use the platform as a marketing tool and benefit from its network effects. Active Life Lab mentioned open APIs and platform transparency as means for brand development which in turn was considered important for attracting partners and developers. Moreover, Active Life Lab argued well done APIs are a proof of excellence and expertise. Therefore, APIs as marketing tools generate opportunities for innovation and support the other described roles.

8.4 Research contributions

This research studied how web-based APIs are used in digital platform innovation. The primary objective was to explore and describe the phenomenon. As such the study did not include theory building or hypotheses testing. This section discusses contributions to the emerging API research in the context of digital platforms and the domain of IS. The findings and implications provided some answers to the research questions put forward by such as Yoo et al. (2010), Ghazawneh and Henfridsson (2013), Barret et al., (2015), Wulf and Blohm (2017), Huhtamäki et al. (2017) and Bonardi et al. (2016). There were identified research gaps in what roles APIs have as boundary resources, what mechanisms APIs influence in digital platform innovation, and how APIs could be holistically described in service innovation.

First, this study confirmed APIs can be studied and described through IS literature. There is already and emerging body of literature exploring APIs ecosystems and their influence on digital innovation. It provides a solid sociotechnical conceptualization that is different from the prior software engineering definition. However, there are still relatively few IS papers focusing on APIs. Thus, this study aims to contribute to the diversity of the academic discussion and build foundations for future studies by the same researcher or others. Digital platform innovation is current and widely researched topic. APIs provide a fresh research lens and explore the topic through boundary resources. Moreover, they provide conceptual links to open and distributed innovation research.

APIs are intertwined with several concepts and phenomena. They influence and are influenced by digital platforms and their ecosystems. Moreover, they influence platform interaction, service co-creation, and value capture through resourcing and securing. Empirical findings provided evidence of the multifaceted nature of APIs. The use of APIs in digital platform innovation was often overlapping and jointed with business, operations, and developmental topics and aspects. Therefore, the modern Internet-connected service economy and service systems are increasingly complex. Combinatorial innovation and the generativity of digital technology, e.g. APIs, increases complexity and dependencies between ecosystem actors. Platforms are important constructs in digital innovation. However, the focus has been moving to the edges and boundaries of the platforms and innovation processes have become organizational and platform boundary crossing.

This research approached APIs in a holistic sense and tried to understand their technical and social aspects and dynamics in digital platform innovation. The findings implied that APIs are often defined as technological tools but are connected to a much wider environment and objectives. During the thematic analysis it was found that APIs were perceived as parts of digital platforms or service offerings. They were seldom discussed in isolation but rather as part of the whole. The organizational context is important in understanding the use and objectives of APIs. The innovation mechanisms can be described and explained through theories and models of open and distributed innovation. However, even if the mechanisms are the same, their utilization and importance vary depending on the organization. Public and publicly funded organizations were more interested in innovation as such and in fostering platform innovation and ecosystems. Private companies perceived innovation as means to achieve business goals and APIs as tools for platform interaction, service innovation and development, and business model execution. An overarching approach fits studying APIs in digital platform innovation as argued by Wulf and Blohm (2017). Another option would be to narrow the focus in a specific innovation mechanism and role of API which might enable to isolate specific parts of the phenomenon more than was done in this study. The integrated approach was found useful also due to that distributed and open innovation were closely related topic. The use of APIs in digital platforms and ecosystem interaction made the relation visible.

The literature and empirical findings were aligned. The research did not uncover any surprising findings. Like Hsieh & Shannon (2005) mentioned, theory-guided research approach is more likely to discover supporting evidence. However, the study enabled a rich description of the use of APIs in digital platform innovation. The studied cases were selected to provide diversity and applicability to different settings. However, it was found that some topics that were emphasized in literature were not present in the empirical data. For example, mashup applications were often mentioned in API literature but none of the interviewees mentioned them. Chesbrough (2012) differentiated open innovation and open source innovation. Empirical findings provided evidence that the two are related and distinction between them might be artificial even if open source innovation is more oriented towards technology and software development. The relation could be studied further. Moreover, developer communities are often associated with open source innovation and are an important part of some ecosystems, as the findings implied.

This study contributes towards several research questions raised in prior research. Barrett et al. (2015) asked how the paradox of generativity and control can be managed in service systems. In addition, Ghazawneh and Henfridsson (2013) called for digital platform research that investigates the mechanisms and opposing forces in digital platform innovation. Based on the literature review and empirical findings, platform boundary resources can be used to tune and balance the paradox. Boundary resources are often bundled together to combine technical capabilities and project control and terms of use. For example, APIs provide connectivity and expose resources and service modules. Generativity is result of the characteristics of digital technology and the combinatorial innovation potential. The generativity can be managed through social contracts and securing capabilities through APIs themselves and bundled social boundary resources. The context of use influences how much securing is needed and the level of openness. However, they need to be constantly evaluated through ecosystem interaction. APIs provide means for market validation and inbound knowledge flows that are required to acquire knowledge to manage the paradox.

Yoo et al. (2010) asked what is are the strategic roles of platform boundary resources. The typology presented in this study provides one answer. It is worth mentioning that differentiating between the roles of platform and APIs can be fuzzy as discovered during the analysis of the research data. Roles of platform boundary resources can be abstracted to resourcing and securing. However, a more detailed typology is required to provide practical and informative contributions. Three high-level role aggregations are 1) service and business innovation, 2) development and operations, and 3) ecosystem and collaboration. APIs have following roles in service and business innovation: enable and support innovation, exploit combinatorial innovation and generativity, creation of new service offerings, business models, and markets, service delivery and distribution channel, and service specialization. Development and operations are more related to the actual use of APIs. However, they influence innovation objectives and are critical for the realization of innovation benefits. The roles are as follows: integration and interoperability, automation and cost-savings, and modular service development. The third role aggregation includes API roles related to ecosystem and collaboration. These roles are important for open innovation knowledge flows and distributed innovation. The roles are ecosystem development, creation of new kinds of partnerships and service co-creation, and brand building and marketing.

Several IS researchers (e.g. Wulf & Blohm, 2017; Huhtamäki et al., 2017; Bonardi et al., 2016) argue there is a research gap in overarching theories regarding the use and influence of APIs in in service and platform innovation. This study utilized an integrated approach to explore APIs the context of their use. Multiple bodies of IS literature, e.g. open and distributed innovation, digital platforms, innovation ecosystems, platform boundary resources, and APIs, were utilized to cover the research gap. Based on the literature and empirical findings the organizational context and its implications play a significant role in the use of APIs in digital platform innovation. This study can confirm that a holistic approach benefits the exploration and description of the phenomenon. However, more detailed studies are required to describe the mechanisms and develop and test hypotheses. Moreover, Bonardi et al. (2016) argued there is a research gap in sociotechnical research regarding APIs. The field of IS research is well suited to produce research to cover the gap.

The primary academic contribution of this study is the typology of API roles in digital platform innovation. Moreover, the underlying themes can be used as starting points to study the roles and the use of APIs in more detail. The study explored the API landscape wider than only in digital innovation. It was found that ecosystem and business-related topics were intertwined with the innovation activities, objectives, and outcomes. These relationships might be interesting to explore deeper. The paradox of openness and control inherent to digital platforms was studied. APIs, especially bundled with social boundary resources, were found an effective tool to manage the paradox. Digital platform innovation as a phenomenon is challenging to isolate and study without the presence and influence of other topics. It is a complex sociotechnical phenomenon.

This study opens avenues for further research. In addition, the findings could be validated and reviewed and used to develop and test hypotheses. The mechanisms of value co-creation and capture could be studied to understand how digital platform innovation benefits companies and other organizations. There is some difference between the two types of organizations, and they could be studied separately. Many of the case studies referred were indeed focused on a single industry or public sector segment. Moreover, organization or business oriented studied could be carried out based on the initial findings and implications. For example, API-enabled partnerships and use of APIs in marketing could be studied further. It is likely that many of the future research topics would benefit from a multidisciplinary and interdisciplinary approach. However, in-detail studies with a narrow focus are likely needed to shed light into specific mechanisms and in deeper understanding on APIs in specific context and use. Platform success and its relation to APIs is another identified topic. It is likely an interesting topic for the practitioners. For example, the positioning and differentiating of APIs in relation to API and platform economy might be interesting and shed light into platform evolution, innovation, and success.

8.5 Practical implications

Some practical implications can be made based on the findings. They can be roughly divided into two categories: 1) API design choices and architecture related implications, and 2) strategic and managerial implications. Both companies and public sector organizations might find them useful.

The most important implication is that APIs are not only technology that are interesting to software developers. They are strategic assets and integral parts of digital platforms. Moreover, APIs can be utilized to achieve the platform objectives and business goals. This study provides a solid overview of IS literature covering digital platform and APIs focusing on digital innovation but also touching topics of ecosystems, value co-creation, and value capture. APIs are utilized in many technical roles and the organizations utilizing APIs might consider some of them obvious. They provide connectivity between service modules and pieces of software, integrate resources and capabilities, and are used to configure and reconfigure service offerings. However, APIs also play many non-technical roles, such as ecosystem interaction, platform growth, market validation, partnership building, and marketing.

The typology of API roles is a helpful reference for practitioners and decision makers when considering how to utilize APIs and what strategic roles they fill and what are the expected benefits from their use. The typology is described in more detail in section 7.3. It describes how APIs can be used in service and business innovation, how innovation opportunities can be created and exploited, how APIs enable the creation of service offerings, and how they can be used to deliver and distribute services and resources. Next, the typology describes how APIs can be used in modular service and platform development and to automate and integrate processes and operations for innovation benefits and cost savings. Typically, operative benefits realize the value of innovations. Finally, the typology describes how APIs help in ecosystem interaction and engagement and provide market benefits. The typology can be used in strategic planning and platform roadmapping. Platform strategies and governance models influence the design choices, development, and the terms of use for APIs. In addition, APIs are most often bundled with other platform boundary resources, like documentation, licenses, developer portals, and such to transfer knowledge. The objective is to decrease the barrier to use and accelerate API adoption. API strategy should be based on platform objectives and strategy. In addition, it should be based on use cases but remain malleable for future opportunities. The literature review provides an overview into digital platform innovation and how open and distributed innovation works. The information can be used to craft suitable platform and API strategies and busines models and to evaluate the current utilization of APIs. In addition to the typology, the described API archetypes of integrator, mediator, and free data provider, can be used to design API strategy based on best practices and research knowledge.

APIs are helpful tools to increase platform stickiness and positive dependencies on it. They attract external developers and market the developer offerings and knowledge embedded to the platform and its boundary resources. In addition, APIs can be used to develop supplementary services in platform ecosystems or enable external developers to complement one's own platform with additional services. APIs enable modularity that in turn enables service specialization and responding to niche markets and needs while the platform provides scalable standard modules and resources through APIs. Therefore, APIs positively contribute to positive networks effects. However, it requires fitting API and platform strategies and good technical quality for APIs.

The outputs of this study are descriptive above all. They can be used to increase the understanding of digital platform innovation. The literature review presents information on important mechanisms and dynamics of open and distributed innovation. They have radically changed the logic of innovation in the current digital service economy. Platform boundary resources can be utilized to respond to the change and increase competitive advantage. Moreover, literature helps to understand the inherent paradox of openness and control in digital platforms. APIs are in a key position to solve and manage the paradox. The empirical findings provide information on how different organizations have approached and solved the paradox. In addition, the findings indicate that the use of APIs and the outcomes of the use are dependent on and influenced by the industry. Public sector organizations and companies approach innovation in different ways and thus the role and management of APIs is different. It highlights the fact that APIs are not only a piece of technology.

The typology and the presented literature review provide insights into how APIs can be utilized in digital platforms for innovation and business benefits. Even if innovation is the primary focus of this study, the creation and exploitation of innovations are intertwined, and thus both topics are touched in this study. The findings are based on an empirical multiple case study to increase the diversity and applicability to other settings. The selected cases included public sector organizations, companies, startups, well-established companies, a publicly listed company, a city development company, and a research and development unit. Moreover, the people interviewed for this study represented diverse backgrounds and roles instead of strict technology focus. Therefore, the practical implications should be more generally usable and applicable. APIs can be used to stimulate innovations but also create growth and business benefits. As such, this study provides a solid background for decision makers, managers, architects, developers etc. working on digital platforms and especially digital platform innovation. It provides a starting point for applied research and API governance and design choices. However, it does not likely cover all related topics and provides a precursory overview into a complex and multidisciplinary topic. Finally, it is extremely useful to provide a feedback loop from research to practice and vice versa and to discover new and interesting practice-based research problems to solve.

9 CONCLUSION

This section concludes the study. First, the research objective and problem are reviewed, and the research is summarized. Second, the contributions for research and practice are briefly reviewed. Third, the limitations of this study are discussed and presented. Finally, future research suggestions are put forward.

9.1 Summary of the research

The objective of this study was to explore and describe how web-based APIs are used in digital platform innovation. For this purpose, two supporting research questions were formulated as follows: *what is a web-based API as an IS concept?* and *what is digital platform innovation?* Answers to them would help to define and conceptualize the phenomenon and contribute towards solving the research problem. Furthermore, the objective of the study included contributing towards the emerging API research in information system science and answering some research questions identified in the prior research. The research started with a systematic literature review on open and distributed innovation, digital platforms, boundary resources, and APIs. The focus was on digital innovation. Next, a qualitative multiple case study was carried out to explore and describe the use of APIs in digital platform innovation in practice. The empirical research utilized a theory-guided post-positivist research approach. The data collection was based on thematic interviews. Furthermore, a qualitative content analysis was done to develop themes and a typology of API roles in digital platform innovation and several themes that provided a context for the findings. Moreover, the findings were compared with literature and discussed to provide contributions to research and practice.

Digital platform innovation is a complex sociotechnical phenomenon that is based on the characteristics of digital technology and the mechanisms of open and distributed innovation. Digital platform is defined as a socio-technical structure that enables processes and services to be built on top of it. APIs enable boundary crossing platform innovation and extend platform capabilities and reach. However, it also means that innovation and business ecosystems have become intertwined and their boundaries fuzzy. Moreover, the innovation environment has become increasingly distributed and complex. Open innovation is based on inbound and outbound knowledge flows that expand beyond the organizational boundaries. Open innovation enables new opportunities for technology insourcing, knowledge absorption, ecosystem interaction, paths to market, and commercialization opportunities. However, it requires relinquishing some control over the innovation process and adoption of new kinds of innovation architectures and governance models. The exploitation of open and distributed innovation provides opportunities for combinatorial and cumulative innovation. Digital platforms operate as hubs and loci of digital innovation. However, digital platform innovation requires aligned and fitting business models, governance, and strategy. API strategy and design choices should be based on the defined use cases but remain malleable for future opportunities.

Web-based APIs can be conceptualized as sociotechnical artefacts and platform boundary resources that provide connectivity between two pieces of software through the Internet but also mediate and moderate the relationship. Modern APIs are building blocks for digital platforms and web-based services. They are used for platform resourcing to enable innovation, value creation, and value capture in the platform economy. A typology was developed to categorize, synthetize, and describe the various roles in which APIs are used in digital platform innovation. The roles are non-exclusive, and an API can operate in multiple roles at the same time. The typology includes three high-level role aggregations: 1) service and business innovation, 2) development and operations, and 3) ecosystem and collaboration. Each aggregation includes a set of roles that have a direct or indirect influence on digital platform innovation.

APIs can be used to *enable and support digital platform innovation*. They are used to resource the platform, to enable and stimulate external innovation, and to decrease the barrier to innovate. The role is associated with the mediator API archetype. In addition, APIs can be used to *exploit combinatorial innovation and generativity* the previous role aims to enable and support. APIs can be mixed and matched to create new services and service offerings. Combinatorial innovation increases the cumulative innovation potential and can enable powerful wakes of innovation. The ability to exploit distributed innovation is required to maintain competitive advantage in the platform economy. Moreover, it requires open innovation capabilities. The role can be associated with the integrator API archetype. *Creation of new service offerings, business models, and markets* presents the business side of digital platform innovation. New kinds of open business models are needed to configure and reconfigure distributed resources and capabilities, i.e. service modules, into service offerings through APIs. The utilization of open innovation models can provide new paths to market and the creation of new markets. The role can be associated with integrator and mediator API archetypes. *Service delivery and distribution channel* is the most common role for APIs in digital platforms. The role can be associated with any of the three

API archetypes, but free data provider provides the best fit. APIs are medium for digital service and content delivery and operate as additional and alternative distribution channels. The exposure and availability of platform resources is a strong enabler and catalyst for digital platform innovation. *Service specialization* role is best suited for the integrator API archetype. Exposed standardized platform modules and resources can be combined and configured into specialized services that can serve niche markets and provide additional commercialization options and revenue streams. The role enables increased service diversity without increasing instability.

The next set of roles are related to service development and operations. They are both realized outcomes of digital platform innovation but also enablers for further innovations. The role of *integration and interoperability* is strongly associated with the integrator API archetype and the convergent nature of digital technology. It is one of the most common purposes to use APIs. Integration of services provides boundary crossing innovation opportunities but requires interoperability. It is also related to how digital services and platforms are developed. APIs are used to connect services, functionalities, and data and increase the interoperability between service modules and information systems. *Automation and cost-savings* is a business-driven role. Automation is pursued to increase productivity and scalability that in turn provide cost savings. APIs are in a critical position to achieve machine-to-machine communication and connectivity that are required for automatization between software modules and systems. Automation and connectivity foster further automation and integration of new capabilities, i.e. cumulative innovation. The role is associated with the integrator API archetype. *Modular service development* is related to modularity and combinatorial innovation opportunities. Modern service systems are based on modular architectures that combine different capabilities and resources. Modularity speeds up the development and decreases the effort for service innovations. The role is associated with the integrator and mediator API archetypes. Moreover, it is related to software engineering.

The third role aggregation covers ecosystem related roles. Each has an important but often indirect influence on digital platform innovation. Moreover, the roles are connected with open innovation knowledge flows. APIs operating in the role of *Ecosystem development* are used to increase ecosystem interaction, to create and foster open innovation knowledge flows, to grow the ecosystem diversity and positive network effects, and to attract external developers and partners. Platform ecosystem has a strong influence on innovation and APIs are in a key position for its development, but they must be aligned and tuned to fit the ecosystem and platform strategy. The role is associated with the mediator API archetype. The role of *Creation of new kinds of partnerships and service co-creation* is also associated with the mediator API archetype. APIs enable new kinds of partnerships based on mutual benefits and positive dependencies. They provide service co-creation opportunities and provide access to knowledge and resources in distributed innovation environments. The cooperation can be based on technology or partnerships. *Brand building and marketing* includes the use of APIs marketing the platform resources and its embedded knowledge. It aims to influence developers as technology gatekeepers and increase the attractiveness and pull of the platform. However, it requires APIs are of good technical quality. The role is associated with the mediator API archetype. Positive brand also increases platform stickiness as the switching costs for APIs are relatively low.

APIs are often bundled with other social and technical platform boundary resources to complement and moderate them. As such, APIs can be used as control points that moderate the platform resourcing. Social boundary resources, such as developer portals and documentation, can be used for knowledge transfer and decrease the barrier to use APIs. Furthermore, terms of use and contracts can be used to moderate APIs in addition to the technical means. The balance between resourcing and securing must be continuously evaluated and balanced. It is related to the inherent paradox of openness and control in digital platforms. Openness increases the generativity, creativity, and innovation potential of digital platform. However, it decreases the stability and usefulness of the platform. Control can be exercised to increase stability and moderate chaotic generativity, but it has detrimental influence on openness and thus the innovation potential. The paradox can be managed through the continuous tuning of platform boundary resources. Moreover, APIs as control points provide value capture opportunities and protect the platform core and IPRs.

The findings were aligned with the literature. API can be conceptualized as an IS concept and provides a fresh and useful research lens to study digital platform innovation. Findings implied and confirmed APIs are used in platform innovation, value co-creation, and value capture. The distinction between the roles and use cases was at times fuzzy and the roles were intertwined with each other. Therefore, the decision to study the phenomenon and its context together were justified. However, some details and mechanisms might benefit from a deeper and more narrow focus and scope. This study succeeded in solving the stated research problem and answering the research question.

However, some findings provoked ideas for further research and review of some prior research. For example, the differentiation between open innovation and open source innovation seemed artificial based on the empirical findings. Most of the interviewees prioritized the technical qualities and benefits of APIs. As the interviews proceeded the social and business side emerged. It seems that even if they are considered sociotechnical artefacts, the technical side is still dominant. In addition, the technological development on the field is rapid, and some descriptions were perceived dated at times in research papers and might need to be re-evaluated. Moreover, some research argued API ecosystems are different from platform ecosystems and they have a different innovation logic. It was not confirmed in by the findings. Instead, APIs were perceived as integral part of platforms and as means to expand their boundaries and access resources and capabilities. In addition, strategic design choices, business models, and governance models were made on the platform level and reflected to APIs that were considered as tools and assets to achieve those.

9.2 Contributions to research and practice

This study contributed towards the emerging API research in IS literature. Furthermore, it provided several practical implications to companies and public sector organizations pursuing digital platform innovation. The literature-based conceptualization of API as a platform boundary resource provides a fresh approach to study digital platform innovation. In addition, the concepts of open and distributed innovation were found the be intertwined with digital platform innovation and the use of APIs as tools for innovation, value co-creation, and value capture. APIs are used for platform resourcing that is moderated by platform securing. It was found that APIs are primarily considered piece of technology in the field. However, they are utilized for business and innovation benefits. In addition, they were perceived as integral parts of digital platforms, not addons or extras. The organizational context influenced the use of APIs and the objective of their use. Literature and the empirical findings were mostly aligned but there were some discrepancies, interesting findings, and suggestions for future research.

The primary contribution to research is the typology of API roles and the description of roles and the case examples. The multiple-case approach aimed to provide good applicability to other settings. The differentiation between open innovation and open source innovation was found fuzzy in practice. Moreover, open source developer communities were often associated with both. The study contributed towards answering research questions put forward by prior research. Barrett et al. (2015) and Ghazawneh and Henfridsson (2013) asked how opposing forces and the paradox of generativity and control in digital platforms and digital innovation can be managed and studied. Boundary resource model was utilized to provide a theory-bound answer which was confirmed by the empirical findings. Platform boundary resources, such as APIs, are bundled together to enable, support, and moderate digital platform innovation and its mechanisms. The typology provided answer to what are the strategic roles of platform boundary resources, asked by Yoo et al. (2010).

The typology of API roles in digital platform innovation consisted of three high-level role aggregations and roles categorized under each aggregation. Furthermore, each role was discussed and described based on the empirical findings and literature. The role aggregation of *service and business innovation* includes roles closely related to enabling, supporting, and exploiting combinatorial innovation opportunities and generativity. In addition, APIs are used as service delivery and distribution channels, and in the creation of new and specialized service offerings, business models, and markets. The second role aggregation, *development and operations*, is related to the innovation benefits, drivers, and motivation. APIs are used for integration and interoperability, automation and to provide cost savings, and in modular service development. The third set of roles, grouped as *ecosystem and collaboration*, include the use of APIs for ecosystem interaction and influence. They are related to open innovation knowledge flows and the management of distributed innovation. Moreover, APIs can be used in partnership creation and marketing.

The study contributed to closing of the research gap identified by several IS researchers (e.g. Wulf & Blohm, 2017; Huhtamäki et al., 2017; Bonardi et al., 2016). It provided empirical findings on the use of APIs in digital platform innovation. In addition, the study utilized a holistic approach that described the organizational context and environment. It combined multiple bodies of literature for an overarching description of the phenomenon. The study and its implications were firmly connected to practice.

The practical implications are related to the design, use, and management of APIs in digital platform innovation. APIs should not be considered only by software developers. Instead, they are strategic and integral parts of digital platforms that can be used to pursue both business and innovation objectives. The research provides a solid foundation for practitioners to understand digital platform innovation and the roles APIs can be utilized to enable, support, and exploit it. The typology can be used as a reference when designing platform and API strategies and objectives. Moreover, it helps in the evaluation of current API strategies and use. The research knowledge can be used to tune and upgrade them. APIs enable the creation of specialized supplementary services and joining platform ecosystems. They provide external developers the means to contribute and benefit strengthening the platform ecosystem. Modularity enables more efficient and productive service development and agile service configurations. Modern innovation environments and platform ecosystems are distributed and complex.

In addition to the obvious technical roles, APIs can be used in service cocreation, ecosystem interaction, platform growth, market validation, the creation of partnerships, and marketing. Moreover, they can be used in platform governance roles to increase interoperability and manage the complexity of service and information systems. Practitioners are likely more interested in the innovation outcomes and their realization. However, the typology helps in understanding how they can be pursued and how to develop the platform and tune it for innovation. Moreover, the study helps to connect platform strategies and governance models with API design choices and management. Platform boundary resources are most useful in bundles. For example, APIs should be bundled with developer portals, documentation, and the examples of use to decrease the barrier to use. APIs are tools to increase the platform pull and stickiness, and network effects and thus contribute to platform diversity and success.

Understanding how to utilize APIs and other platform boundary resources provides many practical benefits and competitive advantage. Innovation, business, and operations are intertwined and dependent on each other. Therefore, it this knowledge can help to achieve ambidexterity and maintain competitiveness in the rapidly changing digital platform economy.

9.3 Limitations and criticism

The awareness of limitations and self-criticism are critical skills for any researcher. Many researchers (e.g. Sarker et al., 2013) emphasize their value and purpose in qualitative research. Data collection and analysis are always subjective. Bias could be introduced by research strategy or data collection and analysis techniques. Interpretive approach requires a keen eye for limitations and the sources of bias. First impressions should not define the findings. Instead, iterative methods help in developing understanding of the data and spot anomalies in it and during the analysis process. (Sarker et al., 2013).

This study can be considered successful and having met is research objectives. Regardless, the limitations must be acknowledged. The study was carried out as a master's thesis and the researcher was relatively inexperienced in conducting research. However, it should be noted that the researcher had over ten years of professional working experience in the field of information technology and digital innovation. The scope of literature review could have been more narrow and deeper. However, it would have decreased the ability to explore the context of the use of APIs in digital platform innovation.

There could have been some bias in site selection and in the design of interview themes based on acquired knowledge, research interests, and access to sites and materials. The professional background was helpful in establishing trust and a professional relationship with the interviewees and in understanding the practice and its context. In addition, the terminology and business cases were familiar. However, the lack of experience in designing and carrying out the semi-structured interviews was likely to influence the data collection. The flow of the interviews was natural but could have benefitted from a more focused approach. Yet, it did provide space for the interviewees to highlight what they considered important based on their experience, knowledge, and work. The presentation of the interview questions had some difficulties. The academic terminology and definitions were at times confusing for the interviewees and required brief introduction by the interviewer. For instance, the term boundary resource was mostly unknown and the definition of terms, e.g. innovation, platform, and resource, were diverse by the interviewees. The preparation of exact questions beforehand would have likely resulted in clearer, shorter, and less unambiguous questions. On the other hand, it would have limited the ability to explore the themes and react to findings during the interviews.

The sample size was moderately low and included only ten interviews across seven organizations. It was less than the saturation point. However, it was justified by research objective, selected strategy, and recommendations by literature. The research sites were selected to provide an overview of different kinds organizations and increase the generalizability and applicability to other settings. However, the number of sites was likely not high enough to make generalizable claims. Data collection was done in Finnish as all the interviewees and the interviewer were Finnish. The data was translated to English for further analysis. This could have influenced the data. Moreover, the full transcription of research data was not carried out due to time and resource limitations. The decision was supported by methodology literature and the chosen method of analysis.

A more formal and structured approach to analysis could have provided different research outcomes, i.e. themes and typology. The utilized method was based on methodology literature and selected research strategy. It enabled to adapt to the findings and develop classification, themes, and typology based on data and literature but perhaps lacked in rigor. Data analysis was interpretative and based on literature, prior knowledge, and intuition. It is possible another researcher could have done different interpretations and conclusions. It would have been helpful to perform the classification by another researcher as well, but due to the nature of a thesis study it was not possible. A theory-guided approach to data analysis is likely to discover more supporting than opposing evidence to the prior research and theory.

Effort was put to provide adequate transparency on data collection and analysis and to provide reasoning for the selected research strategy and approach. In addition, a description of findings and their interpretation were carried out to establish relevance to both research and practice. Rigor was pursued by maintaining focus on the defined research problem. However, as a descriptive and explorative study the focus likely drifted at times and needed to be refocused during the research. It is possible that the themes could have been more focused to the primary research question. However, it would have decreased the ability to analyze the context of APIs in digital platform innovation and possibly decreased the generalizability and relevance to practice. It was considered important to describe the setting and include it in the analysis. The phenomenon of interest is a complex socio-technical concept, and in the opinion of the researcher, required studying it from a more holistic point of view. The typology of API roles in digital platform innovation was provided as the outcome of the research. It was focused on the research question and provided a clear and justifiable answer. Furthermore, the literature review had a wide scope to cover concepts related to the research problem and the context of the phenomenon of interest, but the research framework synthesized the core concepts and mechanisms into a coherent and compact form.

It is possible these limitations influenced the research and its conclusions. However, the research answered the research question and thus solved the research problem. The findings were discussed and compared with the prior research. Furthermore, the outcomes contributed towards research questions put forward by IS researchers and prior works. The findings were applicable to both research and practice.

9.4 Future research suggestions

This study explored and described how APIs are used in digital platform innovation. The studied concepts were complex and multifaceted. As such the findings opens multiple avenues for further research. The most obvious future research suggestions would be to review and validate the findings, i.e. the typology of API roles in digital platform innovation. Hypotheses could be developed and tested to see if the descriptions hold in other settings. Moreover, each type of a role could be studied further and described in detail.

Several research topics were discovered when carrying out the analysis, interpreting the findings, and comparing them with literature. It could be investigated how API-enabled innovations are realized through value co-creation and capture. Especially, technical innovations have potential that might be left underutilized. The findings implied that public sector and companies could be studied separately as they approach innovation differently. Organization and business management research could be carried out to explore how APIs influence and enable partnerships and how API-based collaboration takes place in innovation and service ecosystems. Furthermore, APIs in platform marketing and developer attraction could provide fresh lens for platform research. The relationship and causality between platform success and the use and design of APIs were highlighted in literature and emerged in findings. However, it would require a dedicated research to study them deeper.

The relation of open innovation and open source innovation emerged as a conflict between the findings and literature. The topic is not downright related to APIs but could be investigated further. Especially as the practitioners and researchers had different views on them. Moreover, open source ecosystems and developer communities can be considered part of innovation ecosystems.

Literature and theory differentiated between API and platform strategies, business models, and governance models. However, in practice those were defined on the platform level and reflected to APIs. It could be worth to study these findings in more detail and investigate how APIs are managed strategically and do they have their own models, how they are defined and why. The inbound knowledge flows influence platform evolution and therefore also APIs. The findings implied the evolution is done to achieve a better problem-solution and market fit. Hypothesis could be developed to validate it.

It is likely that many of the future research topics would benefit from a multidisciplinary and/or interdisciplinary approaches. However, in-detail research on specific mechanism or relationship are likely needed to deepen the knowledge. The research suggestions would provide valuable knowledge to the practitioners but would also benefit the diversity of API research.

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APPENDIX 1 INTERVIEW THEMES (TRANSLATED)

This appendix outlines the interview themes for the empirical part of this study. The interviews were conducted in Finnish. The themes and subthemes are translations, not the original ones used in the interviews. The original ones can be found in the Appendix 2.

1. Interviewee background
- Position/role
- Background (tech/business/domain)
- Connection with digital innovations, platforms, and APIs
- (to be complemented with secondary data on company background)

2. Digital innovation
- Innovation activities
- Objectives and roles in business/activities
- Open innovation
    - Activities, ecosystem, distributed/centralized
    - Knowledge flows (inbound, outbound, coupled mode)

3. Digital platforms and ecosystems
- Platforms & roles (owner/provider/consumer/etc.)
    - General description, focus, size, scope…
    - Rationale, objectives, and benefits
- Platforms and ecosystems (focus on 1-2!)
    - Competition or cooperation
    - Benefits
    - Role
- Governance and orchestration
    - Decision making, roles, and power
    - Open – closed
    - Free – paid
    - IPRs
- Innovations
    - Realized, expected
    - Innovation-driven – byproduct
    - Strategy, design, and decisions

4. Boundary resources and APIs

Focus: previously identified platforms; either own platforms or third-party platforms used by the organization.

4.1 Boundary resources

- Boundary resource offering (SDKs, APIs, documentation, developer portals, contracts etc.)
- Roles, purpose, and objectives
    - Technical and social boundary resources (differences)
    - Target audience

4.2 APIs

- Selection of the most important APIs
    - Generic description
    - Open – closed; business model/case
    - Focus add target audience
    - Competition, market position
    - Importance for the organization
    - Rationale and objectives for innovation
    - Realized vs. expected innovation benefits
    - API offering (provider – consumer)
    - Collaboration, partnerships
    - Integration with service innovation and offerings (own – others')
    - Uniqueness, replaceability, competitive advantage
    - Measuring, innovation accounting
- Governance
    - Resourcing - securing
    - Ecosystem and APIs
- Design choices and strategy
    - API strategy and objectives
    - Development, exposure, utilization
    - Driven by innovation, business, or technology etc.
    - Limitations and barriers
- Impacts
    - Realized innovation benefits
    - Requirements and needs
- Importance on APIs in innovation
- Future expectations and preparing

APPENDIX 2 INTERVIEW THEMES (FINNISH)

This appendix outlines the interview themes for the empirical part of this study. The interviews were conducted in Finnish. The themes and questions are translated in Appendix 1. These are the original questions.

1. **Taustatiedot**
- Asema, rooli
- Tausta (tekninen, bisnes, domain)
- Yhteys innovaatiotoimintaan, alustoihin ja/tai rajapintoihin
- (täydennetään organisaation tiedoilla)

2. **Digitaaliset innovaatiot**
- Innovaatiotoiminta yrityksessä
- Tavoitteet ja aktiviteetit
- Avoin innovaatio
    - o Ekosysteemi, hajautettu innovaatio
    - o Tietovirrat (sisältä ulos, ulkoa sisälle, molemmat)

3. **Digitaaliset alustat ja niiden ekosysteemit**
- Alustat ja rooli sen suhteen
    - o Yleinen kuvaus, koko, laajuus ym.
    - o Tavoitteet ja perustelu käytölle (oma – ulkoinen alusta)
- Ekosysteemi (fokuksessa oleellisimmat; 1-2 kpl)
    - o Yhteistyö - kilpailu
    - o Roolit
    - o Saavutetut hyödyt
- Hallinta ja orkestrointi
    - o Päätösvalta ja roolit
    - o Avoimuus, maksullisuus
    - o IPR
- Innovaatiot
    - o Tavoitellut, saavutetut
    - o Innovaatioiden rooli (ohjaa, sivutuote)
    - o Alustastrategia

4. Rajaresurssit ja rajapinnat

Fokus: aiemmin tunnistetut omat tai muiden käytössä olevat alustat ja niiden rajapinnat.

4.1 Rajaresurssit

- Käytetyt tai tarjotut resurssit (SDK:t, API:t, dokumentaatio, kehittäjäportaalit, sopimukset ym.)
- Rajaresurssien tehtävät ja tavoitteet
  - Tekniset ja sosiaaliset resurssit
  - Kohdeyleisö

4.2 Rajapinnat

- Keskeisimmät rajapinnat
  - Yleiskuvaus
  - Avoimuus, liiketoimintamalli / -tavoite
  - Kohdeyleisö
  - Kilpailu, asema markkinoilla
  - Tärkeys organisaatiolle, kilpailuetu, korvattavuus
  - Perustelut ja tavoitteet innovaatioille
  - Saavutetut ja odotetut innovaatiohyödyt
  - Yhteistyö, ekosysteemit ja kumppanuudet
  - Liittymäpinta palveluiden/tuotteiden kehittämiseen (omat-muiden)
  - Innovaatioiden (ja hyötyjen) mittaaminen
- Hallinta
  - Resursointi – turvaaminen
  - Rajapinnat ekosysteemeissä
- Suunnitteluvalinnat ja strategia
  - API-strategia ja tavoitteet
  - Kehittäminen, julkaiseminen, käyttö
  - Innovaatio ajurina vai keinona
  - Rajoitukset, esteet
- Vaikutukset
  - Saavutetut ja odotetut hyödyt
  - Tarpeet ja vaatimukset hyödyntämiselle
- Tulevaisuus
  - Odotukset
  - Päätökset ja ennakointi