The Digital Transformation of the Manufacturing Industry

Metamorphic Changes and Value Creation in the Industrial Network

VINCENT FREMONT
The Industry 4.0 trend poses many challenges for the manufacturing industry and societies generally. The trend presents new challenges and opportunities related to industrial competitiveness and sustainability, as industrial firms adopt digital technologies to change how they interact and exchange data across their industrial network. The introduction of digital technologies is resulting in a complex technological and organizational structural change process called digital transformation, which sees interfirm interactions, capabilities and identities changed across the industrial network. The digital transformation change process has remained relatively ill-defined, as most industries are yet to show the full potential of successful digital transformation. Firms within the manufacturing industry still have difficulties grasping the impact and costs of Industry 4.0 and of the digital transformation process. The prevailing assumption in the literature is that industries will achieve value creation simply by engaging with digital technologies, either in higher revenues, profitability or both if they are successful. The change process affects all aspects of industrial network, from the single product functionality and production process efficiency to interfirm business interactions, thus affecting in many regards value creation in the industrial network. By employing an Industrial Marketing and Purchasing approach, the dissertation analyzes the issues of interaction, change and value creation in the resource context of two large industrial networks undergoing complex digital transformations. This article dissertation will present four qualitative studies of two large manufacturing industrial network undergoing complex digital transformations with the interaction approach. This dissertation presents several findings and contributions specific to the digital transformation change process, including the presence of metamorphic irreversible and interactive changes challenging the status quo of interactions and value creation in the resource context, creating conflicts, controversies, and friction effects. It also underscores the importance of organizational elements of organizations for the digital transformation, and how a unique combination of changes across the resource context, from new roles to new ways of working allow the industrial network to create value beyond simple technological incremental innovations. The dissertation presents a theory of metamorphic change in the industrial network, to describe complex change processes like the digital transformation.

Keywords: Industrial Networks, Industrial Marketing and Purchasing, Resource Interaction, Digital Transformation, Industry 4.0

Vincent Fremont, Department of Civil and Industrial Engineering, Industrial Engineering and Management, Box 534, Uppsala University, SE-751 21 Uppsala, Sweden.

© Vincent Fremont 2021

ISSN 1651-6214
URN urn:nbn:se:uu:diva-450154 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-450154)
He who has come only in part to a freedom of reason cannot feel on earth otherwise than as a wanderer-though not as a traveler towards a final goal, for this does not exist.

- Friedrich Nietzsche, Man Alone With Himself
Acknowledgments

Five years of thoughts are going into writing these words. Five years filled with many of the most humbling moments of my life. Five fulfilling years that would not have been possible without the support of many.

Aihie, Jens, Lars-Johan, and Enrico, I feel immensely grateful for the supervision that I have received. The experience of being a doctoral student can be very confusing, and many don’t get to be as lucky as I have been to receive this amount of direction, clarity, support, and cold-headed feedbacks. I hope that we will continue to work together on the topic of digital transformation or another.

This dissertation would of course not have been possible without the participation of all the great people at Sandvik Manufacturing and Machining Solutions and the Cibes Lift Group. Both companies had such interesting stories to tell, which I hope I did justice to in here. I miss the days when I spent all my time traveling to their respective sites to conduct my interviews.

My thoughts go to all my colleagues at the Department of Economics at HiG. I have found at HiG more support than I could ever hope for, as well as great colleagues to teach or to chat at the coffee machine with. To the people of the Department of Civil and Industrial Engineering at UU, I really enjoyed my occasional visits to Ångström, the seminars, and the meetings. To the IMP community, it has been a pleasure to be a member of the church. I hope that we will be able to resume our IRL events soon.

My thoughts go especially to my family and friends for their indefectible support during all these years, spanning beyond this doctoral journey, and to Sanna, for tolerating me working during our vacations and for being the kindest person that I have ever met.

Funding
Part of this work has received support from the Knowledge Foundation (Stiftelsen för kunskaps- och kompetensutveckling), Sweden, under the grant agreement n° 20150221.
List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.


IV. Fremont, V., “Friction and digital transformation in the industrial network”, Submitted to *Journal of Business and Industrial Marketing*.

Reprints were made with permission from the respective publishers.
Contents

Prologue ......................................................................................................................... xiii

Introduction ...................................................................................................................... 1
  Overview ....................................................................................................................... 1
  Problematization ........................................................................................................ 3
  Narrowing Down the Phenomenon .......................................................................... 5
    Background of Industry 4.0 .................................................................................. 5
    Industry 4.0 in the Literature ............................................................................. 7
    Cyber-Physical Systems ...................................................................................... 10
    Digitization and Digitalization .......................................................................... 11
    Digital Transformation ....................................................................................... 13
    Defining the Digital Transformation ................................................................ 14
    Factors of Digital Transformation ....................................................................... 17
    Impacts of Digital Transformation ...................................................................... 20
    Challenges of Digital Transformation .................................................................. 24
The Theoretical Perspective .......................................................................................... 27
  Digital Technologies ................................................................................................. 27
  IMP Research on Digital Technologies .................................................................. 30

The Empirical Setting .................................................................................................. 35
  The ISNET Research Project .................................................................................. 35
  Sandvik Machining and Manufacturing Solutions ................................................. 37
  Cibes Lift Group ....................................................................................................... 39

The Theoretical Framework ......................................................................................... 41
  The Industrial Marketing and Purchasing Approach ............................................. 41
  The Interaction Approach ........................................................................................ 42
  The ARA Model ......................................................................................................... 43
  The Resource Interaction Approach ....................................................................... 45
  Theory of Value Creation .......................................................................................... 47
  Resource Interaction and Value Creation .............................................................. 48
  Friction, Heaviness, Variety, and Path Dependence ............................................ 50

The Articles .................................................................................................................... 54

Methodologies .............................................................................................................. 59

Empirical Findings ...................................................................................................... 64
Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMT</td>
<td>Advanced Manufacturing Technologies</td>
</tr>
<tr>
<td>CODE</td>
<td>Center of Digital Excellence</td>
</tr>
<tr>
<td>CLG</td>
<td>The Cibes Lift Group</td>
</tr>
<tr>
<td>CPS</td>
<td>Cyber Physical System</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>IMP</td>
<td>Industrial Marketing and Purchasing</td>
</tr>
<tr>
<td>INM</td>
<td>Industrial Network Metamorphosis Change Theory</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>ISNET</td>
<td>Innovative Strategic Network in the Age of the Digitalizing Manufacturing Industry</td>
</tr>
<tr>
<td>RIA</td>
<td>Resource Interaction Approach</td>
</tr>
<tr>
<td>SIMS</td>
<td>Smart Inventory Management Systems</td>
</tr>
<tr>
<td>SMMS</td>
<td>Sandvik Machining and Manufacturing Solutions</td>
</tr>
<tr>
<td>TDMS</td>
<td>Tool Data Management Systems</td>
</tr>
</tbody>
</table>
The research for this dissertation officially kicked off in 2016 at the headquarters of a large Swedish manufacturing firm. In an open discussion about digitalization and Industry 4.0, managers described in very broad strokes, what the digital technology trend meant for their company, the company’s vision, their goals, the projects that the company had been pushing forward, and several challenges. They depicted their company as a market leader. Their complex network of diverse organizations, a center of excellence, product areas, and subsidiaries included the largest brand in their industry. They also described a fragmented company, which included several large brand organizations running their own affairs and projects. At the core of their concern was to increase the cooperation between these different organizations to drive innovation on digital solutions. They perceived themselves as “very strong,” as in very good with digital technologies. The company had been investing in developing multiple digital capabilities and solutions internally. The managers described what they understood digitalization to be and their expectations about the positive changes they could achieve with digital technologies regarding their product offerings and their business relationships with their customers. They described a complex picture of multiple ambitious changes that could have the potential to fundamentally change their business if realized. They understood that digital technologies could drive new opportunities, allow them to retain their market leadership position, and that it would change what they would sell, their business models, and who they would interact with. They also perceived these changes as an opportunity to achieve several socio-environmental goals, to become more sustainable by becoming a more efficient and resilient company.

Through several workshops with a top-tier management consulting firm, their business development and business strategy team, part of the organization's corporate apparatus, has devised several strategies to address these changes in a way suitable for their needs. These would require them to make significant investments in capabilities, technologies, and competencies. It would possibly also require acquiring several companies with the resources that they needed. They understood that the road to achieving these changes would require navigating through the buzzwords, understanding what it meant for them to create value in the future, and, like an “oil tanker,” that it would take years for them
to move their large organization in the right direction. They also understood that one of the keys was to rethink their interactions with customers and their suppliers and partners and increase the amount of interaction within their large, fragmented organization, between the multiple different actors that constituted it. They also described several risks, such as the risk of killing innovation by using the wrong business models. They were also invested in a technology that they thought could bring in potentially radical changes and disrupt their industry. In total, we spent a couple of hours there listening to managers describing the multiple changes related to digital technologies, digitalization, and Industry 4.0 at their company.

A couple of weeks later another meeting took place, at another Swedish manufacturing company’s headquarters. The main topic was also how the firm was dealing with digital technologies, the related changes, potential opportunities, and challenges they had envisioned with them. The company was a market leader from a different industry, with a long-established history and know-how. They described their network of multiple foreign subsidiaries, distributors, and suppliers. They presented their plans and previous international expansion. In fact, following a change of ownership, the company focused on growing the business by entering new markets and acquiring other actors, distributors, and competitors in their industry. The managers explained that they understood digitalization to be a driver for their growth. It would allow changes in how they interact with other actors and create new relationships with new customers. In the technologies they saw several opportunities for creating value for their companies and their partners and customers. They also understood that they were responding to a greater industrial-technological trend and needed to address these changes to remain competitive. Like the other Swedish manufacturing company managers, they understood that they were also missing several answers as to what digitalization meant for their company and that finding the answers and achieving these changes would be a long journey. They didn’t know yet which tools would allow them to fully benefit from digitalization changes, such as which would allow them to improve their production and integrate it better with their back office and customer-facing activities, which would allow them to improve their interactions with other companies in their network, nor what changes they would need to implement internally to increase inter-firm interactions.

The information content of both meetings was a lot to unpack. It became immediately clear that both companies would be important troves of empirical data. In both cases, the companies presented visions of bright futures with digital technologies, making their businesses better. Although their sizes differed by a few orders of magnitude and operated in different industries, they presented several similarities. Both interacted with a multitude of different actors, suppliers, and customers in their industrial networks. In digitalization,
both companies saw an opportunity to further develop the cooperation and relationships with their industrial network, their “ecosystem.” Both were under similar pressure from environmental factors, new entrants, and price competition. Both are seeing an increasing need to innovate and develop new value-adding services to remain competitive. They both hoped that researchers from academia could help them better understand digitalization and what it meant concretely for their industry and help them develop managerial tools for managing the changes. Addressing these would require first defining the actual main phenomena present in both cases. What is happening to these companies? The meetings had left me both inspired and also a little confused by the issues and key concepts described by the managers, digitalization, Industry 4.0, etc. The problem was a complex one. Both companies needed to develop their solutions to address these changes. However, addressing both cases in a single research project would perhaps allow for the development of abstract knowledge or theory on the phenomena.
Introduction

Overview
This doctoral dissertation broadly addresses Industry 4.0 but focuses on the changes taking place at the organizational scale, within and between interacting firms. The dissertation investigates how the specific changes, digitalization and the digital transformation process, which are taking place within the broader Industry 4.0 trend, may affect how firms interact and create value in networks. Industry 4.0 is a household name for researchers of all academic fields. Industry 4.0 is an important trend affecting all industries undertaking this new digital transformation (Bartodziej, 2017). Industry 4.0 is mainly a governmental vision, which many actors picked up on, driven by the wide implementation of digital technologies creating changes in all areas of industry (Kagermann et al., 2013). The changes are characterized by connectivity and recombination and are often described by terms like digitization, digitalization, or digital transformation. Previously discrete and unconnected objects, individuals, and activities are being connected via digital technologies. The previous great digital revolution, arguably the wide adoption of robots and IT, saw digital technologies connecting humans and objects and allowed people to interact and collaborate remotely via communication technologies. Today’s revolution sees objects communicating with each other, objects creating data that becomes the input of other objects performing certain production processes.

Industry 4.0 was made possible by the Internet of Things and the emergence of Cyber-Physical Systems (Kagermann et al., 2013; Schumacher et al., 2016). These changes can help firms increase the value that they create from their present resources. It can help firms increase their competitiveness and sustainability (Westerman et al., 2014). Ultimately it changes both how firms create and capture value (Albukhitan, 2020; Henriette et al., 2015; Westerman et al., 2014). Industry 4.0 is about rethinking how firms develop outcomes that create more value for their customers. For firms dealing with industrial customers, Industry 4.0 is about how firms can create solutions that help their industrial customers increase their own productivity. It is also about finding new business models such as outcome-based monetization (Iansiti and Lakhani, 2014).
The greater context of this dissertation and the research that it contains, is a research project conducted in collaboration between a group of marketing researchers and industry practitioners. It is one of the main outcomes of the Innovative Strategic Network in the Age of the Digitalizing Manufacturing Industry project (ISNET). This research project was initiated in 2016 as a collaboration between the University of Gävle (HiG), and two large Swedish manufacturing companies, the Cibes Lift Group and Sandvik Machining and Manufacturing Solutions. The ISNET project was initiated to investigate how digitalization is affecting the manufacturing industry. ISNET’s initial goals were to investigate challenges regarding value creation in interactive innovation processes within an industry pursuing Industry 4.0-oriented goals; to analyze how the network of inter-organizational relationships is affected by Industry 4.0 and digital technologies; to analyze how these changes affect the interaction of resources within the development, production, and use settings; and lastly to fill the gap of missing agency within strategic network research by developing a dynamic model for managing innovation. Within the framework of this project several articles at the core of this doctoral research were produced.

The two selected industrial marketing cases were followed from 2016 to 2019, during which time several phases of data collection were undertaken, and several scientific papers were written. The Industrial Marketing and Purchasing (IMP) approach was used as the main theoretical approach (Håkansson, 1982), in particular the resource interaction approach (Håkansson and Waluszewski, 2002a) and business network theory (Håkansson and Snehota, 1995), together with other theoretical perspectives such as boundary objects theory (Star and Griesemer, 1989), and liminality theory (Concannon and Nordberg, 2018), to capture different aspects of business relationships in an industrial market context, and how they can be sources of value creation and friction in the context of digital transformation. The IMP approach defines markets as made of organizations with long-established business relationships, across which firms interact and develop market interdependencies. Therefore, the IMP approach has long developed itself around the study of the business relationship (Håkansson and Snehota, 1995). It posits that firms can mobilize important resources across business relationships, and firms interact in an industrial network to create value (Håkansson, 1982).

The first paper (I) produced within this research project used the theoretical lens of boundary objects and looked at frictions and controversies resulting from the introduction of new digital resources within the interaction processes of two large manufacturing companies (Fremont et al., 2018). A second paper (II) used the liminality lens to look at challenges related to developing digital-related radical innovation in relative isolation from business relationships (Eklinder-Frick et al., 2019). The third paper (III) used the resource interaction
approach to study how different organizations may implement a specific technology based on their different resource structures. Finally, a fourth paper presented how digital transformation may affect value creation and friction effects in an industrial network (Paper IV).

This dissertation posits that the Industry 4.0 paradigm is a trend within which firms’ digital transformation is a change process taking place in industrial networks of interacting firms. Digitization and digitalization, respectively the action of putting physical information formats into digital form, and the process of introducing digital technology-related changes into different business processes, should be understood as subset change processes of the digital transformation. This dissertation aims to investigate how digital transformation is affecting the manufacturing industry, how firms interact and create value in their industrial network. The dissertation will present how digital transformation can be better understood using the theoretical tools provided by the International Marketing and Purchasing approach that has been developed in the last four decades (Håkansson et al., 1982).

The first chapter of this dissertation will narrow down the topic by addressing first what Industry 4.0 is, the state of research on the topic, and the challenges of Industry 4.0. Then it will do an account of key concepts, including digitization, digitalization, and digital transformations. Then it will focus on the phenomena studied, by providing a review of the literature on digital transformation, its definitions, the challenges, and provide an outlook on the empirical research. The theoretical framework will present the IMP approach, the core concepts, models, and theories central to this field of research, and how this literature has been investigating digital technologies and digital transformation. The four papers and their findings will then be presented and discussed. Lastly, an explanatory model of digital transformation built from IMP theory, named the Industrial Network Metamorphosis Change Theory, will be described, and proposals for future studies of digital transformation or of other similarly complex phenomena.

Problematization

Digital transformation offers new challenges and opportunities for all industries and the organizations interacting in industrial networks. Digital transformation has been described in many ways, and much of the research on the topic has focused on identifying technological aspects and capabilities, therefore also mainly focusing on internal issues of the single firm. Value creation and interaction are two key issues of digital transformation, as it entails many changes in the way firms interact with each other, such as by possibly increasing the number of total interactions with the purpose to increase the value
created (Reddy and Reinartz, 2017; Roblek et al., 2016). Digital transformation introduces changes by introducing solutions developed with digital technologies to the technical resources essential to manufacturing firms to create value. It changes the way business relationships are developed and managed, and therefore in the way value is created during the interaction process by industrial firms (Albukhitan, 2020; Morakanyane et al., 2017; Ojala et al., 2016; Stolterman and Fors, 2004; Westerman et al., 2014). According to the interaction model developed early on within the industrial marketing and purchasing (IMP) approach, firms create value during the interaction process with other firms in the network (Håkansson, 1982). The IMP approach has looked at business relationships, understanding that resources like new technologies are intertwined into a wider context, and that technological innovation takes place within the interaction process across the industrial network. Thus it is dependent not just on the actions of the single firms alone, but on the actions taken by the different organizations interacting in the network.

The purpose of this dissertation is to investigate how digital transformation affects firms’ interactions and value creation within the industrial network. By employing an IMP perspective, and more specifically the resource interaction approach (Håkansson and Waluszewski, 2002a), the dissertation will analyze the issues of interaction, change, and value creation in the context of two large industrial networks of manufacturing firms undergoing complex digital transformation. The dissertation will develop answers to the following research questions in its discussion chapter and construct a change theory applicable to the case of change within industrial networks undergoing transformative change processes like digital transformation.

RQ1: How can digital transformation affect the way researchers conceptualize interaction in industrial networks? (Papers 1 and 2)
RQ2: How can firms cope with digital transformation-related changes while interacting with other firms in their industrial network? (Papers 1, 3, 4)
RQ 3: What are the effects of digital transformation on value creation taking place during inter-organizational interaction? (Papers 1, 2, 3, and 4)
Narrowing Down the Phenomenon

Background of Industry 4.0

In 2013, Kagermann et al. (2013) published the final report of the Industrie 4.0 working group for the German Federal Ministry of Education and Research. A few years earlier this same group coined the term Industrie 4.0, or Industry 4.0 in its English version, which stands for the fourth industrial revolution. Several other governmental organizations quickly picked up this term to describe their plans to promote their industries’ digital transformation (Calenda, 2016; Geissbauer et al., 2015; Klitou et al., 2017; Sommer, 2016). This strategic initiative, a collaboration between industrial and scientific organizations, was launched by the German government in 2011 as part of a future strategy action plan for the country’s manufacturing industry (Bartodziej, 2017). Considering how important the manufacturing industry’s contribution is to this country’s GDP, it seems natural that Germany became a trendsetter in coming up with this term for what is essentially a global industrial trend (Bartodziej, 2017).

The introduction of the Internet of Things (IoT) in the industrial environment brought new opportunities for firms. In their report, Kagermann et al. (2013) foresaw the future development of global networks of different resources, machines, production facilities, and warehousing systems. They expected a generalization of Cyber-Physical Systems (CPS) or the convergence of physical and virtual worlds. These CPS comprise different elements or production resources that can, thanks to IoT, communicate with each other. This should in turn lead to the emergence of new kinds of production facilities, smart factories, tailoring smart products to individual customer requirements by using dynamic business and engineering processes. Additionally, they expected to see end-to-end data transparency over the entire manufacturing process. The newly established data and information ubiquity should allow for optimal decision-making by managers across the value chain, leading to the development of new ways of creating value and to new business models.

The Industry 4.0 trend should also help societies and their governments address several social and environmental challenges. It is expected to improve energy efficiency, waste reduction, and allow societies to better cope with societal and demographic changes. And perhaps more importantly for the researchers behind the German report (Kagermann et al., 2013), the new industrial revolution is an opportunity for manufacturing industries to remain on top of an increasingly fierce global competition, which has been building up for decades from lower labor cost regions. On one hand, the development of Cyber-Physical Systems should help German firms improve their production
efficiency, and on the other hand, investing in this development should allow them to export more new technologies and products. Industry 4.0 has three main features: the development of horizontal integration through value networks or cross-functional integrations; the end-to-end digital integration of engineering across the entire value chain; and vertical integration and networked manufacturing systems (Kagermann et al., 2013).

Examples of governmental plans similar to the German Industrie 4.0 are plentiful and continue to emerge everywhere (Calenda, 2016; Geissbauer et al., 2015; Kagermann et al., 2013; Klitou et al., 2017; Sommer, 2016). More recently, the Japanese government took the Industry 4.0 philosophy a step further and articulated their Society 5.0 plan. Society 5.0 is a plan for the future of Japanese society the aim of which is to integrate the technologies, mainly IoT and Big Data, and principles of Industry 4.0 in every aspect of society (Nagahara, 2019). While Industry 4.0 is concerned with the interconnectivity of industrial processes, systems, and actors, Society 5.0 would be concerned with the interconnectivity of societal systems, such as healthcare, infrastructures, mobility, and fintech (Government of Japan, 2018). Society 5.0 is about creating a system of systems, as it is about developing interconnectivity between previously non-connected systems, including roads and energy management, to create new systems of systems, such as carbon emission reduction systems (Nagahara, 2019). This approach by the Japanese government illustrates how Industry 4.0 is less about technology than it is about developing an approach articulated around principles of interconnectivity, efficiency, and sustainability, to creating systemic solutions for complex problems.

According to Deloitte (2015), Industry 4.0 is characterized by four main principles: vertical integration of smart production systems, horizontal integration of industrial networks, cross-disciplinary engineering, and acceleration through “exponential” digital technologies. It is a topic that remains to be further explored by academic researchers. Industry 4.0 could appear like the panacea to all society’s problems when reading industry and governmental strategic reports. However, it remains unclear how manufacturing firms will address Industry 4.0, how its principles will be translated into the industrial environment, how firms should undertake the journey to integrate digital technologies in their operations, and how this will affect how they interact with each other and value creation. More importantly, firms remain rather uninformed about the challenges related to the implementation of such technologies, and therefore there is a need for further research that can better articulate these challenges for practitioners in industry (Bartodziej, 2017).
Industry 4.0 in the Literature

Sheth (2007) identified six major contextual trends, presenting research opportunities for business to business (B2B) marketing doctoral students. Among others, Sheth (2007) named the first of its major trends as “Internet revolution,” perhaps an anticipatory term for what is now called Industry 4.0. The author presented a few interesting issues on the impact of the internet as a new ICT for B2B businesses. The internet has delocalized geographical markets, which bears many implications for traditional “territorial” marketing and sales organization, and for the activities and competencies required to manage such organizations. It has allowed companies to develop many new marketing tools, such as online product catalogs and configurators, bringing new real-time marketing information to transactions. Sheth (2007) also anticipated that it would lead to the emergence of B2B “bazaars” and reverse auctions, changing the way buyers interact with sellers and vice versa. Ten years later, Industry 4.0 and digitalization are now equally popular topics among researchers as they are for German industry practitioners (Kagermann et al., 2013). The two concepts are almost inseparable for the industrial marketing researcher. Industry 4.0 provides a greater context for digitalization; it is the trend that firms are following by undertaking the digitalization of different aspects of their organizations. Industry 4.0 encompasses a lot more than digitalization, as it also relates to governmental policies and multiple other societal factors (Kagermann et al., 2013; Zhou et al., 2016). Therefore, when addressing the trend of digitalization, one is addressing the Industry 4.0 trend, while focusing on digitalization as a change process affecting multiple organizational aspects (Brennen and Kreiss, 2015).

Several extensive literature reviews have been made to define Industry 4.0 (Alcácer and Cruz-Machado, 2019; Ardito et al., 2018; Ghobakhloo, 2018; Maresova et al., 2018; Roblek et al., 2016; Strange and Zucchella, 2017). Roblek et al. (2016) identified and defined nine “key concepts” of Industry 4.0: smart factories, new production system, self-organization, smart products, new distribution systems, human needs adaptations, CPS, smart city, and digital sustainability. They also identified CPS, IoT, IoS (Internet of Services), and smart factories as central technologies of Industry 4.0, and distinguished smart products and machine communications as subsets of CPS and IoT respectively. In their paper, they also coined the term Knowledge Management 4.0 (KM4.0), which they defined as the establishment of communication channels for the continuous real-time exchange of information about needs and individual situations of industry actors (customers, manufacturers, distributors, etc.) (Roblek et al., 2016). New information and communication technologies allow continuous communication to take place between humans, humans and machines, and between machines themselves (Roblek et al., 2016).
Through a patent analysis, Ardito et al. (2018) looked at which particular technologies enabling Industry 4.0 were relevant to firms in supply chain management and marketing integration. These technologies can create connections between firms’ machinery, production facilities, supply and ERP systems, and products and customers, through the production and sharing of operational information (Ardito et al., 2018). The authors listed the following enabling technologies of Industry 4.0: advanced manufacturing, additive manufacturing, augmented reality, simulation, cloud computing, industrial IoT, cybersecurity, big data analytics, and customer profiling. In their literature review, Alcácer and Cruz-Machado (2019) made a rather similar account of the technologies present in the Industry 4.0 trend. The authors described what they saw as the upcoming “Digitalization era,” where every business aspect should become digital, such as business models, environment, production systems, machines, products, and services (Alcácer and Cruz-Machado, 2019). Ungerman et al. (2018) conducted an empirical quantitative study on the impact of Industry 4.0 on marketing innovation. The authors identified 15 different types of marketing innovation, or digitalization, in the context of Industry 4.0. Their list included information terminals, big data, augmented reality, blockchain, the vertical lining of distribution channels, advergaming, autonomous distribution, additive manufacturing, Industrial IoT, social media marketing, CSR, cloud computing, engagement, viral and mobile marketing. In a review of the ongoing research on Industry 4.0, Ghobakhloo (2018) draws a picture of Industry 4.0 as a system of value creation comprising 12 design principles and 14 technological principles. The author concluded by proposing a strategic roadmap for implementing Industry 4.0. However adding also that there is no one-size-fits-all type of digitalization strategy suiting all businesses or industries. Industry 4.0 transition is pretty much always undertaken in unique ways by companies, based on each one’s core competencies, goals, resources, capabilities, etc. Strange and Zucchella (2017) conducted a literature review on how technologies of Industry 4.0 were affecting the deployment and location of activities in global value chains. The authors here focused on four technologies: IoT, Big Data and analytics, robotics and additive manufacturing. Industry 4.0 as a technological trend is broad in the scope of technologies that it encompasses. In fact, it appears to have very unclear boundaries or limitations as to which particular technology or set of technologies drive the trend, indicating that using listings or typologies of technology alone might not be appropriate to describe or define Industry 4.0.

Other authors have attempted to develop normative models for assessing how far firms had progressed or succeeded in their Industry 4.0 journey, which focused not just on technological aspects (Schumacher et al., 2016; Westerman et al., 2014). Schumacher et al. (2016) developed a model for assessing firms’ “Industry 4.0” maturity within the manufacturing industry. By assessing maturity, the authors mean assessing how far along firms are into
implementing changes related to Industry 4.0 over their entire organizations, including for the areas that they labeled products, customers, operations, technology, strategy, leadership, governance, culture, and people. The model is meant to integrate further than others the organizational dimensions of a digital transformation that used to focus mostly on digital technology capabilities. The authors proposed a model measuring the nine areas according to 62 items, which can be individually measured in the manufacturing environment by researchers and managers. It is fairly complex and distinguishes the dimensions as either “basic enablers” (products, customers, operations and technology), as necessary conditions for Industry 4.0, or as organizational. In a qualitative study on digitalization within the manufacturing industry, Lenka et al. (2017) developed a capability view of digitalization and identified three main digitalization capabilities and two main mechanisms through which value could be co-created through digitalization. They labeled the capabilities as Intelligence, Connect, and Analytic capability, and the mechanisms as either perceptive or responsive. Their conceptualization of digitalization in terms of capabilities and mechanisms contrasts with other more technical descriptions of digitalization (Alcácer and Cruz-Machado, 2019; Ungerman et al., 2018), and is perhaps also more suited for researchers less well versed in the technical aspects of this trend.

There seems to be no consensus on what Industry 4.0 entails, nor does there seem to be a defined formula for how firms should implement the digital technologies of Industry 4.0. Research on the topic involves studies of technologies and sets of technologies (Alcácer and Cruz-Machado, 2019; Ghobakhloo, 2018; Lenka et al., 2017; Roblek et al., 2016; Salkin et al., 2018; Ungerman et al., 2018; Ustundag and Cevikcan, 2018). The relative earliness in the development of this trend, and the relative lack of clarity around the concept of Industry 4.0, is an opportunity for increased collaboration between academics and practitioners to develop the learning on this broad industry phenomenon (Alcácer and Cruz-Machado, 2019). However, the literature shows that looking at Industry 4.0 may be too broad of an issue or phenomenon. It is a trend that affects industry, driven by the implementation of different technologies, but it is not what organizations are doing, and for researchers studying the firm, and firm interactions, the research focus should instead be on what firms are doing as a part of this trend. They innovate and change what their organizations do through digitization, digitalization, and digital transformation. This dissertation proposes to narrow the focus and create a clear distinction to improve the understanding of the change processes studied and bring clarity to our collective understanding of Industry 4.0.
Cyber-Physical Systems

The Industry 4.0 trend sees changes in human to machine, and machine to machine interactions. These interactions increase, and are increasingly done in novel ways, and changes to the interactions happen with the emergence of Cyber Physical Systems, or CPS (Kagermann et al., 2013; Schumacher et al., 2016). Here, CPS will be described as a concept that is key to understanding what drives changes in interactions in Industry 4.0 and how this particular trend differs from past introduction of digital technologies, such as computerization and automation (Garsombke and Garsombke, 1989).

CPS or Cyber-Physical System is a central concept to Industry 4.0 (Nwaiwu et al., 2020). Industry 4.0 entails several economic, social, political, scientific, and technological challenges as a multidimensional societal phenomenon. Schumacher et al. (2016) defined Industry 4.0 as the technological trend where the internet and related technologies served as support for the integration of “physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries to form a new kind of intelligent, networked and agile value chain” (Schumacher et al., 2016, p. 162). To yield the full benefit of this transformation, firms need to develop smart devices with functionalities specific to each one’s requirements (Zhou et al., 2016). One of the goals envisioned for Industry 4.0, is to develop flexible production models, producing customized and digitalized products and services, with real-time interactions between actors, products, and production facilities (Zhou et al., 2016). The goal is to build smart factories that integrate digital technologies into Cyber-Physical Systems. A CPS is a collection of transformative technologies managing interconnected systems of physical objects and ICT systems (Lee et al., 2015). CPS are specialized networks connecting physical objects from the industrial (or other) environment to the internet and present five functions: computing, communication, precision control, coordination, and autonomy. As an example, smart products are applications of CPS, integrating virtual and physical elements (Zhou et al., 2016). Because of the increased availability and affordability of sensor technology, computing systems, and networks, an ever-increasing number of firms and industries have been implementing these technologies into developing their own CPS (Lee et al., 2015).

Mobile technologies have been integrated into industrial applications to create intelligent processes with increasing qualities, portability functionalities, computing power, storage, and communication capability (Zhou et al., 2016). As these technologies emerged in the industrial environment, they have been applied to objects to have them communicate with each other, blending physical and digital into an Internet of Things (IoT). IoT is an important technical aspect of Industry 4.0, often found in the digital transformation of firms. IoT
may require many different technologies, including sensors, RFID (radio frequency identification), GPS, laser, 5G communication modules, etc. Cloud computing is another key technology of Industry 4.0, often employed by companies undertaking a digital transformation. It allows users to benefit from multiple services, software, computing, and other IT systems, with an internet connection and a browser. It is a form of on-demand access to computing and storage systems, where users only use and pay for what they need (Zhou et al., 2016).

Digitization and Digitalization

“Digitization” and “digitalization” are two closely associated concepts and often used interchangeably in a broad range of literature (Brennen and Kreiss, 2015; Henriette et al., 2015; Morakanyane et al., 2017; Ritter and Pedersen, 2020). Thus, the analysis of these phenomena can only be improved by establishing a clear distinction between the two. The use of both digitization and digitalization can first be traced to the introduction of computers in the 1950s. The first was defined early in the Oxford English Dictionary as the action or process of digitizing, as the conversion of text, pictures, or sound into a digital form that a computer can process, and then later as the adoption or increase in the use of digital or computer technology. Digitization refers to a physical or technical change process, to an action taken by individuals or groups, and can be described as “moving from analogue to digital data for streamlining existing processes such as building an operational backbone or introducing ERP systems” (Ritter and Pedersen, 2020, p. 181). On the other hand, digitalization refers to the change process from an organizational perspective to changes related to the use of digital technologies that can be observed and are taking place within a certain group, organization, or country. Digitalization is the use of digital technology, digital information, and other resources to create value in new ways (Gobble, 2018). Digitalization is not about replacing old analog processes with their digital versions, but about rethinking operations with the new paradigm offered by digital technology (Parviainen et al., 2017). Digitalization may refer to how many aspects of social life are restructured around digital technologies, communication, and media infrastructures (Brennen and Kreiss, 2016; Ritter and Pedersen, 2020). The changes taking place within digitalization may include digitization, but not only as the use of digital technologies to convert data. Digitization regards technical processes, while digitalization is concerned with business aspects. Digitization is an operational concept, while digitalization offers opportunities to redefine a business. Servitization is a term that is sometimes used synonymously for digitalization. However, servitization is a case of digitalization. It is associated with digitalization because servitization is a business model often driven by digitalization (Gobble, 2018).
At the center of these two processes, digital technologies are used to analyze data, create new data, replace physical steps performed by people, communicate, etc. Digitization is the process in which computerized digits represent data (Ritter and Pedersen, 2020). The nature of this process allows stripping information and communication of its imperfections, errors, repetitions, and static. The digitization of physical data creates digitized data, and digitized data presents multiple benefits. It can be more easily stored and compressed in large volumes. It allows for more activity between the user and the digitized information and cheaper, lossless, and easier ways of transferring data between different loci. The transfer of digitized data includes no transfer of physical material, only the copying of data and information from a data memory support to another.

Digitization is now ubiquitous, as digital technologies are routinely used and interacted within all strata of society because digital technologies can be found in all social groups and are part of most social interactions. In essence, this is what drives digitalization, as it is concerned with socio-technical changes resulting from increased digitization, as technology acquires its meaning and interacts with humans in an organization (Orlikowski, 2000, 2010). Digitalization is associated with several convergences. It creates convergences in infrastructures of communication, both in the physical network and in the digital system, as in seeing the convergence of multiple functions in single systems. It is also associated with convergence in the hardware terminals, or devices, as they are increasingly converging into single devices, such as smartphones or IoT-equipped machines. Functionally also as devices are increasingly centralizing multiple functionalities. To some extent, industries and markets also converge as a result of digitalization, as different sectors, such as computing or telecommunications, are consolidating (Brennen and Kreiss, 2015). These convergences imply changes in the value network; as firms interact, they also see further vertical and horizontal integrations through digitalization.

This dissertation argues that such greater systemic convergences should be understood not solely as the result of digitalization, but as resulting from the digital transformation of firms, which encompasses greater social and organizational changes than digitalization does. A digital transformation implies goals, a plan, and a strategy (Westerman et al., 2014). It can be viewed as the process of transforming an entire organization in a way that uses digital technologies to drive changes in all business and organizational aspects (Parviainen et al., 2017). Digital transformation encompasses greater organizational changes that may completely reshape the organization undertaking it. It is irreversible and can lead firms to greater levels of productivity and revenues (Westerman et al., 2014). The access to cheaper digital technologies paired with all other existing resource structures drives the digital transformation, bringing firms to rethink all aspects of their organizations, including...
what they sell, what a product or service is, and what their organization should be (Gobble, 2018; Westerman et al., 2014). Distinguishing digital transformation from digitalization, Industry 4.0, and digitization, appears even more important given that companies within the manufacturing industry have difficulties grasping the impact of Industry 4.0 and digital transformation (Morakanyane et al., 2017).

**Digital Transformation**

There is analytical value in explicitly making a clear distinction between the terms used in the broad body of research of Industry 4.0 (Mergel et al., 2019, Morakanyane et al., 2017, Parviainen et al., 2017). To understand what is happening in the manufacturing industry, it is important to grasp the multiple concepts and terms used to discuss this trend (Gobble, 2018; Morakanyane et al., 2017). Industry 4.0 goes hand in hand with digital transformation, as the global trend that sees firms undergoing their digital transformation but encompasses more issues than this change process. Digitization as a change process is to digitalization, what digitalization is to digital transformation. Each are change process nested within the other, but each more complex process encompasses more than the previous one. Each of these key concepts is summarized in Table 1 below. Each is also its own object of research and therefore should also be addressed on their own. This dissertation will focus on the phenomenon that is digital transformation as a complex change process taking place in industrial networks. The present research will be on organizations that interact and produce value with each other in the industrial network, and on the changes and effects that digital transformation brings to the network.
Table 1: Summary of Key Concepts

| Industry 4.0: | A global trend of complex change processes taking place across all industries, to achieve economic and sustainability goals. The trend is driven by governmental strategic plans, industrial efforts, societal constraints, and the development of cyber physical systems with digital technologies (Kagermann et al., 2013). |
| Digital Transformation | A complex change process of industrial networks taking place across organizational and technical structures, to achieve new value creation goals. The change process is driven by multiple investments, changes and developments undertaken by different actors across the industrial network (Henriette et al., 2015). |
| Digitalization: | A complex technical and organizational process taking place within and between organizational boundaries, to create value at a specific business process, product or service. The process is driven by the recognition of value creation opportunities from digital technological applications by a group of individuals (Gobble, 2018). |
| Digitization: | A technical change process taking place within organizational boundaries, to create user value and efficiencies, from the conversion of information from an analog to a digital format (Ritter and Pedersen, 2020). |

Defining the Digital Transformation

In the literature, the term digital transformation has often been used synonymously with digitalization, digitization, or even Industry 4.0, indicating a general lack of clarity over what these different concepts concern and a lack of maturity in the literature on digital transformation (Morakanyane et al., 2017). Digital transformation received many definitions, sometimes too general and reflecting a general use of digital technologies to serve business processes (Fitzgerald et al., 2014; Liu et al., 2011; Piccinini et al., 2015), or too specific and reducing it to a business model or business strategy (Berman, 2012; Bharadwaj et al., 2013).

Digital transformation can be defined as an evolutionary change process that can leverage digital capabilities and technologies to enable business models, operational processes, and customer experiences, to create value (Morakanyane et al., 2017). Evolutionary implies that digital transformation is a continuous change process taking place over time, with the understanding that although digital transformation evolves with time, its impact brings radical change(s) to the organization transforming. Digital transformation is
concerned with the adoption of new, emergent, and constantly evolving digital technologies and the knowledge to perform certain actions, or capabilities, related to digital technologies. This definition also implies changes happening on different levels, the action, the process, and the inter-organizational level, as in the customer experience. The main outcome of digital transformation is value creation, both for the firm transforming and for its customers. It can happen in different forms such as operational efficiencies, improved customer experiences, enhanced business models, strategic differentiation, competitive advantage, improved stakeholder relationships, cost, savings, etc. (Morakanyane et al., 2017).

Henriette et al. (2015) described digital transformation as a process driven by changes related to the implementation of digital technologies in all aspects of society. These authors’ view of digital transformation is quite broad and regards many issues including digital capabilities, digitization, internet technologies, data analytics, mobility, social networks, digital-related knowledge, and skills. Digital transformation appears to have a greater impact on larger organizations (Henriette et al., 2015). Firms undertaking a digital transformation execute digital transformation projects, which the authors define as the “implementing of digital capabilities to support business model transformations impacting entire organizations, especially operational processes, resources, internal and external users” (Henriette et al., 2015). A digital transformation doesn’t just happen, it is something that firms do and concerns all aspects of their organizations.

Parviainen et al. (2017) defined digital transformation as the changes in ways of working, roles, and business offerings caused by the implementation of digital technologies in organizations. Here, digital transformation is the consequence of the implementation of digital technologies and refers to changes taking place on multiple levels, including process, organizational, business domain (industry), and societal. Digital transformation is referred to as adopting digital tools to streamline processes and reduce steps made by human actors. It should allow the creation of new service and product offerings, make certain practices obsolete, as well as allow for improvement in how existing offerings are provided. It should lead to changes in roles, value chains, and ecosystems on the firm and the industrial network levels. On a societal level, digital transformation could lead to changes in social structures, affect professions, make certain work obsolete, and influence new policy decisions. Digital transformation may affect multiple areas of business, including the use of information technology, strategy and business models, products and services, internal and external processes, organization, and company culture.

Westerman et al. (2014) defined digital transformation as “the use of technology to radically improve performance or reach of enterprises.” The authors’
work brings some nuance into what digital transformation is and what firms undertaking a digital transformation are like. They named “digital masters” firms that successfully digitally transformed. These firms have leveraged “significant benefits,” meaning that a digital transformation has a quantifiable impact on a firm’s economy. Intermediary stages of digital transformation are qualified as either “beginner,” “fashionista” or “conservative.” Additionally, they categorize firms that undertake a digital transformation as from all but non-tech native industries. They “don’t do digital technology for a living.” Digital transformation implies successfully implementing digital capabilities, digital technologies, and leadership capabilities, vision, strategy, goals, oriented towards the digital. These two aspects are important in understanding that a digital transformation is not a linear path, and firms can achieve this process in different ways. Furthermore, digital transformation is not appropriate to all, and not to digital technology firms that grew digital from the start. It should instead be reserved for describing the journey of firms that are changing their DNA to become digital.

Mergel et al. (2019) looked at the digital transformation of governmental organizations and proposed to define digital transformation as a “holistic effort to revise core processes and services of (organizations) beyond the traditional digitization efforts.” This definition was drawn from observing public organizations, which have different goals than firms. They are not driven by growth goals (Penrose, 1959) but by efficiency and sustainability goals (Mergel et al., 2019). The authors observe that these organizations are undergoing digital transformations too, and although they may have different goals and be distinct in their administration and functions from the firms from the manufacturing industry, their definition may be relevant to describe certain aspects of digital transformation for the latter. The term “holistic” describes how it is the result of multiple and different functional actors’ efforts. A digital transformation should affect the core business areas of an organization beyond the simple implementation of digital technologies, implying that changes that don’t lead to changes in core business activities are not related to or don’t constitute alone a digital transformation.

There is not yet a unique and universal definition of digital transformation. However, several important principles of digital transformation could be drawn for a review of literature descriptions and definitions. Digital transformation is a change process enabled by access to digital technologies and initiated by firms with traditional industrial profiles. Firms undertake digital transformation by implementing change project(s) that can be concerned with all business aspects and have multiple impacts on the individual process, organizational, firm, industrial network, and environmental levels. Digital transformation is a process that may take different paths, and progress with time in different stages. A successful digital transformation should have for the
outcome an increased amount of value created for the firm and/or its customers. Additionally, it is implied that when researching digital transformation, one will be investigating change processes including digitization and digitalization. These can be understood as issues and key concepts of digital transformation. However, not all cases of digitization or digitalization might be related to digital transformation as the outcome of these change processes might not always be aimed towards a specific goal of deeper organizational transformation.

Factors of Digital Transformation

Firms that have been truly successful at undertaking a digital transformation and at leveraging significant benefits from digital technologies are rare (Westerman et al., 2014). Several factors can bring firms to undertake a digital transformation (Henriette et al., 2015). Firms can undertake a digital transformation because they have seen their activities threatened by new technologies. Digital technologies have shown to be capable of disrupting industries. As a result of the introduction of new digital technologies, the publishing and media industries needed to undergo radical transformations of their activities. Digital transformation may also provide market growth opportunities. It allows firms to expand existing markets as well as diversify to new markets. To do so firms can adjust or transform their business model. Digital transformation can also be driven by changing customer expectations. Customers may demand firms to introduce more technologically advanced offerings, as they see these changes happening in other aspects of their lives (Henriette et al., 2015). Although there are many apparent reasons for undertaking a digital transformation, studying the success factors and bottlenecks should provide some understanding of why many successful digital transformations haven’t been accomplished yet.

Scholars studying digital transformation have proposed several key success factors. Nwaiwu et al. (2020) proposed that to achieve a successful digital transformation, companies need to integrate old IT systems with new digital technologies, such as production-oriented IT systems with digital technologies. In other words, the new doesn’t replace but connects with the old. Those integrations are characterized by a high level of data analytics maturity over the entire value chain, meaning that they are associated with a lot of new data creation and therefore require good data analytics capabilities. Such change is constrained by resource availability, more specifically by the availability of digital technologies to create systems like CPS (Nwaiwu et al., 2020). Regarding so-called “traditional organizations,” Parviainen et al. (2017) developed a model for addressing digital transformation. The model is meant to help companies find their way through digitalization and find their positioning, meaning the desired digitalization impact, goals, and possible scenarios. It should
help firms evaluate their current situation in light of the envisioned positioning, from which they should set up a digitalization roadmap to fill the gap between their situation and vision, and then set up ways of implementing their digital transformation. It is not a normative model, but rather a framework for rationalizing a digital transformation. Digital transformations, although bearing similarities, will be unique to a firm’s situation as in its current business area, the state of technology used, the bottlenecks, available competencies, financial resources, and limitations. But it will also be specific to the envisioned impact of digital transformation, how much change the company foresees on its organization, its vision, and goals regarding its transformation.

Albukhitan (2020) investigated digital transformation in the context of the manufacturing industry and concluded that for firms to create value with a digital transformation, they need to integrate different cultures, processes, resource structures, and business strategies oriented towards the digital. A digital transformation strategy should encompass all previous aspects of business activities, development, production, quality control, delivery, etc. It is not a tabula rasa, as it should take into account legacy systems and processes to identify potential challenges and opportunities. Digital transformation doesn’t happen in a vacuum but in a context of historical pre-existing investments in technologies and capabilities into which new digital technologies will be integrated.

Loonam et al. (2018) described digitally enabled organizations as organizations that have successfully implemented new information and communication technologies, or digital technologies, to develop new business opportunities and growth. The new ICT includes virtualization, mobile communication, and data analytics integrated into back-office IT systems. The sum of these technologies allows the development of a holistic digital representation of the organization, as in a cyber-physical system. The implementation of these technologies is a digital transformation. The authors investigated the actions that firms should take to accomplish their digital transformation. They proposed that it is important to look at organizations’ business models, as these generally reflect how firms create and capture value. Business models are characterized by a set of roles and relationships among different actors, customers, suppliers, etc. Firms undertaking a digital transformation must have business models that are aligned with their digital transformation goals. Investigating the different managerial action types required to undertake digital transformation, the authors uncovered four main perspectives or themes of actions taken by firms: strategy-centric, customer-centric, organization-centric, and technology-centric. With these, they also highlighted challenges stemming from the competing nature of the types. Organizations need to rethink their relationship with their customers. Customers need to be seen as participants in the process as customer insights influence products and services. This
change will also challenge the power structures within organizations, exposing management to external influences and scrutiny. To overcome such challenges, Loonam et al. (2018) suggest the development of a digital-oriented culture (speed to market, collaboration, and smart use of data), a more bottom-up approach to technological implementation, and flexible management adaptation of business models to changes in technological demands.

There are several internal limitations to achieving a digital transformation. Firms need to have a certain set of digital-related competencies, capabilities, and culture to fully leverage digital technologies' opportunities and achieve the best results in their digitalization journey (Morakanyane et al., 2017). According to Westerman et al. (2014), most fail to exploit the benefits of digital transformation because they fail to develop appropriate digital capabilities and leadership capabilities, to develop ways of working, and a vision fitting to the digital reality. For Leading Digital, Westerman, Bonnet, and McAfee (2014, p. 17) surveyed 391 large organizations in 30 countries, from multiple (non-digital native) industries, to investigate how firms fared in their digital transformations. They categorized firms into four main categories according to how well these had progressed in developing digital and leadership capabilities. They identified them as either beginners, fashionistas, conservatives, or digital masters. Beginner firms had only initiated their digital transformations and on average performed below industry and regional average on profitability and revenues. Fashionistas had invested in digital technologies, but they lacked clear goals and vision around their digital transformation, and therefore also risked wasting unnecessary investments in technologies. Fashionistas tended to perform better in revenues generated from equivalent resources, but worse in profitability than industry and regional average. Conservatives had established strong leadership structures to carefully assess all investments towards a digital transformation, and were unconcerned about technological hype. However, their conservatism or excessive prudence had prevented them from developing the necessary digital resource capabilities. Conservatives appeared to perform worse on revenues created from equivalent resources and better in profitability than the industry and regional average. Finally, Westerman et al. (2014) named successful firms digital masters. Digital masters had both developed digital resource capabilities and leadership structures to undertake a successful digital transformation and were shown to perform significantly better in revenues generated from existing resources, and in profitability, than their industry and regional average. They are large firms from non-tech native industries that “don’t do technology for a living.” The authors argue that key success factors are not so much access and investments in technological resources, as it is about organizational resources like human capital, leadership, orientation towards making long-term strategic decisions for digital transformation and developing capabilities, and knowledge for successfully implementing and managing digital technologies. Digital masters
develop digital capabilities by changing and developing new business processes, customer engagements, and business models. They drive these changes with leadership and a vision. Westerman et al. (2014, p. 78) proposed five general business model types driven by digital transformation: reinventing or disrupting the entire industry, substituting products or services, creating new digital businesses with new products or services, reconfiguring value delivery models, and rethinking value propositions.

Impacts of Digital Transformation

In *Information Systems Research*, Stolterman and Fors (2004) wrote about digital transformation from the individual’s perspective and about its impact on individuals’ lives. In this early reference to digital transformation, they defined it as all the changes digital technologies cause in all aspects of human life (Stolterman and Fors, 2004). They saw digital technologies as increasingly common in all parts of individuals’ lives and companies’ activities. Technologies are not only present as single technological digital artifacts but are increasingly blended in all other artifacts. Therefore, firms and individuals within them have been increasingly experiencing their environment with and through digital technologies. This is what the authors argue is defining digital transformation. It is a change process that is not just affecting what firms and their employees do but reality itself (Stolterman and Fors, 2004). The digital transformation is creating an ever-interconnected world with blurred boundaries. Single objects are becoming less distinguishable from the whole and digital objects become material of the physical reality.

The most important expected impact of digital transformation for firms regards value creation, both for the firms and their customers. In a theoretical article, Matthyssens (2019) calls for a reconceptualization of value innovation in the context of Industry 4.0, arguing that the concept itself of value innovation, or value creation, will change because of the changes created by new technologies such as IoT. Matthyssens (2019) observed that firms would pursue value innovation and value creation, as the creation of new markets, enabling companies to “out-competence” rather than outperform their competitors. Value creation can happen in different forms such as operational efficiencies, improved customer experiences, enhanced business models, strategic differentiation, competitive advantage, improved stakeholder relationships, cost savings, etc. (Morakanyane et al., 2017). Westerman et al. (2014) observed that successful digital transformation led to largely greater economic outcomes for firms in both revenues generated from equivalent resources, and in profit. These outcomes are the results of the sum of multiple benefits created with a digital transformation, such as cutting costs “by up to 90 percent,” and reducing turnaround times (time to complete a process) by several multiples (Parviainen et al., 2017). Replacing physical information
supports, such as paper forms, allows for automatic collection and centralization of data, which can be mined to develop new knowledge in real time over a company’s performance, costs, and risks. The real-time assessment allows managers to pre-emptively address problems and issues before they become critical for the company.

A digital transformation may have an impact on multiple scales, from the process to the society (Parviainen et al., 2017). Internally, it can create efficiencies that can be achieved such as improved ways of working, the re-thinking of processes, the elimination of manual steps in production processes, improved accuracy of tasks with better data, etc. Digital transformation can also create several external opportunities, such as new business opportunities in existing business areas, improved delivery times and service quality, etc. It can create disruptive changes on an industry level, completely change business roles, or make a company’s business obsolete. On a societal level, digital transformation allows drawing new economic benefits. It is expected to reduce unemployment, improve the quality of life, facilitate citizens’ access to public services, and increase government transparency and efficiency, which should also be better for democracy (Parviainen et al., 2017). Although the potential impact of digital transformation can be great, it should also be understood that the likelihood of the impact realizing itself will be greater on a smaller scale than on a larger. Although impacts on all levels should be expected, they are simply not all equally likely to be realized.

Ojala et al. (2016) investigated the digital transformation of B2B distribution networks, specifically how digital technologies streamlined the buying-selling process, focusing on the selling side. The authors observed multiple benefits such as increasing profits by improving marketing and sales activities, which require increased collaboration between sellers and buyers. The authors observed the role of sales configurators, a form of sales automation. The authors observed that these were particularly relevant and impactful for firms selling technically complex products and selling to customers that may require very specific combinations of products and services.

Albukhitan (2020) proposed five categories of benefits derived from digital transformation for the manufacturing industry specifically. First, it should create improvements in productivity, through faster and higher quality processes. Productivity improvements can be achieved by creating machine connectivity (IoT) communicating essential maintenance data that can help prevent faults and improve outputs. Second, other benefits should be derived from overall quality improvements, through better production monitoring, output measuring, and fine-tuning. As an example, machine learning can be used to automatically assess the quality of products and apply the learnings back into the production parameters. A third benefits category relates to the cost reductions
made possible from the analysis of all the processes, machines, production line, transportation, and logistics data captured. Data analysis helps to find new cost reduction opportunities, as well as to do better inventory management. Fourth, there are benefits related to customization of product offerings. Digital technologies allow firms, while still producing efficiently and at a competitive price, to develop new functionalities and more customized and specialized offerings that better address customer requirements and needs. Finally, digital transformation should lead to safety benefits in the workshop environment for the production line employees. The addition of sensors, robots, and IoT creates an additional safety layer for employees, reducing the number of human errors and the number of accidents and injuries.

Lenka et al. (2017) also looked specifically at the manufacturing industry and ran a qualitative study on four different manufacturing companies to investigate what constitutes digitalization capabilities, and on how they allow value co-creation in B2B business relationships. The authors observed that digitalization and servitization go hand in hand for industrial manufacturing firms. Firms rely on digitalization to address increasingly complex and dynamic customer interactions. They also observed positive impacts echoing Albukhitan (2020) findings in terms of quality, efficiency, and offering related benefits. The implementation of digital technologies into the manufacturing environment offers opportunities for firms to develop new product functionalities, to have increased reliability and efficiency, and overall increase the value provided by manufacturers to their customers. The authors also noted that the manufacturing industry has been increasingly vested in servitization enabled by digital technologies, and thus increasingly investing resources in developing digitalization capabilities. Such capabilities might lead to further developments, including developing smart products by embedding intelligence and remote functionalities in conventional products, and improved data gathering and analysis capabilities (Lenka et al., 2017).

Bauer et al. (2018) evaluated the outcome of different Industry 4.0 cases and digital transformation projects where different firms implemented the same digital IoT-based technology. The technology would allow the firms to create direct horizontal integration within their value chain, between manufacturer and supplier, as well as decentralize the collection of information, create real-time control, allow flexible physical positioning of the products, and improve stock transparency. The benefits for the companies were the security of supply, optimal stock management, elimination of scheduling processes, consumption-related deliveries, elimination of manual ordering, retrofitting with changing other existing processes, optimization or material goods flows. They created several process efficiencies and quality improvements (Bauer et al., 2018).
Strange and Zucchella (2017) expected that IoT should overall reduce transaction costs and, while possibly increasing cybersecurity risks, reduce the number of intermediaries and simplify value chains. The authors also foresaw that Big Data and analytics should help firms improve their productivity and financial performance. Thanks to lower costs and increased performance, robotics has recently become widespread and a viable economic alternative to human labor. Strange and Zucchella (2017) anticipated that robotics might bring the reshoring of production activities. Additive manufacturing should democratize manufacturing, CAD (computer-assisted design) software being virtually usable by anyone and anywhere. This technology should also bring a high level of customization and relative ease in the production of very complex products. The authors believed that the technologies of Industry 4.0 should overall simplify global value chains by reducing the number of production activities, their dispersion, and the relationship between the different involved actors.

Ungerman et al. (2018) attempted to measure Industry 4.0 to determine the most important effect of this new trend on marketing innovation, as perceived by industry actors. They conducted a quantitative study among companies in the automotive industry and anticipated that the greatest effect of Industry 4.0 should be perceived increased competitiveness, increased productivity, and corporate cultural changes. From their survey, the authors could identify a dozen expected impacts by the industry participants. They expected that following Industry 4.0 and implementing new digital technologies, should help firms better advertise or communicate to their partners and customers that they had a long-term vision for their business. Like in other articles cited above, they expected that it would also lead to a decrease in the amount of manual labor (Hungerland et al., 2015; Matthyssens, 2019; Roblek et al., 2016), while they would see an increase in requirement for highly trained individuals. This would lead to them having better customer knowledge and to gain a new competitive advantage from digital marketing innovations. They expected to see overall cost reductions in the long term, to create new growth strategies thanks to improved technologies. Labor productivity was expected to increase dramatically, as production processes would be accelerated and refined. Distribution channels also would be shortened and facilitated by industrial IoT, which will automate the ordering to the production process (Ungerman et al., 2018). They observed that the use of IoT would also lead to more vertical integrations, which would lead to more mergers and acquisitions, but also more autonomous distribution, a similar observation that other researchers have made on the impact of IoT on value chains (Bauer et al., 2018; Strange and Zucchella, 2017). Finally, industry respondents thought that Industry 4.0 would lead to having improved service and product offerings, to have a better business overview and strategic planning, and to the creation of new ways of working and new business models. Their respondents didn’t seem to agree on
whether total costs would be increased or decreased overall with Industry 4.0. Instead, it appeared that they expected them to increase in the short term, because of the investment required in new digital resources. These investments would lead to a cost decrease in the long term. Although they perceived all impacts as important, they foresaw the potential increased competitiveness (due to increased understanding of customer needs) as the most important impact of all. Lastly, their research also showed that large firms were quicker to embrace and more sensitive to digital transformation than small and medium-sized firms (Ungerman et al., 2018).

Reddy and Reinartz (2017) anticipated several negative and positive impacts on multiple levels for the firm, customer, individual, and society. Their reasoning is based on several assumptions about digital transformation. They expect that the adoption of digital technologies will lead to lower costs of interaction. This lower cost should increase interactions and therefore exchanges and subsequent benefits. The structure of these exchanges should be affected by the increased number of connections between individuals and will increasingly change from being linear and single to be increasingly multiple and networked. A lot more data will be created from the increased distribution of computational power (IoT). Changes are permeating all aspects of life and are essentially irreversible. These fundamental changes should lead to new benefits and risks. It will allow firms to deliver new products and services, with more convenience and choice, experiences, and better prices to customers. On the other hand, the changes will create increased costs of learning and information search, loss of privacy, and create temporary performance uncertainty for customers inherent to the change. Companies should be able to develop greater efficiencies and new opportunities to create value and diversify their businesses. Still, they should also see a certain loss of value chains, loss of configurations, increased competition from new entrants, and technologically more advanced competitors. They will have to deal with faster innovation cycles and technologies (Reddy and Reinartz, 2017).

Digital transformation presents multiple potentially positive impacts, which vary depending on which process, industry, or scale one takes to observe it. However, these positive impacts or benefits of digital transformation seem to also be related to several challenges.

Challenges of Digital Transformation

To achieve a successful digital transformation, firms must mitigate and overcome a number of challenges (Albukhitan, 2020). Traditional processes, manual and time-consuming processes, may become obstacles once the firm adopts digital technologies. Employees with a strong relation to traditional processes may present a certain resistance to change. Change can challenge
employees’ roles, job security, and more generally bring them out of their comfort zone. Companies may also feel too comfortable in their legacy business model and therefore feel no motivation to change. In that regard, firms producing with a limited amount of automation, and with a focus on repetitive manual tasks, may have seen more hurdles to their digital transformation. Parviainen (2017) shared a related point, arguing that digital transformation may create priority re-alignments within firms, with new priorities conflicting directly with legacy priorities. Parviainen et al. (2017) investigated some case studies where firms adopted digital technology and observed some bottlenecks. Many companies have failed to implement new IT systems because of previous generations’ knowledge management systems. They have failed because they didn’t manage to get the organization over the previous systems used. Firms failed because they failed to change mindsets and processes oriented towards the digital or build culture fostering change in the firm. Firms failed also because they didn’t have an overall digital strategy, and didn’t have a long-term plan for their digital technology implementation.

Digital transformation may also be challenged by inflexible company structures, as the process requires changes from technologies to business models. Strong hierarchical structures will obstruct the changes related to digital transformation, as these may challenge those structures and the inherent power dynamics (Albukhitan, 2020). These barriers were well described by Hunter et al. (2020) when investigating digital transformation within the construction industry. The authors observed a firm at the early stages of a large digital transformation project. The firm was setting out to implement several digital marketing-related investments, restructure its organization, and develop a vision and mission statement around its digital transformation. The authors observed some barriers and hurdles to digital transformation, including skepticism, a perceived lack of control, and perceived increased risk around the use of digital communication tools. They also observed a lack of mobilization of internal competencies for the implementation of digital transformation projects, misalignment of formal roles and competencies, friction in bureaucratic administrative structures of the firm causing inefficiencies, and friction caused by information gatekeeping by individuals leading to inefficiencies.

Large investments may be necessary to a digital transformation, and therefore limited budgets may obstruct the transformation. Introducing technology alone is not sufficient to lead a digital transformation, and a lack of appropriate knowledge and competencies for integrating the technology can challenge the success of the transformation (Albukhitan, 2020). Firms will need to hire new competencies to manage digital technologies and change (Matthyssens, 2019; Roblek et al., 2016). In their article, Roblek et al. (2016) explain that there could be resistance to changes in individuals' mindsets and ways of working. They suggest that firms will need to increase the knowledge around the use of
digital technologies and adopt a “digital thinking” to manage the digitalization process. Digital transformations taking place in industries are expected to put pressure on the overall job landscape (Roblek et al., 2016). They will demand a certain restructuring of jobs within industries, creating more qualified positions while making the less qualified roles disappear. Digital transformation in the long term is expected to decrease the number of jobs, according to several authors (Hungerland et al., 2015; Ungerman et al., 2018).

Digital transformations are forcing firms to break from their industries' traditional business models (Matthyssens, 2019). The digital mindset is different and requires a new way of understanding innovation and the acquisition of new capabilities. Digital innovation is not so much about the technological aspects, as it is about re-defining an industry, business models, and creating new customer outcomes. Matthyssens (2019) identified several challenges regarding achieving such digital innovation. First, the potential lack of an inquiring and non-traditional mindset and the difficulty of unlearning and sense-making echo the suggestion made by Roblek (2016) that firms should develop new ways of working and a new mindset around digitalization. Additionally, companies’ inertia, caused by established strategic frames and routines, and learning myopia can also be challenging to a digital transition. To address these challenges, Matthyssens (2019) proposed that firms should adopt what he describes as the “IoT mindset” (Internet of Things mindset). This is achieved by addressing real-time and future needs in a perspective manner, doing continuous refreshing of products by updates using IoT-generated information, enabling recurring revenue (subscription model), providing personalized and context-driven customization of offerings, and coupling and leveraging other ecosystem partners for mutual benefit.

According to Ghobakhloo (2018), another challenge for companies, beyond challenges regarding their capacity to innovate, is that Industry 4.0 will require new strategies, organizational models, and organization-wide changes in physical infrastructure, manufacturing operations and technologies, human resources, and management practices. According to the author, manufacturing firms might simply avoid undertaking a digital transformation out of fear of not owning all single technological resources and design principles of Industry 4.0. Therefore, companies need to draw an individual strategic roadmap before undertaking a digital transformation of their businesses, to better allocate time and investments (Ghobakhloo, 2018). Industry 4.0 will also require the removal of functional silos, willingness to change, a supportive culture, and data transparency across entire value chains. However, according to Ghobakhloo (2018), this might be very difficult to implement in the short term for typical manufacturing industry networks given the required amount and depth of changes.
Lastly, digital transformation brings new concerns and challenges related to cybersecurity, as the new technologies often connected to the internet can expose firms to new risks (Albukhitan, 2020). Many authors and studies bring out the same concern for cybersecurity-related risks as a hindrance to digital transformation or the use of digital technologies (Albukhitan, 2020; Kane et al., 2015; Strange and Zucchella, 2017). As an example, big data and data analytics may help firms to be more productive and to deliver better offerings to their customers, but they might also pose a risk for privacy, as data, including private data, becomes exchanged as a commodity (Strange and Zucchella, 2017).

In summary, firms undergoing a digital transformation have to deal with multiple and varied challenges. These may come from the legacy structures of organizations in the industrial network, from individuals’ skepticism towards change or from inflexible organizational structures. The cost of entry stemming from initial investments for acquiring the resources may also act as a barrier. Digital transformation appears to also raise new concerns related to new risks or vulnerabilities that digital technologies are creating. These challenges seem to be found in many observations; however, they also seem to stem mostly from issues internal to the firm, not from their interactions and dealings with other firms in their industrial network. The literature has been less focused on the inter-organizational aspects of digital transformation and the challenges that may emerge from the interaction with other firms or other actors in the industrial network. It appears that by not investigating the phenomenon in the context of the industrial network, the literature may have developed a blind spot for other sources of challenges to organizations undertaking changes to create value from digital transformation.

The Theoretical Perspective

Digital Technologies

Our understanding of technologically driven changes largely depends on how we view and define technology itself. Here technology is a black box, a resource which can be produced as the result of a combination of other resources, of other technologies, and which presents certain functionalities that allow individuals interacting with them to create value. The insertion of digital technology by organizations into established structures across the industrial network drives digital transformation, driving multiple changes and value creation for the individuals interacting directly or indirectly with digital technologies.
The technologically driven trend Industry 4.0 sees digital technologies driving many changes. Technology is intrinsically related to the nature of our world, our human society, and its most fundamental issues. It has redefined our lives, and changed how work is done by taking the place of many manual tasks. Technology has even assumed certain biological functions by replacing certain malfunctioning organs. In other words, technologies are part of the very self of human beings. Technologies are the most known or understood objects of human lives, as they are the results of human designs and inventions. However, paradoxically, little is known of the nature or deepest meaning of technology. In essence, all is known about individual technologies and their history, and the sum of all this knowledge covers all technologies in their details, but the principles governing the nature of technology are lesser known. Arthur (2009) posits that a reason for this asymmetry may stem from the fact that technology has been mainly studied by social scientists and philosophers, taking individual technologies as stand-alone and separate black-box type of objects, with apparent functionalities and features, but with no insight on the inner aspects of these. Arthur (2009) argues that writing about “evolution” of technology in the biological and Darwinian sense is inappropriate, and that a new theory of evolution of technology is required. He proposes to describe technology as follows: that technologies “form using existing primitive technologies as components, or building blocks, for the construction of further new technologies. Some of these in turn go on to become possible building blocks for the creation of yet newer technologies” (Arthur, 2009, p. 21). He refers to this combinatory mechanism of technology, as building block of other technologies, as combinatorial evolution. The author adds that by itself this mechanism is not sufficient to explain the existence of certain technologies.

The meanings that we assign to technology vary from designating the single concrete objects, the device, process or method (a single technology), to the collective and abstract meaning as a phenomenon which may affect our lives positively or negatively (technology). Arthur (2009) posited that technological evolution happens with purpose and to capture natural phenomena. It serves to capture phenomena occurring in nature, such as gravity or electricity, and is developed through the knowledge created by scientists studying these natural phenomena. Therefore, technology is not science but a product of science. Technologies, such as digital technologies, also exist to fulfil a human purpose, they have a function or functions and perform operations or tasks. A technology both embodies an intangible sequence of actions, method, or algorithm, to accomplish an operation, which Arthur (2009) defines as the software, and a physical or tangible equipment or set of tools to execute the sequence of actions, or the hardware. The two reflect two aspects of technologies, as devices and processes.
Arthur (2009) outlines a structure of technology in terms of several principles: combination, modularity and recursiveness. First, the combination principle reflects that technology is a combination of components, put together for a purpose. These components or parts are arranged around a principle, method, or essential idea, that allows the technology to function. The principle, or essential idea, is expressed via the assembly of physical components. The technology will have its components organized, depending on its complexity, in a main assembly performing its principal, or base, function. The main assembly may be supported by sub-assemblies of components, which will provide supportive functions to the main assembly. The modularity principle allows for more resilience in technologies. A technology consisting of a single assembly of several individual parts will be less resilient and more complex to assemble than a technology that consists of the same number of individual parts but organized in a number of modules or sub-assemblies. Modularity allows for a technology to be assembled in its separate modules in different assembly points, making the assembly work more efficient. Similarly, the modularity principle makes the design work more efficiently. Modularity also allows for a technology to have modules to be replaced individually when a failure occurs.

The structure of technology presents the recursiveness principle. Technologies, because of their structure, main assembly, sub-assembly and elemental parts, are hierarchical. Depending on their complexity, a technology can have several layers, from the main object to the elemental part constituting its structure. Each of these elements and sub-elements performs a task, each has a purpose, and each can be defined as a technology. Therefore each technology is recursive as each is composed of technologies of technologies, as “systems that consist of systems, interconnected, interacting and mutually balanced” (Arthur, 2009, p. 40). The recursiveness applies both when looking at lower and higher layers of technologies. Technologies may be used in a greater context, greater systems, which together perform a greater function. This principle also implies that changes taking place at one layer, may imply changes in other related layers.

Digital technologies follow these principles of combination, modularity and recursiveness, developed by Arthur (2009). They are combinations of tangible and intangible technologies, of material and digital objects, which can be separated into different sub-technological elements, and which are parts of greater technological systems of interacting and interconnected technologies. Digital technologies emerge from a combination of existing technologies, as the new is made possible by the existing. They serve a human purpose, as they advance efforts made by firms, which are by combining technological resources with other technologies, to create systems of systems, such as cyber physical systems. Technologies are the means of production with which society produces
value, and changes to technologies affect changes to value production (Arthur, 2009, pp. 191–202). Therefore, to understand how technology leads to value creation, how they are combined by different organizations in the industrial network within and across organizations, into new technologies with new functionalities, forming recursive systems of technological systems that serve greater value creation purposes, should be investigated. In this dissertation digital technology is black-boxed and investigated as a resource that interacts and is combined with other resources. It will also be discussed as a phenomenon for which individuals across industrial networks create multiple cognitive expectations.

IMP Research on Digital Technologies

Similarly to Arthur (2009), the IMP literature has described technologies as resources that are combined with other resources in different structures spanning the industrial network, for the purpose of creating value for the actors that interact with them (Håkansson and Waluszewski, 2002a). IMP research has also had an important focus not just on technology but also on information technology and digital technologies. The topic of digital technologies can be traced in early publications. Because of their key role in inter-firm interactions, digital technologies always have had an important place in IMP research (Baraldi, 2001, 2003; Salo, 2003). Therefore, digital transformation, a complex phenomenon affecting industrial networks, characterized by an important level of change induced by digital technologies affecting firms’ interactions and value creation, has naturally emerged as a key topic of the IMP approach.

In 2001, Baraldi (2001) investigated a product-centered industrial network, where IT technologies were used to create efficiencies and increase the effectiveness of various aspects related to product manufacturing, including lead times, costs, quality, flexibility, and adaptability. The author observed that information systems and information technologies created a meta network, or a digital representation of a physical production resource network. The IT-based “meta-network” translated relations between resources and activities into a digital representation, creating new affordances for managing and coordinating resources and activities with IT technologies. Baraldi (2001) did an analysis of the physical resource and activity network, and of the IT resource meta-network, and observed that IT tools were based on models that essentially were simplifications of the physical reality, and that the representation that these tools created sometimes failed to match the complexity of the physical resource and activity network.

According to Salo (2003), when investigating the digitalization of business relationships, one should understand that it will impact both the directly related parties in the dyadic relationship and indirectly related parties in the
wider network in which the relationship is embedded. Salo (2003) developed a conceptual framework based on the IMP approach to describe digital business relationships. This framework described them as constituted of episodes, which include acts that are either digital and/or physical (“atomistic” as in made of atoms, in the paper) in nature. The combination of digital and physical acts characterizes the different digital episodes, which in turn characterizes the digital business relationship. Karjaluoto (2003) elaborated on this conceptual framework by bringing nuance to the model. There, episodes with solely physical acts are described as traditional, episodes made of both physical and digital acts as transitional, and fully digital episodes as digital. In a traditional episode, parties will interact face to face, using physical artifacts to conduct their transactions; in the transitional they introduce tools like emails while keeping some degree of direct interactions; and in the digital, all interaction will take place digitally (emails, webstore, etc.) (Karjaluoto et al., 2003). Parties of a given business relationship can move towards having more digital episodes, as the interaction ages and the number of acts are repeated between them. As an example, when re-ordering items multiple times, the exchange becomes simpler as it requires less information to be transmitted from the supplier to the customers. Once a customer is “educated” on the product that they purchase from a given supplier, they don’t need to be trained and taught again about how to use their purchase.

Baraldi and Nadin (2006) looked at the digitalization of inter-firm business relationships in the Italian textile industry. The authors used the IMP approach to analyze their case and identified sources of challenges related to different phases of an IT infrastructure design and construction project aimed at digitalizing business relationships. The first such source of challenges identified, was the complexity of the business processes and heterogeneity of the resource related to the relationship. The work involved in the interactions was found too complex to codify in an IT system. Individuals would carry different views of the resources involved, therefore making developing a common communication standard challenging. Another source of controversy was the power and dependence dynamic between the parties involved in the relationships. Some firms feared losing control over or being locked into a relationship by adopting an IT system from a larger firm. Digitalization here was found to affect these two. Trust was identified as another source of challenge. The authors explained that a certain level of trust was necessary between firms for them to be willing to share potentially critical information via an IT system with each other. Later in the project, they identified several cognitive issues, regarding the coding of information and processes across an entire network into a software. The software is an abstraction of complex and different cognitive frameworks that cannot realistically digitalize all processes and interactions of an industry network (Baraldi and Nadin, 2006).
Salo et al. (2010) investigated the influence of information technologies on the bonds that make business relationships, and more specifically on digital bonds. Taking a dyadic perspective, the authors aimed to identify which type of digital bonds exist in business relationships, and how these can be managed. The authors defined digital bonds as “a hybrid IT that is built out of two or more shared and integrated IT which is used for information exchange and transactions in the relationship or a network” (Salo et al., 2010, p. 5). They empirically identified four types of digital bonds according to different degrees of complexity of the IT involved and according to the perceived importance of the dyadic relationship of which it is an element. They also characterized them by their proposed balancing/managing strategies, including oversized digital bonds, strong digital bonds, weak digital bonds, and strategic digital bonds. Salo et al. (2010, p. 4) described bonding as a “gradually evolving process where two parties are tied together.” How tied the parties are, depends on several issues underlying the bonding process. So, a digital bond occurs when two parties invest in mutually adapting digital resources. Firms will invest in digital capabilities, such as a shared IT architecture, which requires trust and willingness to invest in the business relationship. They also need to share a common goal. The authors also raised a few concerns regarding security and privacy of shared information in digital bonds. In relationships with strong digital bonds, security is made complex because either of the counterparts might own the information shared in the relationship. The question of ownership of a company’s information by another might be a source of friction. Additionally, when a bond is untied, a new supplier or customer must be tied into the existing digital resource structure for the new bond to yield benefits.

Ojala et al. (2016) investigated the effect of digitalization on distribution networks and focused on sales configurators, a type of sales force automation. Their goal was to empirically investigate how digitalization (and digital sales tools) might affect the formation, structure, and development of distributor relationships and networks, by using the industrial network model. Depending on individuals’ perceptions of the digital tool, and on firms’ IT capabilities, different potential benefits for this tool emerged. Their article supports that digitalization requires new resources and changes in activities intra- and inter-organizationally, for different parties to reap the benefits from the digitalization of their business relationship (Ojala et al., 2016).

Pagani and Pardo (2017) investigated how digitalization is affecting exchanges taking place in B2B relationships. The authors looked at changes in these exchanges using the characterization of business relationships offered by the ARA model. This means that they looked at how digitalization affected activity links, resource ties, and actor bonds within a business relationship. Digitalization is transforming the business-to-business relationship because it
offers firms new technologies for managing these interactions. The authors defined digital transformation as “digitalization of previously analog machine and service operations, organizational tasks, and managerial processes in order to drive new value for customers and employees and more effectively compete in an ever-changing digital economy” (Pagani and Pardo, 2017, p. 185). Digitalization here covered very diverse types of technologies, based on the use of the internet, such as EDI systems (electronic data interchange), webpages, web marketplaces, extranets, web auctions, MRP (manufacturing resources and planning systems), ERP systems, RFID technology, intelligent agent systems, etc. (Pagani and Pardo, 2017). The authors identified an activity link-centered type of digitalization, the primary effect of which is to facilitate coordination between already existing activities. Resource ties-centered digitalization relates to digital resources which when combined with existing resources, support the creation of new activities carried out by actors. And third, they identified actor bond-centered digitalization, where newly introduced digital resources support and create new bonds between actors (Pagani and Pardo, 2017). The authors suggested that their framework could help bring clarity into understanding how digitalization affects firms’ relationships with suppliers, customers, and other actors in a given industry network. They also called for more research into how companies address digitalization internally and what strategy they should adopt to create new activity links, resource ties, and actors bonds from digital technologies (Pagani and Pardo, 2017).

Salo et al. (2020) applied the interaction framework of the IMP approach (Håkansson, 1982; Håkansson and Snehota, 1995), to investigate the digitalization of buyer-seller relationships. The authors used the interaction framework to describe how digitalization gradually takes place. They proposed to present on the one hand its evolution in terms of structural aspects, and on the other in terms of processual elements. Across these dimensions, the relationships evolve in different degrees, representative of investments and changes made on both structural and processual dimensions. During the digitalization of a buyer-seller relationship, digital infrastructure is added as a structural element to the relationship. It is strengthened by successive investments and resource adaptation, and these enable digital communication which is added as a processual element to the relationship. Their findings indicate that digitalization takes place gradually over time, as a series of successful investments and adaptations across the business relationship. Firms will adopt certain digital technologies to solve managerial challenges and problems. The investments will create benefits, leading to further digital transformation investments, and a “virtuous cycle of digitalization” will emerge. The investments in digital infrastructures allow for digital communication across the relationships to be established, and leads to further technologies being implemented. However, according to Salo et al. (2020), the opposite is also possible as a
reversal of digital transformation, and a termination of the relationship may take place.

IMP researchers have been taking an interest in digital technologies, digitalization, and more recently digital transformation. Authors have used the interaction approach (Håkansson, 1982; Håkansson and Snehota, 1995) to study the changes caused by digital technologies to business relationships (Salo, 2006; Salo et al., 2020); the resource interaction approach (Håkansson and Waluszewski, 2002a) to study changes in IT resource infrastructures and interactions across industrial networks (Baraldi and Nadin, 2006; Hunter et al., 2020); as well as the ARA model to unpack the activities, resources, and bonds layers of business relationships (Ojala et al., 2016; Pagani and Pardo, 2017; Salo, 2006).
The Empirical Setting

Empirical data was collected throughout the ISNET project lifespan since its initiation in 2016. The data was collected in several phases, and case descriptions were drawn and redrawn after each successive data collection episode creating a different screenshot of the empirical context. Two cases of industrial networks were drawn in the context of this dissertation work, Sandvik Machining and Manufacturing Solutions, and the Cibes Lift Group. As a result, four papers on qualitative research were produced, on either or both cases.

The ISNET Research Project

Innovative Strategic Networks in the Age of the Digitalizing Manufacturing Industry, or the ISNET project, was initiated by marketing researchers at the University of Gävle, Sweden. The group observed the multidimensional impacts that digitalization had on the manufacturing industry (Friedrich et al., 2011). Having established contacts with industry practitioners, who naturally shared similar concerns regarding the technological trend, the inspiration for the project emerged naturally. The research group observed that digitalization would lead to deep changes for the manufacturing industry, which had implications for several industrial marketing issues, for innovative networks and creating and developing business to business relationships, collaboration, and networking. It presented potential changes for firms’ business innovation processes happening in industrial networks, and for the dynamics of their inter-organizational relationships and business acumen. From these observations, the research group sought funding from the Knowledge Foundation (KK-Stiftelsen), to study how two large Swedish manufacturing firms handled value creation and innovation in an increasingly digitalizing industry. The project was structured around four main preliminary objectives. The first aim was to investigate challenges for value creation within innovation processes taking place during the interaction between different industrial actors facing technological change related to digital transformation. The second was to analyze how networks of inter-organizational relationships may be affected by digital transformation. Third, how digital transformation may affect resource interaction within the development, production, and use settings of novel technology.
would be analyzed. Lastly, the project was aimed at filling a gap of missing agency within the strategic network research by developing a dynamic model for managing innovation processes.

The project was structured as a qualitative study based on an interactive research approach, to develop a collaboration between the research group and practitioners aimed at fostering joint learning and critical knowledge production (Nielsen and Svensson, 2006). The approach was anticipated to create opportunities for long-term competence development and support learning within the participating companies, while at the same time linking the research process to the companies’ activities. A dynamic model for managing innovation processes would be developed and validated by doing industrial case studies, in collaboration between industry practitioners and the research team. The ISNET project was designed in four phases, following the principles of Design Research Methodology (Blessing and Chakrabarti, 2009). A research clarification phase developed the general understanding of the existing issue or problem, using a situation analysis of challenges and key factors of value creation in an industrial network undergoing rapid technology-driven changes. Secondly, a descriptive study would focus on the identification and mapping of the innovative strategic networks. A prescriptive study, as a third phase, developed a dynamic innovation process model for managing innovation. Finally, a second descriptive study was done to evaluate the implications of the dynamic innovation process model.

The ISNET research project included diagnostic, descriptive, retroactive, prescriptive, and explorative components. Its main aim was to investigate the challenges and key success factors of value creation of innovation during the interaction process within manufacturing industrial networks. The case study approach (Yin, 2014) was used all through the project. It is a commonly used methodology and has played an important role for theory building in industrial marketing purchasing research (Visconti, 2010; Wagner et al., 2010). A qualitative research methodology was chosen to develop a deeper understanding of how case companies could innovate collaboratively. Data collection was collected through semi-structured interviews with key individuals, managers, at both case companies. The ISNET project was based on a combination of real-time and retrospective cases of the participating companies, which granted access to various actors in their value networks. A PhD student was hired within the ISNET project to work actively with the project for three years. The research group would participate together with the doctoral student in the data collection work. Several workshops were organized with industry practitioners and researchers at the end of each project year according to themes based on what had been identified or on what emerged from the project. The workshops would provide competence development via feedback
from researchers and empirical contributions to research via feedback and discussions from the industry practitioners.

The analysis of the collected data followed the Miles and Huberman (1994) guidelines, defining data analysis as consisting of three concurrent flows of activity: data reduction, data display, and conclusion drawing. Data analysis for the ISNET project would follow six steps. From the project's starting point, a review was conducted of the literature relevant for the project, including IMP and digital transformation-related literature. The review would lead to developing analytical tools. The empirical data would then be documented and coded in a case study database. Third, analysis within the cases would be done to become familiar with and to identify unique patterns for each (Eisenhardt, 1989). Fourth, a cross-case analysis would be completed to identify general patterns across cases, to go beyond the initial conclusions (Eisenhardt, 1989). Fifth, a comparison of the analysis results with existing theory, the literature on the topic, would be done. Finally, the ISNET research project conclusions would be drawn.

Sandvik Machining and Manufacturing Solutions

Sandvik Machining and Manufacturing Solutions (SMMS) is a Swedish market-leading metal cutting tool manufacturer. SMMS is one of the five business areas within the Sandvik Group. Among the different business areas within the Sandvik Group, SMMS is also the largest in revenues and operating profits (Sandvik, 2017). SMMS provides cutting tools for the metal cutting industry, predominantly to customers in the automotive, aerospace, energy, medical, die & mold, and general engineering industry segments. SMMS is the global market leader in the cutting tool industry. SMMS is organized in a group of different organizations that they call product areas or brands. These product areas include Sandvik Coromant, Walter, Seco Tools, and Dormer Pramet for metal cutting tools. They are of different sizes, have different histories, and each operates as an independent profit center. All four product areas have been undertaking a digital transformation of their business in different ways.

At the start of the ISNET project, SMMS had already taken some initiatives to learn more about the business opportunities and challenges the manufacturing industry's digital transformation might lead to. SMMS wanted to make large investments in digital technologies into digital manufacturing to transform itself and enhance its value proposition so that it can further help its customers increase their productivity and outcomes and their satisfaction with SMMS as their supplier. Apart from significant investments, this initiative towards digital manufacturing also meant that SMMS would need to move outside the areas where they normally focus their R&D efforts. It further meant
that SMMS would need to complement its existing business models with a wider range of alternatives or move its existing business models towards more flexible models. Furthermore, SMMS would need to create new strategic partnerships, with industrial firms, academia, and institutions.

Sandvik Coromant, by far the largest metal cutting tool product area, had been investing a lot of resources into a new unit called Digital Machining, to support growth and drive a sustainable business, with a focus on technological innovation. They have created their portfolio of digital solutions under the umbrella name CoroPlus. Walter, also a large product area, has been investing a fair amount of resources in digital solutions. They established a unit called Digital Manufacturing to drive digital transformation for their entire organization. This unit led to the acquisition of a software company called Comara, a small independent software company. Seco tools established Seco Point and Seco Consulting Services (SCS) more recently as part of its strategy to address digital transformation. Seco Point was established to handle tool logistics solution activities, while Seco Consulting Services created a new business activity proposing digital solutions as part of a greater service offering. Finally, Dormer Pramet, the smallest metal cutting tool product area, and issued from several recent mergers, has been addressing digital transformation as part of its strategy to support its channel partners (distributors) and as part of its effort to harmonize internal processes and enterprise systems.

At the center of SMMS’s digital transformation, a new business unit called the Digital Center of Excellence was established. Shortly after its inception the unit was renamed the Center of Digital Excellence, or CODE. It was established originally as a project led by the business strategy and development department of Sandvik Machining and Manufacturing Solutions. After several months of start-up work, the management of CODE was handed over to newly recruited managers with extensive industry experience with digital businesses. At the time of their interview, the unit was undertaking three main projects called Cloud Line, Smart Supply, and Shop Floor Programming. It underwent rapid organic growth, with 15 employees within its core team, consisting mainly of software developers, in addition to the 120 or so employees already working with Tool Data Management Systems (TDMS), an organization that was transferred entirely to CODE when it was first established. A few months later, the management restructured CODE and established the Advanced Manufacturing Technologies (AMT) product area, which was to include TDMS, CODE, and other companies focused on different manufacturing areas. AMT dealt with all issues related to the overall manufacturing chain and digital technologies, and its mission was to supply digital solutions by adopting a customer-centric approach. AMT was structured in four big areas, Design, Prepare, Execute and Evaluate. TDMS belonged to the “prepare” area, which focused on the information surrounding the particular tools one finds in a
manufacturing facility. CODE was positioned on creating new initiatives, including Allting. Allting focused on developing digital solutions applications for small and medium-sized companies. Allting was established to diversify the activities of the product area into new markets, SMEs, and firms with fewer resources than the large customers traditionally dealt with by SMMS, and for which solutions produced by organizations like TDMS were not adapted given their higher cost and complexity. AMT also included Metrologic of the Verify area, and more were planned to be included depending on their future developments and acquisitions. Metrologic provided a solution that would allow customers to test that they have the right material and components. In summary, AMT was envisioned to become a large digital solution-focused product area for the SMMS group, with business activities on par in size with the like of traditional metal cutting tool manufacturers. During the project, the digital-focused organization evolved rapidly, took several names and forms, and was still evolving and growing at the time the project ended. With the dynamic nature of the objects studied, a certain amount of change related to digital transformation could be captured as an evolution of the case description. The data evolved with time, as the different data collection moments occurred, and therefore certain outcomes of change could be observed.

Cibes Lift Group

The Cibes Lift Group (CLG) is a technology-driven manufacturing company. During the 1970s, CLG revolutionized the accessibility product market by developing a wheelchair accessible car lift propelled through the utilization of a tripod-loaded screw rod. By the end of that decade, this wheelchair lift was still considered technologically advanced over what the competition could do. It was designed with numerous advanced safety features. CLG has its manufacturing activities in Gävle, Sweden, and exports approximately 80% of its products globally. Their products are exported mainly to the Netherlands, Poland, Italy, and the UK. Since the 2000s, CLG has been focusing its efforts towards geographically developing its market presence, finding partners and new markets in Africa, the Middle East, and Asia. Today, the Cibes Lift Group (CLG) is a Swedish global market-leading manufacturer of electric screw-driven lifts (Cibes Lift Group, 2016). The company has grown from mergers and acquisitions of competitors and distributors in their business. The company is organized as a wide group of subsidiaries and brands, which include the Cibes brand, Kalea, and NTD. CLG manages a vast global network of 185 distributors and ten subsidiaries. The different brands have a different market presence and brand awareness. The group sells its products to public institutions, companies, and private customers.
CLG operates through several mostly European subsidiaries, and a wide professional worldwide network of distributors of market-leading accessibility solutions. The company focuses on developing successful long-term business relationships with partners within both emerging and developed markets. The distributors have access to the CLG online quote and ordering system featuring a complete product database and the possibility of quoting customized products and generating immediate product drawings. The lifts market is driven by legal concerns for safety and accessibility, most importantly in Europe. Demographic developments and the quest for private homeowners to enhance the value of their properties with integrated lift solutions has also been increasingly a driver of growth for their industry. Their prefabricated solutions designed by CLG for quick installation have been preferred by private property owners over alternatives. The increased interest in lifts in private homes also presents challenges such as new sets of requirements, increased demand for more options and customizations, and a need for more targeted sales channels.

The lift industry is undergoing radical changes, and there is an increasing number of alternative accessibility solutions for both public spaces and private homes. So-called conventional lift firms are getting better at designing solutions that are easier to install, and new, smaller, and/or cheaper players are entering the market. CLG understood that to remain a market leader and to fend off the competition durably, it should follow the global trend of Industry 4.0, and engage with digital transformation. CLG foresaw multiple potential benefits to be created with digital technologies for their different customers, their service practices, their distributing partners, and their business offering. To address these, CLG initiated a digital transformation project around the update of their product and manufacturing processes. CLG launched the CiCon and CiLine projects, both for the development of a smart product and for the development of a new production line to manufacture the smart product, CiCon, which would integrate IoT technology that could be piloted with a digital software solution. The new product had an improved design, including more standard parts and other cost-effective aspects, which would allow the company to implement several changes and efficiencies in the production line and to their service practices.
The Theoretical Framework

The Industrial Marketing and Purchasing Approach

The IMP literature has been studying business relationships and inter-firm interactions (Håkansson, 1982). Understanding that relationships are part of wider structures, this tradition has with time shifted its focus to studying business networks (Håkansson and Snehota, 1995). The IMP approach has for an underlying assumption that a company’s technological, social and economic features result from its interaction with other companies (Håkansson and Waluszewski, 2007). The IMP approach provides a thorough conceptualization of business relationships. Business relationships are the interface for different types of simultaneous exchanges between different organizations. These exchanges have both economic and social elements and include investments, mutual adaptations (technical and processual), information exchanges, and a common goal (Baraldi and Nadin, 2006). According to Håkansson and Waluszewski (2002a), the IMP approach has focused on looking at exchanges between different actors and has been built upon the collection and analysis of a large number of empirical observations. Researchers within the IMP approach have collected thousands of interviews, all based around the same core assumption that interaction plays a key role in the life of an organization (Håkansson and Waluszewski, 2002a).

The IMP Group was established in 1976 to conduct a large empirical study on international business marketing and purchasing across five European countries (Ford, 2004). The IMP project analyzed around 1000 business relationships between industrial suppliers and customers. The project resulted in several findings confirming the role of long-term relationships in the marketplace. From this study, researchers developed the interaction approach (Håkansson, 1982), which views the market as made of long-established and significant business relationships between different industrial actors, and where exchanges are complex and mutually developed and adjusted.

In *International Marketing and Purchasing of Industrial Goods*, Håkansson (1982) developed the thesis that industrial marketing research should focus on the buyer-seller relationship. The author posited that markets were not atomic and formed of freely gravitating business entities, but instead are made of stable structures of complex and lasting relationships. Håkansson (1982) also
challenged the separation between industrial purchasing and industrial marketing as disciplines, because of the strong inherent similarities between the role of the buyer and the seller. Instead, to understand industrial markets, researchers should study both sides of business relationships. The interaction approach takes the dyadic relationship for unit of analysis and posits that firms need to focus on developing and managing their relationships with other firms to be successful. This approach implies that firms should have a long-term view on profit-making, a commitment to individual customers as opposed to a market, and a certain degree of mutual adaptation with suppliers and customers. Researchers have also used the interaction approach to analyze the role of technology in industrial marketing (Mattsson and Johanson, 2006).

Relationships are made of exchange episodes, which include the exchange between two parties of products or services, information, financials, and social elements (Håkansson, 1982), each of which characterizes the relationship. As an example, financial exchanges are an indicator of the economic importance of the relationship, while social exchange helps reduce uncertainties between parties involved in a relationship. Episodic exchanges of products, information, etc. can lead to the creation of unique long-term relationships (Håkansson, 1982). The routinization of these exchange episodes over time leads to reciprocal expectations from parties involved, which in turn become institutionalized (integrated with both organizations’ daily operations). Parties of the relationship will develop contact patterns, which interlock to some extent both parties in the relationship. It should be noted that exchanges, and therefore the relationship, can start happening before any product, service, or finances are exchanged between the parties. Parties can also develop certain mutual adaptations, making exchanges more efficient and interlocking themselves to the relationship (Håkansson, 1982). Therefore, a key aspect of managing business relationships is finding the right balance between mutual adaptations and the resulting cost efficiencies within a business relationship and the dependence that it creates. A company's performance is related to its ability to develop relationships; resources are developed between companies, so internal process efficiency is influenced by these relationships, and the more successful a company’s counterparts are, the better it is for its success (Håkansson and Snehota, 1995).

The Interaction Approach

The interaction approach was the first theoretical analytical framework to emerge from the IMP approach, to break down the inter-firm interaction process into variables (Håkansson, 1982). Håkansson (1982) described the interaction model based on principles that he understood to have been neglected in previous research. In the interaction model, interaction is investigated from
the perspective of how it relates to the actors' characteristics, how they perceive each other, and how their actions towards one another are shaped over time (Håkansson and Waluszewski, 2002a). It is treated as a process that is related to collective actions in a larger environment of connected actors. When it was established as a way of viewing industrial exchanges, two assumptions were also made: these exchanges are characterized by social exchanges between parties involved, and adaptations are made to the product/service involved (Håkansson and Waluszewski, 2002a).

Buyer and seller are both active participants in the market, both engaging each other to impose their requirements, both attempting to manipulate and control the transaction. The buyer-seller relationship is often long term, where much of the work involved in each role is dedicated to maintaining that relationship. The links forming the buyer-seller relationship often become institutionalized, and both buyer and seller develop expectations on their counterpart’s performance and contribution to the relationship. In the interaction model, Håkansson (1982) conceptualized four groups of variables: parties involved, elements and processes of interaction, the environment within which the interaction takes place, and the atmosphere affecting and affected by the interaction. Håkansson (1982) suggested that researchers should investigate each group of variables and the interplay between each of them. Even when considering infrequent transactions, previous interactions, purchases, and associated relationships influence the present relationship. Lastly, although the interaction approach appears to focus on dyadic relationships, its principles could also be applied to multiple-party relationships.

The ARA Model

In Developing Relationships in Business Networks, Håkansson and Snehota (1995) developed an in-depth description of the substance of business relationships making the industrial network or ARA model. They described them as layered and made of activity links, resource ties, and actor bonds. Activity links are the mutual adaptations made by parties of a given relationship to their activities, resource ties are created through the mutual orientation of both physical and organizational resources, and actor bonds are made of social interactions between individuals and organizational units. Activity links, resource ties, and actor bonds are all related to each other in a given business relationship and are connected to other links, ties, and bonds. Resources are combined through different activities, which actors perform. Lastly, these are embedded into network-like activity patterns, resource constellation, and a web of bonds.
Through interaction, companies combine, develop, and exploit resources, therefore capitalizing on the heterogeneity of resources. Resources are activated through their interaction with others. Resource interaction is also an evolutionary process; no present new resource is introduced without context, they are not introduced in a resource vacuum, nor are they free from interfaces with past resources. Therefore, the value of a single resource varies in time and in the different combinations in which it can be used. Resources are part of greater constellations of resources, where they interact and are constantly adapted to each other. Resource interfaces, where resources interact, can be located within and across organizational borders (Håkansson et al., 2009).

When new resources are introduced, they are brought into a space already full of existing resources. They are combined with new and previous resources. The value of a newly introduced resource is influenced by how it is combined with already existing resources. Resources change and develop characteristics over time. Every resource is embedded in a multidimensional context, and therefore changes of a resource create tensions with other related resources. The intensity and broadness of interaction influences respectively the effects of a change in a resource, and the number of resources affected by a resource change (Håkansson et al., 2009; Håkansson and Waluszewski, 2002a). If a company and its supplier or customer are successful in adapting a resource in a mutually beneficial way, it might create problems with other counterparts. The negative effects on third parties of a given resource might lead to a reaction from them. They might attempt to hinder the development of this resource adaption by developing a competing alternative resource or breaking their relationship with the company (Håkansson et al., 2009).

Resources don’t just combine themselves; they are combined through activities (performed by actors). It is therefore essential to study activity patterns and their complexity. Activities are coordinated, and direct and indirect interdependencies can appear across firm boundaries. The activity structure of an organization is the subset of the activity patterns in the network the organization is a part of, and activities are connected across firm boundaries via activity links. The execution and outcome of activity are dependent on other activities. Adjustments between activities improve their joint performance, and logically, these adjustments between activities lead to the creation of interdependencies. A single activity can be part of several activity configurations, and the more two activities become adjusted to each other, the better they function together (Håkansson et al., 2009).

Because of the tendency of activities to be linked across firm boundaries, changes or adjustments in activities within one organization can require changes or adjustments in activities within another organization, which might be a cause of tensions or friction. Because of the adjustments of activities over
time, making them more efficient, they also tend to specialize, therefore creating a path and favoring certain changes while constraining other modifications (Håkansson et al., 2009). Like resources, no activity exists in isolation, and they are characterized by interdependencies with other activities in activity patterns.

Actors’ views on a relationship, and their identities in the relationship, are influenced by the bonds that they create. Similarly, as between two people, a relationship between two firms creates bonds (Håkansson and Snehota, 1995). These are created when two or more firms direct their attention and interests towards each other when the firms develop mutual commitment. Bonds affect the knowledge that different parties of a relationship have on each other, and therefore they also have an effect on what they exchange. Commitment is derived from both learning about each other’s organizations and a certain level of belief and trust. Trust and belief are not solely dependent on the interaction itself. Factors such as perceived relationships with other organizations also influence these two aspects. Commitment, identity, and trust are constraints for the behavior of the different parties in a relationship, therefore creating a type of bond between them (Håkansson and Snehota, 1995).

Bonds are themselves embedded in, or portions of, a wider web of actors, and past bonds affect present and future bond creation. When studying business relationships, one should understand that by looking at an organization, one is abstracting several individual actors carrying activities constructing the business relationship. These individuals may have different goals and perceptions limiting or guiding their interactions. Therefore, interaction is influenced by who is defined as the actor in a given business relationship (Håkansson and Snehota, 1995).

The Resource Interaction Approach

Because of its utter complexity and importance for innovation and technological development, the resource layer of the ARA model has been further developed into what is now referred to as the Resource Interaction Approach, or RIA (Håkansson et al., 2009; Håkansson and Waluszewski, 2002a). While the ARA focuses on inter-firm interactions and resource changes directly resulting from this interaction, the RIA focuses on resource interactions happening between and within firms, connecting resources in a network within and across organizational boundaries. The RIA offers a framework to investigate resource structures, directly or indirectly connected, and related directly and indirectly to business relationships. In fact, in the RIA, the business relationship is not just substantiated by resource ties, it is a resource type of its own, a complex organizational resource type that interacts with other resources and
connects different resource structures across firm boundaries. While the ARA model can provide an in-depth picture of inter-firm interactions between a number of suppliers and buyers within an industrial network, the RIA will create a detailed picture of how firms' organizational and technical resources to create value are connected across the industrial network.

In *Managing Technological Development. IKEA, the Environment and Technology*, Håkansson and Waluszewski established the grounds for the RIA to investigate the technological development taking place across different business relationships. Outlining a typology of resources, commonly named the 4R model by authors using the RIA to map a resource context (Prenkert et al., 2019), they could present how technological development could take a different path depending on the specific set of resources available to the different actors interacting with each other. The 4R model categorizes resources as either product, production facilities, organizational units, or organizational relationships. Products are combinations of tangible resources produced and used by different units’ business contexts. They can be moved to a different location and can relate to different resource structures. Production facilities are also combinations of tangible resources but are more sustainable and durable than products. Their stability in time and space creates a context for other different and successive resource combinations (Håkansson and Waluszewski, 2002a). Organizational units include experience and knowledge contained in individuals and groups. This also includes their skills in handling different resource combinations. Organizational relationships are combinations or structures of tangible and intangible resources. They span across company boundaries, therefore affecting other intangible and tangible resource combinations or structures within different organizations. These resources are more complex and diverse than other resource types, which can lead to problems and opportunities for organizations managing organizational relationships. All four types of resources interact with each other, in different combinations, leading to organizational problems and opportunities, to value creation and friction. The combination and activation in the interaction process of the four resource types are what “manufactures” or shapes resources (Håkansson and Waluszewski, 2002a). These four types are developed with each other over time. They are combined as interfaces are created between them. Structures result from the systematic combining of these different resources, as they are built together into resource constellations (Håkansson and Waluszewski, 2007).

To look at products is to look at features (training, specifications, etc.), production facilities relate to technical development, business units to skills, abilities, expectations, and knowledge (such as the ability to co-operate), and relationships to situations over time (memories and expectations, of past and future activities). All four are highly dependent on each other. To make a
product, one needs a facility owned by a business unit, and products are sold via business relationships. It is, therefore, necessary to include them all when analyzing technological development in an industrial setting. Additionally, these resource features are interpreted, developed, and preceded by individuals. Resources don’t gain an economic value on their own, but when “represented” by individuals acting on them (Håkansson and Waluszewski, 2002a). According to Håkansson and Waluszewski (2002a) when a resource changes, or is subject to pressure for change, or when a new resource is introduced into existing resource structures, it produces a reaction or friction because of existing tensions in both the focal and related interfaces. Resource systems tend to be organized as efficiently as allowed by the present resources. Resources act like different passive and active forces in tension. New resources will create new forces, changing the balance in the system, creating frictions/potential energy loss, until the system gets to a new state of balance (Håkansson and Waluszewski, 2002a).

Industrial technological development is an organizing process, which participating actors can influence. Organizations interact, confronting and relating multiple resources to each other. The development of single resources, such as a new technology, is dependent on interaction, where resources are given specific characteristics. Every resource item, production facility, single machine, or business unit is uninteresting by itself. It is only in use, or with other resources that value is created (Håkansson and Waluszewski, 2002a). When investigating resource interaction, researchers should consider a few key issues. One can only really capture partially how these are developed and used, and how they interact in an interactive process, which constrains the choice of methodology. Resources are part of both totalities and a subset of interrelated components. To understand the interactive dimensions of a resource is to look at it both as given and non-given at the same time, both as static and as with the potential to develop and change. And it should be seen both as a source of development in itself, and as a fixed point of reference for other resources as a source of development (Håkansson and Waluszewski, 2002a).

Theory of Value Creation

Among all topics that are addressed within the industrial marketing and purchasing approach, value creation has been a central issue (Johanson and Wedin, 2000). Value creation is also the main purpose of the digital transformation change process, as firms undertake multiple structural changes allowed by the adoption of digital technologies, seeking new value creation opportunities for their customers and themselves (Albukhitan, 2020; Henriette et al., 2015; Westerman et al., 2014). In an industrial economy, the firm is the basic unit for the organization of production. The firm can be understood as a
collection of resources, the purpose of which is producing and selling products and services (Penrose, 1959). The coordination or disposal of these resources is done through administrative decisions. The physical resources of a firm may include production plants, equipment, land, and natural resources, raw material, unfinished goods, production wastes and byproducts, and finished goods. These may vary in their durability, being either consumed quickly, used over long periods to provide certain services, or transformed into other physical resources. Physical resources are objects that firms act upon, buy, sell, lease, etc. Organizational resources may include all labor, skilled and unskilled, administrative, financial, technical, legal, etc. Some of the human resources will present greater investments or costs for the firm and may be more durable within the firm than others. Penrose (1959) argued that it is from resource use, and the combination of resources, that services or sets of services are created, implying that firms create growth, and therefore value, by using and combining resources. The resource interaction approach further develops the relation between resources and value creation, which provides a more detailed and holistic picture (Håkansson and Waluszewski, 2002a). The RIA creates a more nuanced and in-depth description of non-physical resources, i.e., organizational resources, with business unit and business relationship resources, in relation to their technical counterparts, production facilities and products, spanning across the industrial network, thus offering a more detailed description of complex value creation processes taking place across the resource context of firms.

Resource Interaction and Value Creation

A quick search for the keyword in the IMP group database yields a few hundred results, showing the centrality and importance of value, and of related topics such as value creation, value co-creation and value destruction, for IMP research. The RIA, like Penrose’s *Theory of the Firm* (Penrose, 1959), relates resources, resource interactions and value creation (Baraldi and Strömsten, 2008; Håkansson and Waluszewski, 2002a). In the simplest terms, value is created through exchanges of resources between firms (Johanson and Wedin, 2000). Economic value emerges when firms develop resources, for which there is a use and an exchange between different parties (Baraldi and Strömsten, 2008). The value of a resource is “realized” in the exchange. This understanding stems from the fact that exchange is a process creating resource value. As the resource moves from one locus to another, it goes from being valued less to being valued more by different actors, gaining value in the process. The value creation process is affected by multiple actors, as interactions and economic exchanges take place in a network of interactions between multiple firms. Value creation is a process of managing the embeddedness of resources in a resource network, with the network providing the affordances and
constraints of the process (Håkansson and Waluszewski, 2002a; Johanson and Wedin, 2000). Value is associated with resources, as in resources are vehicles of value, and the value of a resource emerges when combined with other resources (Prenkert et al., 2019). Resources have value for actors or in relation to something (Baraldi and Strömsten, 2008). When resources interact with other resources, their features emerge as a result of the interaction process (Håkansson and Waluszewski, 2002a). The value of a resource can be defined as the benefits and “sacrifices” resulting from resources’ emerging features (Baraldi and Strömsten, 2006). Because of the various potential resource features that can emerge as a result of resource interactions, resources may have a multiplicity of value, and value may have multiple forms, such as financial, functional, sustainable, design, aesthetic, etc. (Baraldi and Strömsten, 2008).

When resources interact, they create interfaces, conduits for resource interaction. Resource interfaces specify how resources connect to each other, with more or less specificity and adaptation (Prenkert et al., 2019). Value creation occurs at the network level and depends on the configuration of the resources and their interfaces constituting a particular network. Resource interfaces create opportunities and obstacles to value creation (Baraldi and Strömsten, 2006; Håkansson and Waluszewski, 2018). Value creation involves both organizational and technical resource interactions, as value is both related to the configuration of the resource interfaces, and composed of two distinct but related sub-processes, value embedding and value production and utilization (Baraldi and Strömsten, 2006). During value embedding, a certain value is built into the resource through new combinations and features with others. The embedded value is produced and used in routine resource combinations (Baraldi and Strömsten, 2006). Both value creation and utilization are dependent on how actors develop and manage interfaces between technical and organizational resources. The interaction between different actors enables the identification, creation and development of new business opportunities. On the other hand, the interdependencies, specific to strong and hard-to-break interfaces, developed between various forms of physical and social resources, may also create hurdles for these developments (Baraldi and Strömsten, 2008).

Resource interfaces are both the product of the inherent features of resources, physical or social, and of human actions of creating resource interfaces (Baraldi and Strömsten, 2005). A resource interface is not just two resources interacting, but the result of interacting resources that have resulted in a shared boundary between the resources (Prenkert et al., 2019). Resource interfaces can be technical, social or mixed. They can also vary in their depth, which depends on how much two interfacing resources are mutually adapted, as in their “reciprocal importance,” and how much time and money was invested in developing the interface between them. They can also be characterized by their varying degrees of heaviness (how difficult to break them) and variety.
Friction, Heaviness, Variety, and Path Dependence

Value creation is related to resource interactions, and therefore also to the characteristics of resource structures within which the interaction process is taking place. Håkansson and Waluszewski (2002b) outlined mechanisms describing how resource structures and resource interactions affect value creation within these structures. These mechanisms or effects, including friction, heaviness and variety, were further explored and defined by researchers using the RIA to investigate technological development in different complex industrial resource networks contexts (Baraldi and Nadin, 2006; Baraldi and Strömsten, 2009; Håkansson and Waluszewski, 2018; Prenkert et al., 2019).

Over time, social and material resources in a given context interact and create connections, developing complex resource patterns or structures across organizational borders. Actions or forces causing changes into resource structures will lead to effects or changes in directly and indirectly related resource structures (Håkansson and Waluszewski, 2018). Friction is the result of forces directed at interacting resources (Håkansson and Waluszewski, 2002a). Changes taking place in a resource network, create tensions. When established resource combinations are changed, these tensions may result in unintended positive and negative effects in different loci of the resource structure. Friction appears when a force of change is applied onto a resource interacting with other resources. The force creates friction or a reaction that can be distributed to other resources interacting directly or indirectly with the focal resource.

The difficulties in creating changes into established resource structures stem from friction, because of the potential for unexpected effects which may positively or negatively affect the outcome of change (Håkansson and Waluszewski, 2002a). Friction tells us that the intent behind the force of change, is not always coupled with the effect. Friction is a concept borrowed from physical sciences, like in Newton’s third law of motion; an action creates a reaction, a force applied onto interacting surfaces will result in negative opposing forces. Friction will cause effects to the interacting resources themselves in the form of excess “heat,” wear, deformation, etc. Friction also has a dissipating effect (of tensions), stabilizing and destabilizing resource interaction. Friction is an important aspect of resource creation and development. Friction also makes it difficult to predict what new patterns will emerge when change forces are applied. However, it also makes a few aspects foreseeable,
as friction always creates stabilizing effects within interfaces subjected to forces (an action always creates a reaction). Friction is the result of both forces creating changes in established resource interfaces, and from the resilience forces of the same resources’ interfaces. In practice, resources can be combined in a stable and difficult to break apart combination, but when a force is applied in the structure of which these are a part, they may suddenly become easy to recombine. The ease or difficulty of breaking apart stable resource combinations is an illustration of both positive and negative friction effects.

Friction is relational, time dependent, and transformational. It is relational because it appears when force is applied on two interacting resources. It is a tool to “capture the interplay between resources whose features are relational.” Friction is transformative because, when a force is applied, it will create tensions at the interfaces between the different resources, transforming these resources and creating new resources. Friction is also time dependent. The same force may create different effects depending on when it is applied. Friction as a stabilizer of certain resource structures can be desirable (Håkansson and Waluszewski, 2002b). However, this effect might be problematic for firms undertaking changes in their resource structures as important as the changes taking place during a digital transformation. During such changes, friction can either be a hurdle or a source of value creation or both. Friction is the reason why changes such as technological developments are rarely linear. Friction influences technological processes towards positive economic results, as in respect of established economic structures. Friction favors existing forms of value creation. Friction is a force that pushes technological development to favor economic development via the use of established resources. Previous investments and the diversity of investments determine the direction as they may present opportunities for improvements. Friction will always take place when changes are applied to resource structure with given heaviness, time and space characteristics, and therefore, firms need not try to avoid, but cope with or take advantage of the friction effects (Håkansson and Waluszewski, 2018).

Heaviness is the sum of all adaptations and investments made into a resource in relation to others over time. Heaviness is there for a measure of economic investments into resource structures, which with increasing investments turn increasingly heavy (Håkansson and Waluszewski, 2002b). This is true of both material and social resources, such as technology and the related technical knowledge. The investments and costs create heavy structures that need to be used or profited from. When a development is made on a given resource, it is made in relation to another resource. With time, these create a form of heritage of the resource structures, which is somehow deterministic of future developments within these structures (Håkansson and Waluszewski, 2018). Variety of resources is related to all the features that resources can develop by being combined to other resources. Variety of resource interfaces, however, reflects
the number of different resource combinations in a given resource structure (Håkansson and Waluszewski, 2002b). The more combinations are possible, the more potential features of resources can emerge, as each combination can provide a new path for further adaptation and heaviness. Variety and heaviness can be compatible resource qualities; however greater heaviness may also decrease a resource variety by decreasing the resource recombination possibilities (Håkansson and Waluszewski, 2002b).

Both heaviness and variety affect path dependence for all changes and undertakings within any given resource context. Effects of friction result from these characteristics which stir economic developments. Path dependence is a mechanism that affects the success of new technological development. Path dependence of new solutions is historically built into resource constellations, inhibiting the rise of certain new paths breaking with the existing structure, while driving efficiencies across other developmental paths (Håkansson and Waluszewski, 2002b). It is an aspect that is part of all technical developments building upon pervious technical systems. The authors argue for a view of path dependence which contrasts with other limiting views, as a mechanism that may facilitate technical developments. Innovation efforts have to account for the resource structural context, defined by historical investments in social and technical resources, made across time and space. These investments are both a source of opportunities and limitations for current investments. New investments such as the introduction of digital transformation-focused technologies, need to account for the heaviness, time and space dimensions, the economic commitments and investments, and the history and location of the resources involved (Håkansson and Waluszewski, 2018).

Failure to innovate can be related to a failure to embed new resources into the existing resources or to recognize the characteristics of present resource structures and their resulting limitations and opportunities for innovation (Håkansson and Waluszewski, 2018). All changes have to account for present conditions, and the larger changes, such as changes creating new interaction patterns, are likelier to face negative forces of resistance and limitations. Also, the more heaviness can be found in resource structure, the larger the resistance or limitations will likely be. In practice, it could be observed as conservatism towards change, which can take place as both an attitude reflecting strong skepticism by individuals, and a form of protectionism towards established structures. Conservatism can also be a source of efficiencies, as established resources have been oriented towards each other to create efficiencies that can be taken advantage of or accounted for into the newly implemented changes. This path dependency in heaviness, space and time, has a so-called “dark side” (Håkansson and Waluszewski, 2018), or a trade-off, in the sense that it may favor, and create opportunities of efficiencies, while simultaneously creating resistance or limitations towards other paths. The importance of these
characteristics for new developments requiring changes and investments into new resource structures is true of both organizational and technical resources (Håkansson and Waluszewski, 2018).

In summary, firms create value by exchanging resources across the industrial network. Resources are exchanged and embedded in different developing, producing, and using resource settings (Baraldi and Strömsten, 2006). They are being embedded in a resource setting where they interact with other resources and develop their features (Håkansson and Waluszewski, 2002a). During their interactions with other resources, they develop features dependent on the resources they interact with, and because of the various potential resource features that can emerge as a result, resources may have a multiplicity of value, and value may have multiple forms (Baraldi and Strömsten, 2008). Therefore, value creation is a process of managing the embeddedness of resources in a resource network, and the resource network is what defines the boundaries, the opportunities and limitations, the resource context path dependency of value creation (Håkansson and Waluszewski, 2002a, 2002b; Johanson and Wedin, 2000). The path dependency of the resource context results from the characteristics of the resource structures that make the resource context, from the characteristics of resources and resource interfaces that span context within and across organizational boundaries (Håkansson and Waluszewski, 2002b, 2018). They may be characterized in terms of their heaviness and variety, respectively reflective of the amount of investments, adaptations made to a focal resource, the difficulty to break apart a resource interface, and reflecting the amount of possible resources and resource interface combinations in a given resource context (Håkansson and Waluszewski, 2018). Furthermore, when changes are applied to resources that interact and develop resource interfaces, friction effects will take place in directly and indirectly related resource interfaces. Friction reactionary forces will both stabilize or resist or destabilize and drive changes in other interfaces. Therefore, to study how the complex digital transformation change process unfolds and affects value creation in the industrial network, it appears essential to investigate how firms embed new resources into the existing structure to create value. As as to study how the characteristics of established resource structures will create a path dependency for the value creation changes, and how resulting friction forces will affect value creation by either driving or resisting the changes.
The Articles

In total, the research work for this doctoral dissertation led to the production of four papers. The content of the papers is presented in Table 2 below. The research for this dissertation started with a general investigation of digital transformation and Industry 4.0, from industry reports and a few scientific articles. A first picture was then drawn of the challenges and hurdles encountered by the two firms investigated. From there, more data was collected to map in detail digital transformation as it was taking place at the two firms using IMP theory for guidance. From the data, a first paper was written using boundary object theory (Star and Griesemer, 1989), and concepts from the RIA approach, the 4R typology and friction effects (Håkansson and Waluszewski, 2007; Hoholm and Olsen, 2012) to highlight how the different actors in the two studied firms perceived different use and interpretation for these digital transformation-related objects (Easton and Mason, 2009; Star and Griesemer, 1989). Four boundary objects related to inter-organizational interaction were identified. These differences in perceptions translated into different expectations of frictions and controversies, thereby highlighting how the perception of digital transformation, here conceptualized as boundary objects, influenced the interaction process. Additionally, this paper provided an example of how boundary object theory could be applied by practitioners managing change related to Industry 4.0 to rationalize and characterize their digital transformation.

The second paper (II) focused its case study on one of the two originally studied firms. By using liminality theory (Wagner et al., 2012), and the RIA on resource embeddedness (Baraldi et al., 2012; Håkansson and Waluszewski, 2002a), the paper investigated a case of digital transformation strategy, where digital transformation and digital innovation are driven by being developed separately from established resource structures in an industrial network context (Eklinder-Frick et al., 2019). The study did not focus on characterizing the digital transformation projects or objects themselves, but on the business unit from which they were driven. The unit studied was to drive digital transformation projects and changes for the entire organization. However, it was established separately from the rest of the organization. The paper identified several challenges and issues of radical innovation for digital transformation in a liminal space, characterized according to the liminal characteristics of that
business unit (Wagner et al., 2012). This paper highlighted the importance of developing innovation close to the structures where it will be deployed and used, adding evidence to the position taken in IMP literature in regards to how firms should implement change in a network context (Håkansson, 1982). It also highlights the importance of managing the resource embeddedness by balancing temporality, ambiguity, freedom and community when creating such liminal space as a strategy to drive digital innovations within a complex organizational network. The first phase put a focus on the key resources and the governance structures surrounding the development of these resources in the digital transformation, thereby developing a more internal perspective on aspects of resource interaction and value creation. The study of boundary objects analyzed both technical and organizational resources that were both important for creating value and a common understanding and coordination for the digital transformation of both firms. The lens made it possible to study how the coordination and cognitive perspective development took place. From this analysis also came the observation that a resource played a key role in coordinating the developments made for the others, a unit with a different governance structure, separated from the rest of the organizations. The observed liminal space was therefore focused on in the second study, as to highlight the potential managerial challenges, and the challenges of managing resource embeddedness from the liminal space.

The second phase of data collection was initiated and took place at about the same time as the second paper of this dissertation was written. This second phase focused separately on the two case firms from the ISNET project, using different questionnaires, but with similar theoretical guidance from the resource interaction approach (Håkansson and Waluszewski, 2002a). While the first two papers produced focused more on the intersection between cognitive and social, with tangible and technical resources, illustrating the socio-technical gap within IMP research, the latter papers were more traditional IMP papers, and took a stronger emphasis on the inter-organizational perspective, aided by a second data collection phase which specifically adopted this focus. They focused on investigating inter-organizational resource interfaces and how these are affected by the introduction of new resources associated with digital transformation, thus exploring value creation across the industrial network by focusing on either path dependency or friction. By using the RIA, these papers covered the relation between digital transformation and value creation, illustrating cases of firms creating customer value, efficiencies and new revenue models, key aspects of digital transformation literature on value creation (Björkdahl, 2020). They offered a detailed description of how value is created within and between firms in practice by undertaking a digital transformation, and offered some answers as to how they may successfully create value, and on the key factors influencing the outcome of digital transformation, such as how opportunities and limitations to value creation may
emerge from the resource context, and how friction forces may affect the changes undertaken to create value.

The third paper (III) in this dissertation looks at a specific technological application, Smart Inventory Management Systems, often found within firms undertaking their digital transformation. The paper investigates how different organizations of one of the two industrial network cases of the ISNET project, may achieve different outcomes by implementing the technological application. The article presents an in-depth qualitative study of the different resource structures and their interfaces and how introducing the new digital transformation-related resources may lead to different paths and outcomes in benefits and challenges for the different organizations. The paper highlights the importance and path dependent nature of resource structures as a result of resource structure heaviness and variety.

The fourth and last paper in this dissertation looked at the digital transformation efforts of a firm within a large industrial network using the RIA (Paper IV). The paper investigates the changes brought by the digital transformation over the industrial network of actors, suppliers, and distributors. The paper used the RIA to highlight the negative and positive effects of friction, either directly or indirectly related to the changes brought by the introduction of new technological resources in the context of a digital transformation. The study highlights the importance of managing directly and indirectly related mixed and organizational resource interfaces when introducing technological and tangible resources to drive changes. The study further highlights the importance of understanding the complex mechanisms of friction and how these can potentially lead to both value being created, and to challenges and hurdles, in multiple, and sometimes also unpredictable, loci of an industrial network.
<table>
<thead>
<tr>
<th>Name of publication</th>
<th>Theoretical framework</th>
<th>Research purpose</th>
<th>Methodology</th>
<th>Theoretical conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Fremont, V.H.J., Frick, J.E., Åge, L.-J. and Osarenkhoe, A. (2018), “Interaction through Boundary Objects: Controversy and Friction within Digitalization”, Marketing Intelligence &amp; Planning, Emerald Publishing, p. MIP-04-2018-0135.</td>
<td>DPU model of resource interaction within innovation processes. Boundary object theory.</td>
<td>To analyze friction and controversies within interaction processes and their effects on forming new resource interfaces in the context of digitalization.</td>
<td>Double case study. Qualitative data collection through 14 semi-structured 1 to 1.5h long interviews, with managers directly involved with digitalization at the respective companies. Data was coded and analyzed by following the framework and structures from theory on Boundary Objects and DPU.</td>
<td>A four-by-four matrix characterizing digitalization, according to characteristics as defined by boundary object theory, and presenting their effects on resource interfaces within DPU settings.</td>
</tr>
<tr>
<td>II. Eklinder-Frick, J., Fremont, V.H.J., Åge, L.-J. and Osarenkhoe, A. (2019), “Digitalization Efforts in Liminal Space – Inter-organizational Challenges”, Journal of Business and Industrial Marketing</td>
<td>Liminality theory of innovation, to characterize a liminal space in terms of relative ambiguity, freedom, community and temporality. IMP theory on change and innovation.</td>
<td>To analyze inter-organizational challenges in industrial organizations when digitalization strategies are deployed to drive competitive advantage and radical innovation.</td>
<td>Single case study. Qualitative data collection method, 19 semi-structured 1 to 1.5h long interviews with managers directly involved with digitalization at the studied firm. Data was coded and analyzed according to the theory on Liminality.</td>
<td>Separating innovation from the structures into which innovation will be deployed, increases the risk of friction. A characterization of challenges and issues related to innovation in a network context according to liminal space characteristics.</td>
</tr>
<tr>
<td>Name of publication</td>
<td>Theoretical framework</td>
<td>Research purpose</td>
<td>Methodology</td>
<td>Theoretical conclusions</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>III. Fremont, V., “Opportunities and limitations for value Creation from digital transformation”, Submitted to <em>Industrial Marketing and Management</em>.</td>
<td>The Resource Interaction Approach to analyze resource interaction with the RIA resource typology. Literature on SIMS to frame the analysis and develop the comparative analytical framework.</td>
<td>To investigate how an application of digital transformation application, Smart Inventory Management Systems, developed and marketed by different organizations with different resource structures may lead to different benefits, challenges, and friction.</td>
<td>Single case study. Qualitative data collection method, 19 semi-structured 1 to 1.5h long interviews with managers directly involved with digitalization at the studied firm. Data was coded and analyzed using RIA and DT theory.</td>
<td>Use of RIA to highlight how differences in resource structure characteristics can result in path dependency from resource embedded contexts. The RIA highlights the role of heaviness and variety in either being source of opportunities or limitation to value creation from digital transformation.</td>
</tr>
<tr>
<td>IV. Fremont, V., “Friction and digital transformation in the industrial network”, Submitted to <em>Journal of Business and Industrial Marketing</em>.</td>
<td>The Resource Interaction Approach to analyze resource interaction across resource interfaces and resulting friction effects with the RIA resource typology</td>
<td>To analyze how digital transformation affects value creation within an industrial network. To investigate benefits, challenges, and the friction resulting from the introduction of digital transformation-related resources within a complex network of diverse interacting resources.</td>
<td>Single case study of an industrial network. Qualitative data collection method, 16 semi-structured 1h long interviews with managers directly involved with the digitalization at different organizations within a particular industrial network. Data were coded and analyzed according to structures and framework from RIA.</td>
<td>Use of the RIA to map the friction mechanism related to digitalization according to different resource types, how friction affects change with hindering and destabilizing effects, and suggest that certain resource interfaces types are more prone to creating friction effects in such change context.</td>
</tr>
</tbody>
</table>
Methodologies

The industrial networks studied in this dissertation were participants and collaborators in the ISNET project. The two presented important key characteristics for the study of digital transformation in an industrial network, as they both are large manufacturing firms, interacting within widely diverse and complex industrial networks of suppliers and industrial customers. Both showed a great interest in digital transformation, and both were undertaking important digital transformation projects.

During two years, 47 semi-structured interviews were conducted in two phases (Yin, 2014) and at different organizations within two large industrial networks. The first phase took place in 2016, during which time managers for different functions at Sandvik Machining and Manufacturing Solutions and the Cibes Lift Group were interviewed. All respondents were selected for their relatedness to ongoing digital transformation projects at their respective organizations. Additionally, these managers had central positions in their respective networks, as they were from these two organizations’ corporate level. The second phase of data collection took place between 2017 and 2018. Then, managers from the two industrial networks involved with digital transformation projects were interviewed in two separate instances, but from a more diverse range of organizations, suppliers, and distributors. In the second phase, the two industrial networks were investigated as separate cases with their own set of questions. In the first phase, interview questions were drawn from IMP theory, to gain insights on resource structures, actors, and activities involved in the different digital transformation projects currently taking place in the studied cases (Håkansson and Snehota, 1995). In the second data collection phase, in both cases questions were drawn from IMP theory and the 4R model of resource interaction (Håkansson and Waluszewski, 2002a).

In their article on methodomania, Håkansson and Waluszewski (2016) described the tendency of over justifying and accounting for the methodology used, instead of understanding the relationship between research questions, theory, and method (Håkansson and Waluszewski, 2016). There is a close relationship between theory and methodology in IMP research (Håkansson and Waluszewski, 2016). These two connect around the object of the focus of IMP research, which is the business relationship. The challenge stemming from this
methodological stance is the ability for IMP research to create representative or generalizable knowledge. IMP research focuses on highlighting the complexity and highly contextual nature of exchanges when investigating specific phenomena such as the digital transformation (Håkansson and Waluszewski, 2016). The IMP perspective has some methodological considerations stemming from its theoretical principles (Håkansson and Waluszewski, 2002a). Adopting a focus solely on economic dimensions limits the understanding of how companies function and interact and how economic outcomes are created. Multiple companies are involved in producing different outcomes, and therefore it is important to understand the mutual views and relations of these companies to understand how these outcomes are constructed. Perspectives that researchers capture on resources embedded into resource structures can only be limited. The combining and development of resources depend on their features and actors’ perspectives on these features. Lastly, researchers can only study fragments of processes, solutions, and ideas, meaning that IMP-based studies are only representing partial depictions of studied phenomena (Håkansson and Waluszewski, 2002a).

From a methodological perspective, using the IMP approach to do the research for the present dissertation did present some limitations. This approach was limited in capturing individual perspectives on resources, the sociomaterial of resources involved in digital transformation. It was limited in describing cognitive aspects of individual interactions with these resources. Capturing the cognitive perceptions was important given the large amount of expectations that people have on digital transformation and digital technologies in general. People tend to have a lot on their minds in regard to these topics, either in a positive or a negative manner. Because data was collected through in-depth interviews, the sociomaterial substance of resources was implicitly present. While using the RIA approach to structure interviews implied focusing on relatively economic and material considerations, to look for characteristics and friction effects, respondents often detailed their own cognitive perception of these resources, their sentiments towards them, towards the technology, the change, etc. These are aspects that may not be so well captured by the RIA. Therefore, when focusing on intra-firm aspects, in particular the individual interactions with resources, other theoretical lenses were added to capture these aspects. The IMP may not be a perfect magnifying glass, but it was very appropriate at capturing the complex digital transformation change processes unfolding across industrial networks. The RIA has been developed studying complex technological developments across industrial networks. The RIA allows abstracting the context into its resource elements, thereby visualizing it in a clear and detailed manner to present resource interaction and interfaces. The IMP does indeed allow focusing only on fragments or partial depictions, but this is a strength as much as it is a limitation. The use of the RIA allowed analyzing complex value creation mechanisms across vast industrial
networks. Lastly, the use of an IMP approach to study the digital transformation meant that the research would be strongly tilted towards qualitative methodology. A reflection over the creation of a survey to be distributed to a large number of individuals across both industrial networks occurred. However, there was no real opportunity to do so, in the sense that there was no question or specific aspect that appeared as needing to be quantitatively measured. The digital transformation phenomenon is a complex change process that unfolds in unique ways. That uniqueness and complexity was more important to capture than trying to find generalizations.

In *Case Study Research*, Robert Yin (2014) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not evident.” Industry 4.0 is itself a phenomenon that is still not clearly defined. Case studies don’t rely on statistical but on analytical inference. This means that their quality comes not from the generalizability but the depth of their findings. Case study research is also common in IMP-related research. Dubois and Gadde (2002) investigated opportunities and hurdles related to single-case research for theory development. Similar to the case presented by the authors to introduce the “systematic combining” approach to case research (Dubois and Gadde, 2002), the case study-based ISNET research project has been articulated in different phases. However, unlike their truck manufacturer’s case, the phenomenon studied, the digital transformation, remained constant. It is rather the scale that changed with time. Starting from a central perspective on two separate industrial networks, it then expanded to collecting viewpoints from peripheral areas of these networks. Likewise, several case descriptions were made to reflect the data collected at these different phases. Also similar to the authors’ case (Dubois and Gadde, 2002), the theoretical framework was adjusted with time to reflect the empirical context, but stayed within the same theoretical boundaries of the IMP approach. The real variable in the research project was the study objects themselves, the companies, which evolved over time as they went through their digital transitions.

The main challenge in case study research consists in the interrelatedness of the different pieces of data involved in the research work. Therefore researchers should adopt an integrated approach to case study research. Instead of seeing the research process as organized in several linear phases, one should see that case study research goes back and forth between empirical data and theory, increasing the understanding of both. “Theory cannot be understood without empirical observation and vice versa” (Dubois and Gadde, 2002, p. 555). Empirical observations can result in the reframing of the theory, as new and unanticipated findings are discovered. The “systematic combining” approach to case research is a continuous movement between the empirical and theoretical worlds, where “research issues and the analytical framework are
successively reoriented when they are confronted with the empirical world” (Dubois and Gadde, 2002, p. 554). This means that over time, as researchers collect their data and change occurs in the empirical world, they adjust and re-adjust their theoretical model choices to respond to these changes. In essence, it is a responsive way of conducting case study research in an unstable empirical world, as the “theoretical framework, empirical fieldwork and case analysis evolve simultaneously” (Dubois and Gadde, 2002, p. 554). This approach is a form of abductive reasoning and is particularly adapted for theory building (Dubois and Gadde, 2014).

In the systematic combining approach, the matching process goes back and forth between theoretical models, empirical data, and analysis. This process is important because data should not be forced to fit preconceived frameworks. Rather, data and frameworks should be worked on in parallel, developing the theory and categorizing the data, as the data collection progresses. The matching process does not necessarily have a specific pattern or direction. These are the results of the process, and just as not all empirical facts can be known in advance, neither can the process's direction (Dubois and Gadde, 2002). Multiple sources allow addressing a broader range of issues. Findings are found to be stronger when corroborated by multiple sources (triangulation). However, in the case of systematic combining case study research, the motivation for using multiple sources is for revealing aspects that would otherwise be unknown using a single data source. By using multiple sources, a researcher can find new insights resulting from unanticipated findings, furthering the development of the theoretical framework (Dubois and Gadde, 2002). In the present research, multiple cases were involved to gather multiple and also perhaps unanticipated findings and insights on how digital transformation affects business relationships. The research started with a couple of kick-off meetings with corporate managers at both SMMS and CLG in the early summer of 2016. A literature review was initiated at the same time, and the theoretical framework to analyze both cases began to emerge as both companies described their challenges and goals with their respective digital transformation. From this early theoretical focus a questionnaire was developed to collect data. Once the data was collected, certain issues appeared to be more important than others, and additional theoretical lenses were brought in to better address them. This process of back and forth between data collection and adjustments to the theoretical lens, went on during the whole duration of this dissertation.

Forty-two managers were interviewed, a few of them several times, for a total of 47 interviews. The interviews were made with different key individuals in the studied networks. The interview participants were found with the help of individuals, corporate managers at both organizations, who worked as a contact point for both. They were conducted at different stages in the evolution of the observed digital transformations from 2016 to the end of 2018. The first
data collection phase, which lasted from late 2016 to early 2017, focused mostly on managers at the respective companies’ headquarters. At SMMS, these included managers from the corporate leadership for business development and strategy. These individuals were responsible for defining the vision of the digital transformation for SMMS. They were the earliest involved in articulating digital transformation goals, and the individuals responsible for the earliest changes in the resource context at SMMS. They had formally established an organizational unit, specifically to drive digital transformation changes, and therefore were also the interim leaders of this unit and its projects. Similarly, at CLG corporate level managers were interviewed, capturing the perspective of the individuals who had also developed the earliest vision and goals for the digital transformation at CLG. Individuals managing digital transformation projects were also interviewed in order to capture these early efforts made at both companies. In 2018, a second phase of data collection was initiated to capture more diverse perspectives spread out in different organizations at SMMS and CLG, with the explicit goal of capturing both industrial networks and the inner resource interactions related to their respective digital transformations. Key individuals at different tool manufacturing organizations, digital solutions organizations, suppliers and distributors were also interviewed.

Lastly, this dissertation presents in its ninth chapter a change theory which uses the metamorphosis analogy. The metamorphosis analogy emerged originally as a metaphor used to abstract certain aspects of the digital metamorphosis, namely the fundamental structural irreversible changes taking place, and the irreversible stage like change cycle that the digital transformation appears to take firms through. It emerged in a discussion within the ISNET group over what analogy could best describe this type of change, and it was first used as an illustration, by presenting the image of the metamorphosis change process of the caterpillar into a butterfly, to present certain key findings when the closing meetings were held with the management of respective firms. It proved to be a relatively successful illustration that inspired the managers and better anchored in their minds the findings and how different these changes related to the digital transformation were. From a relatively simple graphical illustration, the reflection continued around digital transformation as a complex change process. The Industrial Network Metamorphosis change theory was developed to describe complex change processes where structural metamorphic changes unfold in the resource context of industrial networks. The use of metamorphosis's natural biological change process as an analogy is for a figurative purpose only, for differentiating the type of changes taking place, and not to explain them with the same determinism that the original natural term implies. It is used here to abstract certain aspects of the digital transformation, which are detailed in the ninth chapter of this dissertation.
Empirical Findings

The papers included in this dissertation cover two separate manufacturing industrial networks, Sandvik Machining and Manufacturing Solutions (Papers 1, 2 and 3), and the Cibes Lift Group (Papers 1 and 4). The papers were written over a span of four years, with data collection which started in 2016 and ended in 2018, for a lifespan of about three to four years for these two industrial settings. They cover the transformation of both industrial networks, as they implement different digital transformation projects, which affect the interactions of the firms with customers and suppliers, their products and services, their manufacturing operations, etc. The papers paint a dynamic picture of digital transformation in two different settings. This section will present and discuss the findings of the different papers, the contributions and the challenges that they have uncovered.

In “Interaction through Boundary Objects: Controversy and Friction within Digitalization”, Paper I, interaction processes were analyzed taking place surrounding the projects supporting the digital transformation of two industrial networks, the resulting friction effects and controversies, through the theoretical lens of boundary objects. The article uses IMP theory, more specifically the resource interaction approach (Håkansson and Waluszewski, 2002a), and principles from Star and Griesemer’s (1989) boundary objects. Furthermore, the study investigates the interaction across different developing, producing and using settings, to see how the objects will “fit” different contexts in their respective industrial networks (Håkansson and Waluszewski, 2007). The study takes cues from cognitive aspect-focused theory and boundary objects, developing on the economic considerations of the interaction approach, to investigate the particulars of the interaction taking place around digital transformation projects. Boundary objects offer a tool to conceptualize interactions between individuals as actors and the objects, by investigating how the individuals interpret and interact with them. Boundary objects are objects with tangible and intangible elements, which intersect different social environments, filled with individuals with their own knowledge, roles, etc., and which allow for different actors, individuals, to interact with them in varying uses and with varying interpretations. Boundary objects allow for coordination and communication across differing social environments by allowing differing usage and interpretation, while keeping a resilient structure. The introduction of
the boundary objects lens within an IMP-based framework, allows for uncovering how the cognitive interpretation of digitalization-related boundary objects may lead to either friction effects or controversies in an industrial network. There is a relation between the interpretation of the boundary objects by individuals, and economic developments across business relationships.

Boundary objects can be defined as objects that are “plastic enough to adapt to local conditions and the constrains of several parties employing them, yet robust enough to maintain a common identity across sites” (Star, 1989, p. 46). Boundary objects present varying characteristics, which are their modularity and tangibility. Boundary objects can vary in modularity, from standard to modular or complex, allowing from unique to multiple local uses across different social environments (Easton and Mason, 2009). A boundary object may be interacted with in different ways, if it is a system with multiple modules or points of interaction. Boundary objects will also differ in how tangible they are, in how many interpretations they may have for different actors. If the boundary object is interpreted or carries the same meaning across multiple social environments, it will be described as tangible, and if not as abstract. Tangible boundary objects tend to concern technical and material aspects, while abstract ones will encompass more organizational and intangible aspects (Easton and Mason, 2009). Paper I offers an in-depth look at resource interfaces, between various organizational unit resources with boundary objects. By investigating the cognitive specifics of the interactions between these, the study offers insights into how value creation is facilitated by these resources. It also offers a first look at several key projects, also found in the papers that followed: the Center of Digital Excellence (formerly named Digital Center of Excellence), Smart Supply, and the Smart Lift projects, and the Adveon projects (only explored in this study). The point of departure for identifying these objects were discussions on digitalization and digital transformation at the respective firms studied. The respondents naturally focused on these as important objects to the different organizations evolving in their respective industrial networks. The four boundary objects were then characterized in terms of tangibility and modularity, and the related controversies and friction effects were explored across the different developing, producing and using settings at respective cases.
Table 3. Boundary objects matrix, sorting BO by modularity/tangibility, and listing their effects on resource interfaces within developing/producing/using settings (Fremont et al., 2018)

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Tangible</th>
</tr>
</thead>
</table>
| Standard | Adveon:
|          | Controversy due to a “not invented here” mentality within the developing setting |
|          | Friction due to change in ownership of resources in the producing setting |
|          | Friction due to incompatible resource interfaces within the producing setting |
| Modular | DCoE:
| Controversy due to a competitive culture within the developing setting | Controversy due to dualistic culture within the developing setting |
| Controversy due to diverging views regarding the value of digitalization technology within the developing setting | Friction due to change in ownership and control over resources within the producing setting |
| No friction due to a lack of change in resource interfaces within the producing or using setting | No friction due to incompatible resource interfaces within the producing and using setting |
| Lift 2016 | Controversy due to security risks in the using setting |
|          | Controversy due to restricted access to the value creating mechanisms within the using setting |
|          | Foreseen friction due to a lack of resources in the producing setting |
|          | No friction due to incompatible resource interfaces within the producing and using setting |

The paper II entitled “Digitalization Efforts in Liminal Space – Inter-organizational Challenges” (Eklinder-Frick et al., 2019), was the second study to address the Sandvik Machining and Manufacturing Solutions industrial network. The study uses the interaction approach to investigate how imposed liminality may affect innovation at an organizational unit established to drive digitalization efforts. It is also a second look at the organizational unit named CODE, introduced in Fremont et al. (2018). The unit had seen a number of changes between the first and the second study. Liminality theory was used to present certain characteristics of CODE as a liminal space (Wagner et al., 2012). CODE had been explicitly established separately from other organizations at SMMS, with a different culture, different organizational resource structures, and different strategic vision. Furthermore, it was also in between different states, as in evolving from resources integrated in traditional organizational structures, towards becoming an established business organization within SMMS. The purpose for this study was to analyze the benefits and challenges of establishing such liminal space to drive digitalization efforts, and to use the resource interaction approach to relate liminality characteristics with economic friction effects.

A liminal space can be characterized by a certain freedom, ambiguity and community (Turner, 1982). A unit as a liminal space may experience differing freedom from institutional obligations and regulations and freedom to develop new solutions, avoiding existing technical constraints (Turner, 1982).
Ambiguity may allow for the emergence of different ways of thinking, of activities that foster innovation, unaffected by established ways of working and thinking (Wagner et al., 2012). Individuals in these spaces may experience a strong sense of community, a shared sense of belonging, separating them from others on the outside (Czarniawska and Mazza, 2003). Additionally, liminal spaces evolve in different phases, the separation phase where resources are separated from their established structures, then a transition phase where resources are shifted back and forth between the liminal and established orders, and the incorporation phase which sees the introduction of the newly developed resources into the established resource structures (Czarniawska and Mazza, 2003). The liminal space may be terminated as a result of the incorporation phase or remain permanently in its liminal state to continue the shuffling and developing of new resources.

The investigation of the liminal space with resource interaction theory allowed for a number of observations. The separation of CODE from the established SMMS resource structures led to a number of benefits, or positive effects, for the company’s digital transformation efforts. The separation phase allowed circumventing company regulations stifling operation, the conservative company culture, and fostered a professional identity associated with the more innovative digital technologies industry. The separation led to a certain freedom, and to a sense of community being established. However, the study also observed many drawbacks or limitations during the following transition and incorporation phase. A “not invented here” mentality confronted the liminal space. The separation of innovations led by CODE from the core SMS operation made it difficult to predict their profitability. Changes in resource ownership challenged the internal balance of power. The introduction of new resources competing with established resources negatively affected certain established supplier relationships. The new CODE practices, new ways of working, clashed with established business practices, business models and enterprise systems. CODE introduced inter-organizational resource structures that competed with existing structures and investments. The technological resources introduced by CODE presented incompatibilities with other systems. Finally, liminality had led to overlooking corporate risk management, specifically regarding data security and privacy, causing potential future litigation risks.

“Opportunities and Limitations for Value Creation with Digital Transformation” (Paper III) is an in-depth comparative case study of applications of a digital transformation technology. It followed the first two studies, and incorporated perspectives of diverse settings within the SMMS industrial networks, including of actors within the setting of a traditional tool manufacturing organization named Seco Tools, and those of a new digital technology start-up named AMT for Advanced Manufacturing Technology, formerly referred to
in this dissertation as CODE. The study provides a comparative analysis of two applications of Smart Inventory Management Systems, a key technology of digital transformation, made possible by combining digital, IoT technology, and more traditional hardware components. SIMS can be found in many different settings, and more importantly are implemented in many digital transformations of manufacturing firms because of the horizontal integrations that they allow, which afford multiple value creation opportunities to the organizations implementing them (Björkdahl, 2020; Zheng and Wu, 2017). The paper investigates how firms create value with digital transformation applications, by uncovering the key characteristics of the resource structures which affect the development of opportunities and limitations in the different resource contexts. Using a comparative analysis of two different resource settings in which two distinct SIMS applications are embedded, identifying their characteristics, the patterns of interactions, and the differences in the two settings, the study developed new insights into the relationship between these characteristics and value creation.

The study investigated how two different resource settings, their composition and their different heaviness and variety characteristics, created opportunities and limitations for value creation from digital transformation, for two SIMS applications. The study provided several key findings on the relation between value creation and these resource context characteristics, in the traditional tool manufacturing setting, characterized by heaviness and lower variety in established production facility resources and supplier relationships. The heaviness and lack of variety in their resource setting created several hurdles or challenges for them. SIMS as a product was a resource largely controlled by the supplier and was described as presenting limited functionalities. The firm had a thin supplier interaction characterized by little adaptation in the product resources. This lack of product fit resulted in several cascading negative effects in technical resources at first. The resource developed by the supplier and sold by the manufacturing organization presented a lack of technical fit with IT systems used at customers’ and their own production facility, a lack of fit with other product resources used by customers. Downstream from these technical challenges a number of organizational issues resulted, such as a lack of trust and negative feelings towards the supplier relationship, inefficiencies in work practices at the business unit in charge of managing SIMS activities, and a squeeze on revenues from both high costs and low margins on the sale of SIMS. The value created with SIMS in this setting was mostly in the form of short-term process efficiencies, as in technical benefits that facilitated the managing of inventory at the customer’s organization. SIMS created benefits for the selling manufacturing organization, which didn’t produce any value for itself besides supporting the sale of other products.
The second setting identified was digital technology start-up organization. The organization was recently established for driving digital transformation efforts within the SMMS group. It focused on developing novel digital transformation projects for the digitalization of the different activities and offerings of manufacturing firms. The organization had fewer established resource structures, less heaviness and more variety. The SIMS in this setting had been developed with multiple supplier relationships, and was partially, for its digital element, under the control of the organization. They saw that having developed their own resource for the digital element of their system would allow them to develop the variety needed to create more value for their customers and themselves. They were free from economically heavy structures forcing their hands into serving a specific established relationship or technical solution, and had developed variety in their resource setting, allowing them to develop a more flexible and responsive system. However, the lack of certain economically heavy resources also presented itself as an important source of challenges.

The organization lacked several organizational unit resources in sales and marketing, training, sales tools, and sales personnel to support the direct sale of their system. They also lacked direct organizational relationships with customers. They were therefore dependent on their interactions with manufacturing organizations at SMMS for distributing their solutions to customers. This dependence resulted in several challenges in creating changes within the organizational resources at the manufacturing organizations, dealing with conservativism, a fear of challenging established other key supplier relationships, and managing expectations in regard to the place of their product resource into the offerings portfolio of manufacturing firms. Accessorily, they also lacked production facilities resources for the sale of hardware, and the SMMS exchange IT systems lacked a fit for such a digital product offering. With a relatively more complex resource setting, the digital start-up had challenges or limitations which were more organizational than technical. However, the outcomes in terms of opportunities for value creation were also greater and more mature from a digital transformation perspective. The SIMS allowed for process efficiencies in manufacturing processes at customers and producers. It also led to more long-term changes to the activities of the manufacturing firm, with horizontal integrations in the form of disintermediation in the ordering process, integrations with IT enterprise systems, and with the opportunity for establishing just-in-time manufacturing processes.

Finally, “Friction Forces and Digital Transformation in an Industrial Network” (Paper IV) focuses on friction forces in an in-depth case study of the complex industrial network of distributors and subsidiaries of a lift manufacturing company, the Cibes Lift Group (CLG), undertaking its digital transformation. The paper is the second to address the CLG case after Fremont et al.
(2018), and takes a closer look at how their digitalization efforts unfolded across their industrial network, including the friction forces and related changes that took place across their network of subsidiaries, distributors and customers. The study continues to develop on the resource interaction approach (Håkansson and Waluszewski, 2002a, 2002b), but focuses on the particular friction mechanism, on the study of friction stabilizing and destabilizing forces in the context of digital transformation, and on the relation between resource interfaces and these observed forces. CLG had initiated a digital transformation project around the development of smart products, and related change projects in its production operations.

The study focuses on the changes related to the roll-out of the smart product, the Smart Lift, and the related friction forces. The purpose is to analyze how digital transformation unfolds in industrial networks, and which mechanisms may affect the change process. The study investigates the resource structures of the CLG resource contexts, their interfaces, and how they develop a path dependency for the digital transformation. The Smart Lift presented new functionalities made possible by developing IoT-type technology into the lift product. The Smart Lift presented a new control system that could be connected to the internet. The new product would be able to send data to different actors via the digital communication, to CLG and its distributing partners. In return, different actors would be able to remotely pilot and monitor the product. These new functionalities would create a number of opportunities of value creation for the technical support and commercial activities of CLG and its partners.

The study uncovered 11 different points of interaction, resource interfaces, across the CLG resource network, which saw friction effects related to the digital transformation undertaken by the organization. The interfaces were identified across the mapped resource network, and characterized in terms of the resource structure types involved, as technical, organizational or mixed (Baraldi and Strömsten, 2006). The complexity of the CLG industrial network, of its interdependencies, meant that complex friction effects resulted from the changes brought by the Smart Lift across the resource interfaces. At interfaces most directly related to the introduction of the new product, at points of interaction between the smart lift and the technical support production facilities and organizational units, a number of effects were observed. First, product core functionalities and design changes led to faster and simpler access to control systems for technical support personnel interacting with the product. For the technical service and support organizations in regions dealing with higher labor costs and/or an important geographic spread of customers to support, the changes led to lower production costs for their service and support activities, by lowering the cost to access the control systems of the products, key points of interactions for the maintenance employees.
The functionalities were followed by the introduction of tools, cloud-based digital tools, at technical support organizations, which created easier, faster access to product and user data. This access led to a number of efficiencies being created, in terms of more efficient man hour use for the monitoring of product-related problems as less time would be spent traveling between facilities, increased work quality and optimization as more accurate and transparent data was made available for the work to be done, and to lower labor costs for organization units as more products could be serviced per service agent. However, these also led to several negative effects observed in a number of locations, as legacy systems would need to be made compatible with the new ones, thereby creating an adoption cost for the partnering distributing organizations. The increased technical complexity of the new product had created hurdles for certain organizations that saw a loss of certain legacy functionalities, and a resulting increased cost for their maintenance activities during roll-out. Certain technicians had difficulties interacting with the new control system, which had a more technically advanced interface, and therefore saw difficulties in providing the same quality of maintenance work.

A number of friction effects could also be observed at interaction points indirectly related to the smart lift at relationships between distributors and their customers. The changes in product resources were anticipated to allow distributors to develop their market share further with an increasingly diverse product offering. In the short term they anticipated increasing their revenues from product and service price increases, and to see the number of service contract sales increase with the same number of service technicians. The changes would also strengthen the interactions across the relationships with customers. By offering unique functionalities increasing the reliability of service, providing a sense of safety to the customer, they anticipated a lock-in effect to appear in their customer relationships. However, negative effects were also observed in certain customer relationships as the smart lift offering didn’t fit certain customer requirements or even appeared contrary to certain expectations.

A number of effects could also be observed at interaction points between the distributors and CLG, as first the changes led to an increase in the brand equity surrounding the CLG portfolio, perceived as more technically advanced and state of the art compared to its competitors. The changes in product also created a backlink for CLG to access certain user data, which was only partially accessible via its distribution network before. The access to data created efficiencies and improvements in marketing and sales, and R&D practices at CLG. The data would also serve as input to provide better technical support to the distributor network. The changes to the product resources also allowed CLG’s portfolio to better fit distributors’ requirements, for products that are easier to install, and more flexible in the configurations that they need to
respond to. However, negative friction effects could also be observed, as when implementing the changes, CLG lacked support and communication with its distributors to manage their expectations. It appeared that their lack of engagement during the pre-release of the smart lift had caused enthusiasm to drop, and therefore chipped away at their credibility.
Contributions

Fremont et al. (2018) highlights a relation between the organizational digital transformation efforts and the emergence of controversies. Such efforts to affect changes into knowledge, ways of working and other more potentially abstract issues, will create effects in the cognitive domain of interaction. On the other hand, friction effects are of the tangible and economic domain. Friction appears to arise when changes affect tangible resources. Standardization in the resources resulting from digitalization efforts may lead to rigidity in the interactions and lead to cognitive controversies and friction in tangible resource interfaces. On the other hand, no technical resource incompatibilities appeared when modularity was a feature of the changes implemented. Furthermore, the boundary objects study highlights the importance of accounting for cognitive developments with implementing digital transformation projects, and suggests a relation between tangibility and standardization with friction, and between modularity and abstractness of these projects with cognitive controversies. Furthermore, modularity and abstractness were associated with developing and innovation processes, while tangibility and standardization are characteristics that emerge in production and use, when being exchanged and presented to the market.

These aspects provide insights on the value creation process, where objects may materialize and evolve from sources of cognitive controversies to sources of economic friction. The study highlights the importance for managers dealing with digital transformation, of accounting for both cognitive differences across different social environments affected by change. It provides a framework to categorize projects in terms of their modularity and tangibility, allowing them to anticipate and map the emergence of controversies and friction. Therefore, it also allows managers to drive an internal reflection and communication on the challenges presented to them. Managers can use such tools to better present to the parties involved the different perspectives and drive the emergence of a common understanding across the different environments. Finally, the study suggests that practitioners should expect cognitive controversies when their projects are in development, and resistance and friction when they are implemented into the producer and user setting.
The Eklinder-Frick et al. (2019) study highlights how IMP theory can support the study of liminality and liminal spaces. The interaction approach provides tools for explaining how certain benefits and challenges arise from operating in liminal spaces. IMP posits that innovation occurs in networks, where the development should be done in relative closeness to the producing and using settings for benefits to occur. This explains why certain issues, such as the lack of technical compatibilities in certain resources, may occur as the liminal space detaches the locus of development and innovation from the user setting where the innovation will produce value. To achieve its potential for value creation, an innovation must fit into established user structures and networks, and therefore must take place in relation to these structures. The study suggests that imposed liminality may be a strategy for dealing with complex changes meant to drive a digital transformation within heterogeneous resource networks. It may be practical for avoiding limitations resulting from resource over-embeddedness, and to drive digital technological innovations within non-native digital manufacturing environments. The liminality of the CODE space allowed it to develop an internal sense of community and led it to operate more freely from generally conservative SMMS organizational structures. However, liminality may also create hurdles for rolling out digital innovations, as the distance from the user settings may increase the number of friction effects. The ambiguity surrounding CODE, making it seem like a competing and challenging entity by outsiders, affected inter-organizational exchanges negatively. It furthered the distance between established and new structures, making the creation of interfaces between the old and the new more difficult during the incorporation phase. The study suggests that individual and organizational stress resulting from imposed liminality should be better understood by applying an interaction perspective, taking into account economic issues and previous investments made in established resource structures. Applying the interaction perspective should allow for connecting these cognitive aspects, the negative feelings, with friction effects affecting value creation mechanisms. The study also highlights the importance of inter-organizational interactions as source of friction effects affecting these internal stresses. The study illustrates how practitioners can strategically use liminality to drive complex change processes, as a way to loosen rigid resource structures’ organizational constraints. It also highlights the trade-off of liminality, and the potential difficulties in establishing interfaces between old and new resources, resulting from the created sense of community and ambiguity during the incorporation phase. The study highlights the importance of balancing the amount of freedom, ambiguity, and community when establishing a liminal space to foster innovation and reduce future hurdles during the incorporation phase.

The paper entitled “Opportunities and Limitations for Value Creation with Digital Transformation” (Paper III) presented an in-depth analysis of how
resource structures can, from their characteristics, create opportunities and limitations for value creation from digital transformation. The paper focuses on a specific digital transformation technology, Smart Inventory Management Systems or SIMS, which unfolded in two different resource constellations, different in their heaviness and variety, and led to two different outcomes in opportunities and limitations for value creation. The study illustrates value creation processes from digital transformation as a product of resource interactions in two resource contexts of a single industrial network and suggests that increased variety and lower heaviness are associated with more value creation outcomes. More specifically the study suggests that increased variety in the resource structures involved in the digital transformation changes are associated with more value creation opportunities. An increased variety in resource interactions may foster the development of digital transformation solutions with a higher set of functionalities, and which allows for more digital transformation-related changes and benefits.

On the other hand, the study also suggested that the heaviness in resource structures was associated with limitations to changes and value creation from digital transformation. Heaviness, resulting from historical investments and commitments into certain resource structures, means that they will be difficult to break apart, which was observed in organizational resources and therefore difficult to change. The study illustrates the important role of organizational resources as a source of limitation to value creation from digital transformation. As the two organizations were aiming at solving certain technical challenges, a lack of hierarchical control over certain external organizational resources had created a number of cascading limitations to value creation in one setting, while in the other, a thin interaction across an organizational relationship and resulting lack of hierarchical control over technical resources led to further downstream limitations to value creation from internal organizational resources. Furthermore, the study also suggests that an increased number of resource interactions, i.e., a more complex resource setting, may also lead to an increased number of potential challenges. Indeed, variety in one setting served to increase the number of opportunities but also of limitations.

An organization that had created more relationships in order to access more resources controlled by others in the network had also, by expanding its own resource constellation, increased the number of sources of limitations to value creation with its digital transformation efforts. This study suggests that digital transformation projects that yield benefits may also simply be more challenging to accomplish because they appear to involve a more complex resource setting, which by their variety and heaviness create both opportunities and limitations to value creation. Therefore, this study highlights the balancing act of creating value from digital transformation in an industrial network, of choosing to create complex and functionality-rich solutions while dealing with
increased liabilities from the resource context. It also illustrated how unique
the digital transformation as a change process is because it is embedded in
unique resource settings that create unique sets of opportunities and limita-
tions. When these collide, they create a path to the changes undertaken.

“Friction Forces and Digital Transformation in an Industrial Network” (Paper
IV) uncovered a number of findings that depicted certain characteristics of
friction forces, resource structures and digital transformation-related changes.
By employing the RIA approach to a digital transformation case, the study
illustrated how when change is applied to an industrial network, friction forces
can cascade into a number of stabilizing and destabilizing effects, at both di-
rectly and indirectly related locations, across a complex resource context of
different technical, mixed and organizational resource interfaces. These ef-
fects will either be positive developments, changes favoring certain value out-
comes, or hurdles to change and value creation. The study showed how the
positive and negative friction effects aggregation affected the path depend-
ency of digital transformation. In particular, the study highlighted the im-
portance of organizational resources, of mixed and organizational resource in-
terfaces for changes related to digital transformation.

The study uncovered a relation between several friction effects and these re-
source structure types. Therefore, the study suggests that organizational re-
source types may be more prone to creating friction effects in the context of
digital transformation than technical resource structures, thereby calling for
further research on the relation between the nature of resource structures and
their proneness to creation of friction effects. The study suggests that certain
resource types are more prone to foster these positive or negative friction ef-
fects in the context of the digital transformation. Furthermore, the study un-
covered a certain order in the type of resource interfaces involved when deal-
ing with digital transformation-related changes, with friction effects unfolding
directly in the technical aspects, and indirectly at organizational resource
structures. However, this doesn’t indicate in which sequence the effects occur,
as in if technical-related friction effects occur before organizational-related
friction, but that they take place closer to the original locus of change in the
resource network.

Further research could address whether the manner in which change unfolds
across resource structures may reflect a type of change, or if the observations
made here are specific to digital transformation. Because of these aspects, that
friction can be mostly associated with organizational resources that are distant
from the initial changes, certain friction effects, such as a lack of digital tech-
nology-oriented culture or the routines used locally by technicians to perform
certain operations, might live in the blind spot of managers in charge of the
digital transformation efforts, beyond the cognitive perception of CLG
managers. Although the case did illustrate a digital transformation, it didn’t illustrate the “disruptive impact” of digital transformation (Parviainen et al., 2017), as in a transformative change that would have fundamentally changed core structures in the CLG industrial network. Therefore the study calls for rethinking change in the context of a digital transformation. No radically transformative changes were observed, as change took place in a manner that would fit with existing resource structures within the industrial network, and therefore mostly incremental. Friction affects changes related to the digital transformation, and therefore provides both inertia preventing transformative change from taking place, as well as the forces that will allow such changes to take place.
Discussion

All four papers are qualitative case studies conducted over three years, focusing on the digital transformation change process of two industrial networks, allowing them to follow the developments taking place across time during their transformation. All four use theoretical concepts from the resource interaction approach, either partially in combination with other theories (Eklinder-Frick et al., 2019; Fremont et al., 2018), or as main analytical framework (Fremont, 2020, 2019), thereby allowing for a common thread to connect and draw theoretical conclusions across the four studies. First, the studies created insight into how digital transformation can be researched with the boundary object and liminality lenses, highlighting specific cognitive elements of digital transformation changes and resources, and managerial implications for dealing with the particular type of innovation developments and change of digital transformation. The studies also provided a number of insights into how firms may address digital transformation changes, by highlighting how certain resource characteristics may be related to cognitive controversies and friction on both the node, dyadic and network levels.

The consistent use of concepts of the resource interaction approach, such as resource structures and friction, allowed in fact to flatten the levels into a web of resource structures, spanning the different industrial networks, and across which changes unfold during their digital transformation. Finally, the studies make it possible to draw a number of key conclusions into how digital transformation affects value creation in the industrial network. The studies provide a number of insights on how the changes led by the introduction of new technologies may create increasingly complex resource interactions challenging the status quo, allowing firms to rethink their business models towards new opportunities of both short-term efficiencies and long-term growth, while also providing new challenges to value creation. The studies also showed how digital technologies should be combined within and across organizational boundaries with other technological and organizational resources to be purposeful and create value. The papers further illustrate how modular, combinatorial and recursive technological systems (Arthur, 2009) should be investigated with an industrial network perspective, as certain technological changes can only be captured from a perspective that can present the combination process across the network.
Implications for Interactions in the Industrial Network

The articles paint a detailed picture of digital transformation as a change process that affects value creation within an industrial network of manufacturing industries, while tracking the evolution of different developments from the dyadic to the network level. The first two papers focus on the node and dyadic level, while papers three and four paint a picture on the network level. Fremont et al. (2018), shows how individuals interact with different resources at the limen or intersection between different social environment made of actors who will interact with the resources to enact change, and between the old and the new, the pre-digital transformation past, and the future developments that will be taking place. Eklinder-Frick et al. (2019) focuses on liminality, on a liminal space created to initiate the digital transformation and the specific innovations that make the digital transformation specific from other forms of innovation-led change processes. Using the liminality lens allowed for taking a closer look at how firms can undertake developments that deviate from the previous course of developments taken by the transforming industrial network. Using both theoretical lenses of boundary objects and liminality (Star and Griesemer, 1989; Wagner et al., 2012), the present research on digital transformation takes a close look at resource interactions, and shows the internal conflicts taking place at the resource level.

The resource interaction approach focuses mostly on the economic dimensions or resources, how they create value in terms of efficiencies, effectiveness and cost reductions, and on the friction effects that unfold when changes are applied to resource structures in tensions. The Paper I puts the cognitive perceptions of individuals into the picture, by presenting how different individuals interact with these resources, and how controversies which may translate into a resistance to change may emerge from conflicting perspectives. This understanding brings contrast to the rainforest image of long-lasting interactions. The digital transformation appears to bring a certain degree of conflicts and friction within these interactions. It is a change process that may break certain interdependencies, as actors develop conflicting perspectives towards the change. The use of the liminality lens also presents how firms may separate embedded resources, although not entirely, from their settings where they have developed certain adaptations and mutual orientations towards others, and establish new resources in separation from others, and therefore also from developing adaptations to others (Eklinder-Frick et al., 2019).
Coping with Changes of the Digital Transformation

The observations made in Eklinder-Frick et al. (2019) and Fremont et al. (2018), the efforts to implement coordination and collaboration around boundary resources, and the use of liminality to drive innovation and changes for digital transformation, all take place nested within the greater context described by Fremont (2020, 2019). The developments described in the former on specific projects, are connected to greater network effects and changes in the latter. Thus, digital transformation is being presented at a different scale and scope, creating a connection between cognitive perception of change to greater network forces and mechanisms affecting value creation. As an example, Smart Supply was developed with modularity and tangibility characteristics, allowing coordination to happen across different social environments, interacting with the resources and developing different cognitive perceptions on the changes implemented. On the cognitive and intra-firm level, controversies emerged in the form of conservativism and resistance, which led to certain economic limitations to value creation at the network level, as the resistance to change created difficulties for selling the Smart Supply solution by its leading organizational unit, AMT.

Fremont et al. (2018) presents the introduction of some of the first changes that the two business organizations are undertaking for their digital transformation. The paper describes two early sequences of changes taking place within the resource structures during the initial moments of the digital transformation of SMMS and CLG. In both cases, the digital transformation was initiated through changes to product resources in the form of projects for creating new product and service offerings with digital technologies. These were then followed by changes to production facilities and/or organizational unit resources. At SMMS, the initial change was the creation of certain digital technology-focused projects initiated at different manufacturing organizations of the SMMS group. The projects were identified by the corporate leadership of SMMS for their potential to provide transformative changes for the entire group and industry, and later a new organizational unit with the SMMS group was established to manage the projects’ development. At CLG, a project was established around the introduction of digital technologies, and its potential for transformative change was also recognized, which was followed by the introduction of changes to the production facility resources of CLG. The paper further tells us that firms can develop goals for their digital transformation by establishing new organizational unit resources, and they may do it a posteriori of the initial changes that triggered the digital transformation process. The changes to organizational unit resources follow changes to the technical resources, but influence their future changes, as goals are further constructed within the newly introduced unit. The explicit purpose for establishing the unit was to further develop a direction for the changes and articulate concrete goals.
for the transformation of the SMMS group. Controversies resulted from conflicting cognitive views over the digital transformation goals for value creation. As an example, the unit developed a goal for increased internal collaboration which collided with the established competitive culture of the SMMS group. The said goals developed as the new unit was expected to later be shared via future newly established relationships across the SMMS group. The changes in production facilities and product resources were sources of most friction effects and controversies from the cognitive interpretations that individuals built from these developments. As the changes in the product resources are realized into their commercial purpose, friction effects supplant the cognitive controversies, and reveal economic related resistances, as the actors realize the technical limitations or the investments that are yet to be made in order to create value with the introduced resource change. At CLG, managers saw that to create value, efficiencies and cost reductions from their new product, several investments would need to be made into establishing interfaces with other tools used by the technicians interacting with their product.

Firms may separate certain resources, both physically and cognitively, away from stabilizing friction forces, from institutional barriers and the general resistance and inertia. Eklinder-Frick et al. (2019) focuses on the organizational unit that is CODE as a liminal space, meaning a specific type of unit meant to drive innovation development for the digital transformation of SMMS. The paper shows how, by using liminality, firms can drive change that may differ from prescribed changes, which usually dominate the life of firms outside of a period of digital transformation. To achieve its full potential, innovation should fit established producing and using structures, meaning that the development must happen in relative closeness to these settings. However, for a digital transformation, firms may be explicitly trying to drive changes that don’t necessarily fit with current resources in producing and using settings, and instead drive change into these settings. Separating organizational resources may allow the creativity and freedom necessary for developing the changes required for a digital transformation. However, the separation itself will create challenges in implementing the changes when they are being introduced into other settings. Therefore firms should try to create liminality around the organizational unit resources established for the managing of certain key digital transformation changes, by balancing levels of freedom, community, and ambiguity that don’t completely alienate the development from benefiting and inducing changes in another locus of their industrial network. Therefore, the paper paints a picture of how firms can essentially initiate a transition course for their digital transformation.

When firms undertake digital transformation projects, they need to account for the embedded resource context and how it will affect the changes they will need to implement. Fremont (2019) presents an SMMS that has progressed
with its digital transformation, and that has developed the organizational unit resources managing these developments for the group further than in the two previous studies. The paper focuses on studying the path dependency for change in terms of opportunities and limitations for value creation resulting from the resource context. The paper suggests that developmental changes for digital transformation may yield more opportunities for value creation, if they are done with variety. Firms can increase their opportunities if they implement changes that increase the number of resource interactions between different resource types and introduce flexible resources that can create new interfaces. On the other hand, heaviness in established resource structures, as in past investments into material and organizational resource structures, may limit their opportunities for creating value from their digital transformation-related changes. Firms should also be mindful of which resources are under their hierarchical control to implement changes. The study presents how AMT managed to drive more development of its application by having under its hierarchical control the key technical resources that would allow it to be more flexible and prone to develop variety in its interactions. However, limitations to their efforts came from several organizational resources that it didn’t control. The paper further highlights how unique digital transformation as a change process is, because the path of change is determined by the opportunities and limitations that result from the complex and therefore also unique resource context. Firms should see the digital transformation only as a complex and unique change process specific to their industrial network and broader resource context.

Stabilizing and destabilizing friction forces will affect developments undertaken during a digital transformation, as transformational changes may cause negative friction effects at directly and indirectly related resource structures. Therefore friction is a mechanism that can simultaneously cause both positive and negative outcomes in terms of cost, efficiency, and effectiveness, that will either promote or hinder changes. These friction forces will also systematically appear when changes to digital transformation are applied, as shown by all previous studies in this dissertation. Fremont (2020) presents how friction effects may cascade across the resource network, across technical resources, mixed and organizational resource interfaces. Because of the dissemination of friction effects due to the single efforts of a firm to undertake a digital transformation, certain changes producing positive economic outcomes will be favored, while others will be hindered as a result of increased cost or by a resistance to change by actors for whom the developments will lead to a negative value outcome. The paper illustrates how changes are moderated by the nature of the resource interactions taking place, hinting at a strong influence of organizational resource structures, of mixed and organizational resource interfaces, as sources of hindrances to change for digital transformation. Lastly, because of the friction mechanism, digital transformation changes may lead
to both positive and negative value outcomes for the industrial network, and therefore firms should expect to create negative outcomes in their industrial network, when undertaking such changes, which might hinder their efforts in different ways.

Implications for Value Creation

The explicit purpose of digital transformation is value creation (Bharadwaj et al., 2013; Björkdahl, 2020; Matthyssens, 2019). The IMP literature describes value creation as the result of the interaction process, of the confrontation and exchanges of different resources by organizations in the industrial network. Therefore, value is created from and with resources that are combined and adapted by organizations in a complex resource network connected across boundaries by resource interfaces. The configurations achieved by organizations at resource interfaces are how resources provide certain new functionalities that create efficiencies, quality increases or cost reductions that present a certain economic value for the interacting actors (Håkansson, 1982; Håkansson and Waluszewski, 2002a; Johanson and Wedin, 2000). Value creation from digital transformation is largely presented as positive for the firm undertaking the change process (Matthyssens, 2019; Westerman et al., 2014). At both SMMS and CLG, the complexity and number of resource interactions enabled by digital technologies generally increased as both firms implemented their digital transformation (Fremont, 2020, 2019). Digital technologies permeate industrial organizations, and their implementation is accompanied by a number of changes across their resource context and resulting opportunities and limitations to value creation.

In both cases, challenges stemmed from challenging the status quo of value production in the industrial network. Before their digital transformation, both SMMS and CLG occupied a leading market position, meaning that they perceived themselves as producing more value than other actors in their respective industries. At SMMS, the traditional manufacturing organization saw strong support for the status quo, continued to produce value in the same manner around the sale of hardware, and opposed business models related to more intangible digital solutions. Controversy resulted from these conflicting views regarding value creation from digital transformation (Fremont et al., 2018). During the CLG digital transformation, the introduction of new IoT-based resources challenged established ways of working at certain conservative customers and distributors with established ways of working and cultures (Paper IV). Digital transformation therefore implies a certain amount of confrontation with established modes of value creation. Firms will present changes into their resources, both technical and organizational, and conflict will happen in the form of controversies around the resources to articulate new
ways of producing value from the resource changes. Liminality may be used to develop new modes of value creation and develop new organizational resources in relative separation from the established ways of producing value.

Both SMMS and CLG industrial networks illustrated the power of digital technologies, their capacity to create more resource interfaces by their digital elements, and to create value. Central to digital transformation is the capacity to create new digital connections, to establish these cyber physical systems to create efficiencies, quality increases, growth opportunities, etc. (Nwaiwu et al., 2020). A number of positive effects of value creation from digital technologies were observed, as both networks saw the roll-out of IoT-based resources, which would connect different systems to create value (Fremont et al., 2018). The Smart Lift developed by CLG had an IoT-based control system, which could be combined with other applications to create value from new functionalities for the user and professionals interacting with the lift (Paper IV). The new organizational unit established to focus on digital transformation efforts by SMMS’s corporate managers, was to lead a number of projects, besides Smart Supply and Adveon, for the purpose of creating these digital connections between different previously unconnected systems, to create value (Eklinder-Frick et al., 2019). Digital transformation appears to draw value from increased resource interactions, not just between technical resources, but also from organizational resource interactions. Besides developing new technical resources, the unit established around itself new organizational relationships with other organizations to interact and create further value around the trade of its digital solutions (Paper III). Organizations may foster more value creation opportunities from digital transformation by developing relatively complex resource contexts, by introducing new and challenging established resource structures. Furthermore, the characteristics of the resource context, variety and heaviness, will create path dependency in the form of opportunities and limitations for value creation from digital transformation. Firms may manage the characteristics to either foster the creation of opportunities or to cope with limitations (Paper III).

The four studies highlighted the importance of friction effects to value creation in digital transformation. Friction is a mechanism that favors existing forms of value creation (Håkansson and Waluszewski, 2002a). Therefore, as firms are challenging the status quo they are causing a number of negative friction effects or resistance resulting from their efforts across industrial networks. Negative friction effects appeared from a lack of technical compatibilities between systems used by different actors. Adveon had been developed non-collaboratively and too remotely from the intended user, and therefore lacked compatibility with other databases, rendering it sub-efficient for creating value with its intended purpose (Fremont et al., 2018). Effects appeared from the lack of certain resources and the change in ownership and
hierarchical control of other resources. A SIMS project saw its efforts and revenues obstructed by resistance to adoption by partners who foresaw a future revenue loss with controlling the resources associated with the changes introduced (Paper III). Other effects caused increased costs and lower quality of work due to increased complexity in resource changes. Digital transformation implies generally a higher technical complexity that not all actors interacting in the industrial network are ready to address. CLG had distributors that were not all trained and culturally ready to use digital technologies in their work. While most had costs to adapt their resources to the changes, some saw the quality of their work affected (Paper IV). Negative effects were also observed across relationships, as expectations towards the changes were not shared or conflicting, and therefore negatively affecting certain business relationships. Certain groups of customers of CLG expected to feel safer from having frequent visits from their service technicians than with a digital link (Paper IV). Therefore, value creation from digital transformation comes with a certain number of costs. The overall balance of the digital transformation may be overall more efficient but produce less value in the economic sense of the term.
A Change Theory

In the first chapter of this dissertation, the argument was made that the digital transformation phenomenon is a complex change process that lacks a clear definition and understanding of how it affects interactions, changes, and value creation in the industrial network. The following chapter will develop a theory that summarizes the contributions of this dissertation research that describes and helps create a clearer understanding of the digital transformation and similar change processes driven by technologies in the industrial network. Digital transformation may be one in a series of similar transformative phenomenon in the life of manufacturing firms outliving the researcher who observes them.

“When digital transformation is done right, it’s like a caterpillar turning into a butterfly, but when done wrong, all you have done is a really fast caterpillar” – George Westerman

Economics has always borrowed from natural sciences for analogies to describe economic phenomena. The life cycle analogy has been used to picture firms' foundation, growth, and foreclosure, like living organisms that are born, grow and die. Natural selection, a Darwinian term, has been used to describe the viability in a competitive environment of firms, and homeostasis, the term used to describe internal biological system balance and resilience, to explain firms’ behaviors (Penrose, 1952). Penrose argued that these analogies, by especially framing problems, risked hiding certain key important issues, as an analogy can hide or misrepresent the complexity of these problems. The motivation of social scientists for using biological analogies stems from the envy for discovering deterministic laws regulating human actions in firms, to finally cure social sciences of their complexities and uncertainties. Ultimately, an analogy can be used to identify a shared abstraction and make abstract concepts more concrete.

The present chapter is not an attempt to develop a predictive digital transformation model, but rather to develop a good descriptive theory of the complex change process. The theory will be built on the present research on the digital transformations at SMMS and CLG, which has itself been developed using
the RIA approach. It will also take inspiration from organizational change theories and use metamorphosis as core metaphor for a change process which includes metamorphic changes. The present chapter uses terms or adjectives from natural sciences to which a couple of definitions are provided below.

**Evolution:** “change and dynamics in business networks. Evolution emphasizes the process nature of change, and also relates it to the context in which it occurs.” (Halinen and Törnroos, 1998, p. 188)

**Metamorphosis:** “change in organizational structure occasionally punctuated by abrupt, major transformations which sharply distinguish one period of organizational history from another.” (Starbuck, 1967, p. 113)

It is undeniable that firms change with time, in what they produce and their identities. In the industrial network, stabilizing forces tend to be dominant and therefore change mostly follows an incremental evolution. Evolutionary changes reflect cumulative structural changes, and therefore are mainly incremental, and seldom lead to revolutionary or radical outcomes (Halinen and Törnroos, 1998; Van de Ven and Poole, 1995). Digital transformation however appears to lead to non-incremental changes in the network, as the introduction of digital technologies leads to new business relationships being established, while established ones may be abandoned, and to core activities and firms’ identities being reshaped (Mergel et al., 2019; Westerman et al., 2014). The digital transformation happens in the industrial network with its interdependencies, meaning that it is a change process dependent on firms creating and maintaining new organizational relationships to gain access to resources in their industrial network under the hierarchical control of others. It is a change process influenced by the interactions between different actors. Therefore, it calls for a metaphor or analogy that can illustrate the type of changes associated with the digital transformation and consider the industrial network specificities. Håkansson et al. (2009), of the IMP approach tradition, have proposed looking at markets using the rainforest metaphor. This metaphor is based on a different understanding of business relationships and interactions between firms constituting a given business landscape characterized by long-lasting interaction and different forms of cooperation.

The IMP rainforest presents four main characteristics: features, variety, motion, and relatedness (Håkansson et al., 2009). Rainforests are structured in
different layers that present different environmental characteristics, different levels of resources, water, sunlight, biomass, and air. The layers of a rainforest are interdependent, and are populated by different vegetal and animal species. Within the natural rainforest system, certain animals are capable of changing layers or habitat conditions by changing their phenotype, their physical traits, by means of metamorphosis (Oostra et al., 2014). In the industrial network rainforest, organizations’ performance depends on their capacity to achieve a network symbiosis by creating and maintaining relationships with other actors, so that they can benefit from both their hierarchically controlled resources and the resources controlled by others (Håkansson and Snehota, 2006). However, certain firms are undertaking a digital transformation. As a result, they are developing new capabilities, new business models, and new identities, allowing them to enter new markets and find new customers (Mergel et al., 2019; Morakanyane et al., 2017). Thus the metamorphosis metaphor is used as an abstract characterization of these changes taking place during the digital transformation that leads to the redefinition of capabilities, business models and identities of firms in the industrial network.

The aim of using the metamorphosis metaphor is not to provide new knowledge of business landscapes, but rather to reinterpret them and provide an alternative understanding of how they live. The business landscape is subject to both radical and important, and incremental and lesser visible changes. Changes, the intricacies and complexities of the business landscapes, are usually glanced over by observers who tend to develop a more abstract vision of the landscape, focusing on the single firm, and the phenomena considered to be driven by antagonisms and competition. Therefore, all greater issues affecting industries are generally assumed to result from the changes in the competitive environment. This vision includes Industry 4.0 and firms' digital transformation, which can be assumed to at least partially be driven by increased competition and market commoditization. However, the IMP approach has developed a different understanding of what drives changes in the business landscape, as the result of interaction and emergent from networks of different actors connected by long-lasting relationships, and never as the result of a single company’s efforts alone. Change results from the multiple interactions that take place in the rainforest connected with and across the layers that it offers by actors that are either capable of interacting across layers, or by actors that will undertake a metamorphosis transformation to take themselves to a higher layer.
Changes in the Rainforest

“No business is an island” as organizations are embedded in an industrial network where their behaviors are constrained, if not predetermined, by their context (Håkansson and Snehota, 2006). Firms interacting in the industrial network develop interdependencies across relationships, characterized by resource ties, actor bonds and activity links. Therefore, changes happening within the firm will be linked to changes across the network (Håkansson and Snehota, 1995). In fact, the existence of these market interdependencies means for the firm that their capabilities, identities, and performance are constructed as a result of not just the actions and changes taking place within the firm boundaries, but also as a result of actions and changes undertaken across their industrial network (Håkansson and Snehota, 2006). The resulting interrelatedness makes it difficult to disconnect the firm from the network from an analytical point of view, as the firm is in relation to other firms, and its boundaries become blurred (Håkansson and Snehota, 2006). Change is, therefore, inseparable from the interactions and relationships defining the industrial network. Through these relationships, forms are continuously exposed to change generated by others, while generating changes themselves that will affect others (Tikkanen and Tuominen, 2000). Thus, in the industrial network perspective, change is mainly endogenous, as it starts from within the organization, and handles interdependencies within the broader industrial network context (Håkansson and Snehota, 2006). This potential complexity of change in networks makes the predictability of its outcome difficult to handle, as changes propagate through the network in a non-linear manner, starting in different parts of the network and gradually involving other parts (Fremont, 2020; Tikkanen and Tuominen, 2000).

In the industrial network perspective, the business relationship is considered the main locus, recipient or transmitter of change, and therefore changes first affect the relationship and the firms forming the dyad creating it, or become connected and affect other indirectly related relationships and firms (Halinen et al., 1999). The network is both provider of resources and of constraints, of opportunities and limitations, for change options of firms (Paper IV). The industrial network is full of stabilizing forces that create inertia, pushing the network towards stability. Such forces include market interdependencies, ties, bonds and links, and the conservativism held by individuals, the tendency to stick to established patterns of behaviors and their natural resistance to change (Halinen et al., 1999). Stabilizing forces and their resulting inertia are the reason why most change in industrial networks is incremental (Abrahamsen et al., 2007). But change and stability represent a duality of the network, as there are always forces present destabilizing the structures connecting the actors, driving change, as well as forces driving these same structures towards stability (Halinen et al., 1999). Change is also multidimensional and multipurpose,
it happens both within and loosely coupled with established structures, both continuously and discontinuously, where firms coordinate or structure their resources and activities in a stable manner, as well as mobilize or hierarchize other activities and resources in new combinations (Abrahamsen et al., 2007). When actors within an industrial network identify a need for change, they may initiate a complex transition process of change management, and after a given time period, reach a state where the new desired practices or benefits have emerged (Tikkanen and Tuominen, 2000).

Change can thus also be of different types, as industrial networks present both gradual or incremental, and revolutionary or radical changes (Halinen et al., 1999). They see periods of stability, where the underlying structures and activities remain the same, and only incremental changes take place. These periods may be interrupted with revolutionary changes, triggered by so-called critical events, during which existing ties, links, and bonds making the relationships and network stable, are fundamentally changed or dissolved, and new relationships are established (Halinen et al., 1999). Critical events or incidents trigger these periods of radical changes, resulting from existing change forces in the network. It is not the event that will start the revolutionary change, but rather the cognitive response or attitude towards the event of the parties involved that will be decisive. The event is a mere impulse that allows tensions to be released, or the last incremental force in a series of actions, that tips over the system towards radical change. Therefore, radical change may not be triggered as the sole result of a recent event, but as the result of a sequence of events started a long time in the past (Halinen et al., 1999). The resulting revolutionary changes may also be of different degrees, of different impacts, as they involve varying numbers of relationships and actors. Critical events may emerge from the dyad or from the network, resulting in a radical change, which can itself lead to further radical or incremental changes in the network or the dyad. Therefore, changes may go back and forth in a cyclical manner, between critical and incremental, between confined and connected, between the dyad and the network. In summary, both inertia and events are the forces which drive changes in this back and forth between incremental and radical changes (Halinen et al., 1999).

A number of IMP empirical studies have studied change processes of complex networks triggered by different events and to different ends. Abrahamsen et al. (2007) studied the change process of the Japanese fish distribution industrial network, and the perception of changes in the network by its actors. The authors argued that change takes place on a continuum, of which incremental and radical change are in fact the two extremes. They also observed that certain events of change were not perceived as critical or important, there could be radical changes following them, therefore highlighting that the cognitive perception of events may not correspond to their critical nature. Sutton-Brady
et al. (2015) studied critical events and their related changes in the Australian dairy industrial network. The authors studied a specific critical event, a price war with a specifically destabilizing effect on the industry. The authors were able to identify a number of short- and long-term changes or effects related to the single initial critical change events. Critical events appeared to not just start but to amplify changes in the industrial network. The following changes observed were also two-sided, as they created benefits, efficiencies, and put certain actors out of business. The authors concluded that the changes observed were in some regard unique to each actor, adding also that stability or resilience towards the critical event could be fostered with long established relationships. Purchase et al. (2017) studied innovation trajectory in the renewable energy sector, and proposed to classify events as either critical, related or background events. Events can be respectively important in driving change, points of departure for change, triggering or resulting in a critical event, or contributing to the context within which critical and related events occur. Together, critical, related, and background events create a path for change in the industrial network and create a trajectory to the changes. Lastly, certain events appeared to have a lock-in effect, creating unavoidable constraints towards future events, or locking in an organization or an industrial network onto a certain path of change (Purchase et al., 2017). Therefore, critical events as drivers of radical changes are not necessarily perceived as critical, they may not trigger change or drive change, and their effects may be measured both short and long term. Changes take on a certain path and trajectory, which is ordered by the events triggering or driving changes and by events that are related and contextual to the change, all important to understanding change in a network.

Change is affected by the expectations held at firms across the business relationships. These expectations towards changes may be positive or negative, as change may be perceived as constructive or damaging for the business relationships of an industrial network (Tikkanen and Tuominen, 2000). It is how firms perceive events to be either critical or minor which will ultimately trigger radical or incremental change responses by them (Halinen et al., 1999). Abrahamsen (2007) proposed that the cognitive perception of change by actors in the network is really what affects change in the higher dyadic and network level. What actors perceive about the interdependencies and what they perceive as important sets them on a mental process of decision and a course of action. The explanation for the individual change lies in the study of these cognitive aspects, in the actors’ perception of changes in their industrial network. Focusing their attention on actors’ perception of change, Corsaro and Snehota (2012) studied the evolution of customer-supplier relationships of ICT security services over time. The authors found that the study of these interpretations had only limited power of explanation for the changes taking place across relationships in industrial networks. Instead, it was the actors’
The study of change in the industrial network has largely focused on viewing the business relationships as the structural analytical unit of change, and as the point of departure where change first unfolds in the network, to then affect firms directly and indirectly related to the relationship (Abrahamsen et al., 2007; Corsaro and Snehota, 2012; Halinen et al., 1999). This means that the ARA model has been used to conceptualize the business relationships in layers, and therefore also to describe how change would unfold in the different relationship layers, of actor bonds, activity links and resource ties (Butler and Purchase, 2020; Håkansson and Lundgren, 1995; Sutton-Brady et al., 2015). In order to understand the complexities of interconnected changes in the industrial network, the present dissertation uses the resource interaction approach, and especially to study change taking place during the digital transformation change process (Håkansson and Waluszewski, 2002a). Digital transformation is a phenomenon driven by technological developments and innovation, where changes spread as firms introduce changes to their resources from the single node to the network. The resource layer of the ARA network offers a theoretical framework to study these types of development, and allows a look at the broader resource context, connected within and across organizational boundaries (Håkansson and Waluszewski, 2002a).

The resource context offers both a path dependency to change, with opportunities and limitations that lock change into certain paths, and stabilizing and destabilizing friction forces that either drive or hinder changes (Håkansson and Waluszewski, 2002b). The present change theory presumes to study resource structures as fundamental structures of the industrial network to be studied when investigating and describing changes related to the digital transformation. The use of RIA to study change allows for connecting confined and connected changes, the node and the network changes, by flattening the network into its resource network layer (Paper III). When mapping the resource structures of the industrial network with the RIA and its 4R dichotomy, the focal resource and resource interface source of changes become the point of departure of changes in the network, and the interacting firms are broken down into their resource structures (Paper IV). Furthermore, using the RIA makes it possible to investigate the changes to specific interactions taking place between individuals and resources involved during the digital transformation. It allows focusing on specific elements affecting change, such as to uncover the
reasons or events that motivate actions and drive change in a certain direction (Fremont et al., 2018).

Organizational Change Theories

Organizational change is an important and old research topic that has therefore been theorized in multiple and very diverse ways by management scholars. Van de Ven and Poole (1995) studied organizational change theories and provided an exhaustive typology or classification of these theories, which describes them according to four ideal types, including the life-cycle, teleological, dialectical and evolutionary types. Each type is characterized by a different generative mechanism or motor of change, and each is distinguished by a different level (individual or group) and mode (prescribed or constructed) of change. The authors argued that change theories, which have been developed to provide theoretical explanations to organizational change and development, can be categorized either among or across several of these ideal types. Most theories tend to only focus on partial accounts of complex change phenomena. Thus, organizational change theories should be juxtaposed to create contrasted insights on organizational changes, instead of seen as competing.

Life-cycle theories have been developed to describe the growth of organizations from their inception to their termination (Van de Ven and Poole, 1995). Change here is prescriptive, it is part of a natural logic that regulates its process of increasing growth and maturity, from a beginning to an end. Change is sequential, cumulative and conjunctive, it follows stages, or phases, new characteristics resulting from change are retained in later phases, and each change phase follows a common underlying change process. Change follows a deterministic sequence of events, and each sequence is a necessary precursor of the next, while each stage evolves from the previous one. Teleological theories describe change as being determined or led by a constructed purpose and goals (Van de Ven and Poole, 1995). Actors, individuals or groups of organizations proceed with their development with a specific purpose. Initiating change is thus done by envisioning an end goal, and the sequence of events leading to their end is constructed. Teleological theories afford freedom to create one’s own goals and assumes that there can be several equally effective paths to achieve these goals, and therefore cannot prescribe a specific trajectory of organizational change. Dialectical theories describe change as a result of opposing and conflicting forces (Van de Ven and Poole, 1995). Different actors or entities oppose each other’s actions, in a form of power struggle or competition, and engage with the status quo. Change is the synthesis or resolution of this opposition, a novel construct replacing the status quo, with a better or worse outcome. Evolutionary theories describe change as cumulative and applied to organizations in communities, market niches or industries (Van
de Ven and Poole, 1995). Change is developed through a deterministic cycle of variation, selection, and retention. Organizations randomly develop new traits or characteristics through natural variation. Firms and their specific characteristics are selected by means of industrial competition and survival of the fittest. Retention forces of inertia allow for the persistence of certain organizational characteristics and forms. There are Darwinian and Lamarckian branches of theories within evolutionary theories that describe organizational characteristics as either inherited or acquired. Evolutionary theories can be used to describe historical changes in industries and market niches but cannot predict which traits will emerge or which organizations will ultimately fail.

The classification developed by Van de Ven and Poole (1995) applies to change taking place at the single firm or group level. The evolutionary and dialectic types do address a higher level of change. They are concerned with changes within the group of similar organizations evolving in the same industry or market niche, and with changes resulting from two or more organizations with opposing forces. However, the types proposed by Van de Ven and Poole (1995) do not address the industrial network, where the duality of change forces is a driver of both radical and incremental change from the dyad to the network level (Håkansson and Snehota, 1995). Bayne et al. (2021) studied changes related to environmental practices in a complex industrial network, at network level processes, using these ideal types of change theory (Van de Ven and Poole, 1995). The authors studied a number of change processes and found that the different types of change motors could be found across the four types in the industrial network. They could find elements of the life cycle and teleological drivers across all change processes; all were driven with stages and common goals. They found the dialectical motor in change processes between different actors with relationships infused with power asymmetries. The evolution motor was the least recognizable among the change processes studied (Bayne et al., 2021). Studying the evolutionary change mechanism does imply studying greater industrial changes where traits emerge from selection and survival to environmental and competitive factors. The present chapter will apply principles from change theories in a similar manner to Bayne et al. (2021), to illustrate complex changes happening during the digital transformation of the industrial network.

The Metamorphosis in Organizational Change Theories

To avoid further confusion around its use, it should be mentioned that the term metamorphosis has been used extensively in organizational change theories, to describe radical and transformative change, and in opposition to converging
or incremental change (Van de Ven and Poole, 1995). Management scholars have borrowed from natural sciences to a point of saturation, where possibly all natural science terms reflecting any sort of change have been transposed to the social sciences to its own theory of organizational change (Van de Ven and Poole, 1995). Thus, the term metamorphosis can be found in several theories, from Tushman and Romanelli’s Metamorphosis Model of Convergence and Reorientation (Tushman and Romanelli, 1985), to Starbuck’s Organizational Metamorphosis (Starbuck, 1967), as a central concept to describe a type of change taking place during transformative change phases. Starbuck’s metamorphosis (Starbuck, 1967) theorizes change in the single firm’s organizational structures, as articulated in stages of relative stability alternating with dramatic and fast change stages.

The metamorphic change cycle here presents a few clearly defined stages, or steps, with sufficient differences, or amount of change, between them following the radical changes taking place during the metamorphosis. The metamorphic cycle is also irregular and non-repetitive, as each unique stage occurs at varying intervals. These stages alternate as change goes between processes fostering stability and processes disrupting stability. The author proposes that metamorphic changes, which are radical organizational structural changes, can be measured in terms of changes in number of employees of different types in the manufacturing environment, between two stages bordering a metamorphic change period (Starbuck, 1967). In Tushman and Romanelli’s Model of Convergence (Tushman and Romanelli, 1985), metamorphosis is used to describe a change cycle that includes transformative change periods. Here metamorphic changes happen in short reorientation periods of discontinuous changes, which punctuate longer convergent periods of incremental changes. Here metamorphic change is not synonymous with significant but divergent, as in diverging from the single firm’s strategic orientation or set of organization activities that define the firm’s capabilities. It includes changes to the firm’s core beliefs and values regarding its employees and environment, its products, markets, technology and competition, its distribution of power, organizational structure, and control systems. Here the cycle of convergence and reorientation is caused by forces of inertia and change, and the firm’s leadership is there to mediate the forces (Tushman and Romanelli, 1985).

The purpose characterizes change, as in the fundamental structures that change targets (Tushman and Romanelli, 1985), and its impact on the fundamental structures (Starbuck, 1967). The present chapter will adopt a definition of metamorphic changes as changes taking place during a change episode delimited by two phases dominated by forces of stability and inertia, and incremental changes. Metamorphic changes are irreversible, interactive and aimed at challenging or replacing established resource structures in the resource context throughout an industrial network. The aim of metamorphic changes is to
introduce new resource structures to compete with or replace the old ones, thus irreversibly changing interaction patterns and breaking established resource interfaces.

Because of friction forces, metamorphic changes are interactive. Changes aimed at replacing or conflicting with the established structures will cause reactionary effects diffused across the connected resource context, causing several events to occur causing other actors to enact changes, to which further reactionary changes may result in the industrial network. Because of the existing interplay between the resource types and the exiting tensions across the different resource interfaces, changes aimed at challenging or replacing established resource structures will cause changes to directly and indirectly related organizational and technical resource structures. Metamorphic changes taking place during phases delimited by relative stability within the industrial network, differentiate themselves from radical or revolutionary changes (Abrahamsen et al., 2007; Halinen et al., 1999), because they specifically target resource structures that are not confined to the business relationships. Because of the interactive nature of metamorphic changes unfolding, changes are set towards cognitively constructed goals on a nonlinear path, as in unique, non-deterministic and unpredictable.

**Metamorphosis, a Natural Sciences Analogy**

The analogy chosen to describe digital transformation as a change process taking place in the industrial network, is of the metamorphosis, for it illustrates stage-like, irreversible and radical transformative changes that affect all phenotypical aspects of life. The word metamorphosis is from the Greek word for transformation (Liddell and Scott, 1940). In nature, the term metamorphosis is used to describe a fundamental change of physical form, structure, or substance of a living animal. It can take place in different stages, such as the egg, caterpillar, chrysalis, and adult stages constituting the full metamorphosis of the butterfly ("Butterfly Life Cycle," n.d.). Organisms undertaking a metamorphosis become other phenotypically, their external traits take radically different forms and change their identity as in how they interact with the rest of the natural world. It is an irreversible and essential process to many animals’ life cycles (Encyclopedia of Neuroscience, 2009). Unlike evolution, which may happen slowly over multiple generations of individuals, metamorphosis is a transformation process that allows individuals to change their biology. However, the comparison ends there, as nature’s metamorphosis is a prescribed change process that is hard coded in individuals’ DNA from birth. The digital transformation, although dependent on the resource context, is a constructed process, where changes are undertaken based on goals that are constructed by individuals. Besides certain general development processes taking
place incrementally within the firm, such as a pharmaceutical company’s drug development and its cycle of clinical trials (Brody, 2011), a firm’s life cycle interacting in the industrial network is also not deterministically set. A digital transformation can radically change all visible (phenotypical) traits of firms; however, the outcome of a digital transformation is resource and network dependent, and although planned, cannot be determined in advance.

However, the attempt here to liken firms’ digital transformation to the changes taking place in living organisms undergoing a biological metamorphosis, is only for a figurative purpose and not to explain changes taking place in the firm with biological laws. Just like the rainforest analogy, the business metamorphosis remains a simplification. The analogy should not be interpreted in a literal sense, as in a description of firms as behaving like living organisms. Metaphors can be used to create illustrations of phenomena by borrowing from other phenomena that may present similar characteristics. The metamorphosis analogy is used here to illustrate and provide a mental framework for visualizing a firm's digital transformation. As we saw, digital transformation is still a relatively misunderstood and ill-defined concept. It is not merely the application of digital technologies into existing processes, but changes taking place at all strata, all levels of the firms, from the process to the identity and place of the firm in its industrial network. It can fundamentally transform firms and disrupt industries. Firms are governed by the sum of human agency present within them, and not by natural selection or genetic determinism.

The Industrial Network Metamorphosis Change Theory of Digital Transformation

The Industrial Network Metamorphosis Change Theory of digital transformation, or INM, is a descriptive change theory, meant to describe transformative changes during an industrial network's digital transformation. The INM can be described as a form of constructed cyclic change process in a few stages. Metamorphic and transformative changes that are specific to the digital transformation happen during a transitional stage, between two relatively stable initial and ideal stages of incremental changes. The initial stage is characterized by converging changes and stabilizing forces. In this stage the industrial network has some resource structures in place that can foster a digital transformation led by a critical event. Critical events have been defined as events or destabilizing forces, which may be the last in a series of incrementally destabilizing events, or just an important event that tips the balance of tensions over and leads to the emergence of a radical change. In the context of digital transformation, critical events can be the wide commoditization of digital technologies or the emergence of industry disruptive actors. The
transitional stage is characterized by both incremental and radical or metamorphic changes. The Industrial Network Metamorphosis change theory will be described here in terms of its change process or cycle of change events, motor or change generating forces, unit of analysis and mode of change (Van de Ven and Poole, 1995).

Unit of Change
Changes may happen at different loci of the industrial network. In the INM, change takes place across the resource network, across resources interacting with each other, and connected across organizational boundaries via several resource interfaces. Changes will take place at the level of the interacting resources, forming resource structures, and spread across the resource constellation, thereby affecting multiple actors (organizations) connected by their resource interdependencies. Change doesn’t happen in a single linear sequence of events, but in nonlinear and parallel ways across the resource network. The structures that are affected by change are these resource structures. Therefore, change reflects both internal and external developments, within and across firm boundaries, from the focal firm initiating a digital transformation plan, to the industrial network via the resource layer of the network. The INM therefore addresses change happening across multiple diverse interacting entities in an industrial network. Friction effects will connect changes as they unfold across the resource context, and as friction forces resulting from changes will affect the unfolding sequence of change with hindering and driving effects.

The INM prescribes looking at the interplay between the different resource types as metamorphic changes unfold during the transitional stage. When a firm introduces a digital technology to create a smart product, they may do so with changes to the ways of working of the individuals interacting with the product, as well as implement changes to its production facilities, to make them leaner and responsive to data created by the smart product. This in turn will affect several changes to their business relationship, provide different service contracts or seek to establish itself into new market segments. The changes taking place at the firm will have effects at other organizations, customers, and distributors. The firm may establish new distributor relationships, such as with a software developer, who may develop a custom digital solution for the firm to manage their product. The distribution of said solution may allow the distributor to monitor the performance of their solution with the firm’s product, and therefore adapt it to their needs. Customers might use the functionalities of the smart product and to adapt their own production processes.
Metamorphic Changes in the INM

A metamorphic change process can be described as leading to different organizational values, structures, controls and systems (Tushman and Romanelli, 1985). Metamorphic changes happen during a metamorphic change phase, delimited by two phases of relative stability where incremental or convergent changes are dominant (Starbuck, 1967; Tushman and Romanelli, 1985). Metamorphic changes occur during the transitional phase of digital transformation, during which fundamental structures of the industrial network, the resource structures of its resource context, are fundamentally changed. The INM defines metamorphic changes as irreversible and interacting changes that aim at introducing new resource structures that will conflict with or replace established resource structures throughout the industrial network. After a metamorphic change stage or phase, a sequence of metamorphic changes will have introduced irreversible changes across all resource structures, within which the firms of the industrial network are embedded, across products and services, production facilities, organizational units and relationships, thereby reshaping organizational capabilities and identities.

Because change is fundamentally endogenous to organizations and triggered by critical events that are either the last in a sequence of triggering events, or cognitively perceived as significant to the industrial firms in the network, metamorphic change periods can result from actions taken anywhere in the network. However, at both SMMS and CLG, the initial change that caused the digital transformation was the introduction of digital technologies into product and service resource structures. Both organizations saw different product development teams picking up on the potential benefits of adding new functionalities and features to their products by combining them with digital technology. The digital transformation, the vision, and the specific goals were articulated a posteriori of these initial developments by adding further changes into the organizational resource structures (Fremont et al., 2018). Dialectical elements can be found in the conflicting nature of the metamorphic changes developed at this early stage of the transition. The changes following the introduction of digital technologies in the industrial environment, led to new goals for value creation to be cognitively constructed by the individuals interacting with the technologies, and these may conflict with the established goals for value creation and result in cognitive controversies, such as in a conservatism and resistance to change, at both the focal organization that may initiate a digital transformation and at interacting organizations as these goals are being carried across organizational relationships.

In the initial stage of the transitional phase, metamorphic changes may drive conflict or oppose the existing structures, thereby establishing a diverging path of change, which may separate resources from the established structures.
Following the recognition of a value creation opportunity around newly introduced technological resources, the said resources may be separated to develop them outside of certain institutional barriers and avoid present inertia forces. Therefore metamorphic changes should increase the variety in resource interactions by allowing newly introduced resources to be combined and interact with other resources, in a non-incremental manner, creating new resource interaction patterns that may challenge or replace the established ones. The change will cause destabilizing friction effects to emerge at directly and indirectly related technical, mixed and organizational resource interfaces, possibly causing reactionary changes in other places in the industrial network. Heaviness in established resource structures may be a source of limitations, of inertia. To circumvent such limitations firms may need to invest in establishing entirely new resource structures, technical and organizational. Therefore metamorphic changes are limited by the number of resources that firms in the industrial network can mobilize to both enact changes and overcome limitations.

The metamorphic change phase presents a teleological character, as metamorphic change is set towards cognitively constructed goals by different network actors, thereby creating unique, nonlinear and unpredictable change paths. Different sequences of change may lead to the same equivalent outcome, to the relatively ideal stage for the industrial resource network. However, all digital transformation will take unique nonlinear change paths, where change may emerge from anywhere in the network, and spread across the resource network in nonlinear and unpredictable ways. Friction forces will both destabilize and offer resistance within the established resource structures as a result of the changes unfolding. Friction contributes to the inertia forces, as it usually tends to influence development towards positive outcomes that respect established resource structures. Friction favors existing forms of value creation. However, metamorphic changes aim at replacing the established resource structures and forms of value creation, therefore more negative than positive friction forces should result from metamorphic changes.

Finally, metamorphic changes may have different impact on the resource structures. Metamorphic changes may not all result in established resources being replaced. Comparing the digital transformations at SMMS and CLG shows different outcomes or impact of digital transformation and metamorphic changes (a butterfly vs. fast caterpillar). The SMMS digital transformation saw the emergence of important metamorphic changes across the four resource types, as the firm established an entirely new organizational unit, with new products developed with a net separation from the established ones, with its own production facility resources for software development, and to establish its own business relationships with new markets. The changes led to important value creation opportunities emerging in the industrial network.
CLG had less resource-intensive metamorphic changes, while implementing changes to product, production facilities, organizational units, and relationships. CLG introduced new resource structures, which brought some conflict with the established structures while not replacing them. The organization was seeking to facilitate their access to certain market segments within the accessibility market. In both cases, the efforts were aligned with the amount of resources that the organizations at each industrial network could mobilize, and therefore also conditioned the amount of metamorphic change that they could implement, the amount of opportunities of value creation that they could develop, and the number of limitations that they could overcome.

Conditions for the use of the INM

The INM can be used to describe change processes other than the digital transformation, given that they see change taking place with the following conditions:

- Irreversible and interactive change unfolds throughout the organizational and technical resource context of an industrial network.
- Changes follow cognitively constructed goals creating a unique, nonlinear and unpredictable change path.
- The process presents a phase with a significant amount of changes aimed at resource structures and resource interfaces, which are aimed at conflicting or replacing the established resource structure across the resource context of the industrial network.
- The change cycle includes only a few steps with significant differences between them. Mostly incremental change stages delimit the mostly metamorphic change stage. The metamorphic change stage is marked by significantly more negative friction forces than the delimiting incremental stages.

The INM Change Cycle

The change cycle of the INM is articulated here in three distinct steps or stages, the initial, transitionary and ideal stages. The INM change process is a cycle that can repeat itself over the life of the firms that interact in the industrial network. The ideal stage is the initial stage of a future metamorphic transitional stage. The transitional stage, a phase of metamorphic change, is preceded and followed by two incremental change phases. The INM presents both prescriptive and constructive changes, as the digital transformation takes the industrial network from prescriptive, to constructive, and back to a prescriptive change-dominated stage. The INM cycle of change is illustrated in Figure 2 below. The figure illustrates how the INM takes the resource network of an industrial network to produce significantly more value, as value creation
across the industrial network is function of change (value = f(change) ). The
curve that spans across the figure represents v= f(c), where value is the func-
tion of change. This function is first linear during the initial stage, as change
and resulting value creation are mostly incremental. During the metamorphic
stage the function becomes nonlinear. The value creation from metamorphic
change does not progress smoothly, from the initial to the ideal stage in a pre-
dictable or logical way. Instead the industrial network sees value creation out-
comes that can be more or less important, as the changes create higher value
or lead to increased costs. Following the metamorphic stage, the function be-
comes linear as change and value creation become mainly incremental again,
until the industrial network enters the initial stage of the next metamorphic
change cycle. The resource network of structures spanning the industrial net-
work is represented in a very abstract manner as a box of four resource types
that interact with each other.

When initiating their digital transformation, firms will first be leaving a rela-
tively analog pre-digital transformation stage where most changes taking
place are incremental, where firms will pursue investments that fit the present
resource structures, doing adaptations to mutually orient the resources to make
their structures more efficient. During the initial stage, changes are mostly
prescriptive, incremental, stable, and driven by forces of inertia in the net-
work, which pushes change to the resource structures towards efficiencies.
Deterministic forces drive change in a stable and predictable path. Firms are
pursuing incremental changes that can be predictable as they relate to previous
patterns of change. The resource context drives change towards economically
efficient paths. Economic heaviness from historic investments and a variety
that is affected by the mutual adaptations done across resource interfaces, are
sources of opportunities and limitations that foster the status quo. Friction
forces are mostly stabilizing, offering resistance in certain resource interfaces,
and therefore favoring a path of economic efficiencies. The perceived uncer-
tainty is low, as changes are mostly predictable as firms follow organization-
ally prescribed regulations and processes to, for example, pursue incremental
innovations. They are inscribed in a continuity and their direction can be ant-
icipated by the actors involved. Although prescribed, or deterministic, change
can lead to observably radical or incremental changes, such changes should
be rare however during the prescriptive stage.
The transitional stage at both SMMS and CLG’s industrial network was possibly triggered by the introduction of changes to the product resource, by introducing digital technologies into different applications. Following the changes to product resources, both entered their transitional phase, where changes specific to the digital transformation unfold and structural metamorphic changes started to occur. During this phase, new digitalization-related resources were introduced into established resource structures, such as new competencies for digital solutions R&D, new ITC technologies, new ways of working and selling, and new product or service offerings. The changes taking place can potentially affect every aspect of their business, as they allow for new change goals to be developed, new cognitive perceptions to be introduced and conflict with the existing structures to arise. By means of the friction mechanism, the changes introduced locally at the firm initiating the digital transformation will affect other directly and indirectly related resource structures, within and across organizational boundaries. Because of the significant costs and investments that may result from the metamorphic changes, the transitional stage should be resource and problem-solving intensive compared to the initial stage for the industrial network. During the transitional stage, changes are mostly constructive and unpredictable, as no particular path of change is prescribed in advance in the network. This stage does not prescribe a path of change, certain value creation goals are constructed based on previous changes in the network, and individuals will take actions to reach these goals. These value creation goals represent a number of benefits, short-term efficiencies and long-term growth opportunities, specific to the organizations.
where they are being constructed, and which will call for more or less complex courses of action, across more or less complex resource contexts, to be reached. Metamorphic changes will be aimed at breaking away or deviating from past frameworks of value creation. During this stage, individuals have to deal with increased uncertainty because of the unpredictable outcomes of the metamorphic changes that they undertake.

The third and ideal stage is reached once the industrial network has overcome all implementation problems, inefficiencies and other limitations to value creation with digital technologies, across their resource context. The metamorphic stage ends when metamorphic change stops yielding more value for the industrial network than incremental changes. Firms re-enter a predictive and mostly incremental and linear change phase, where firms can yield the maximum benefit from their investments and have reached all the possibilities that technological developments of their digital transformation can afford. Changes again become mostly incremental and prescribed, as in following the newly established institutional boundaries and processes. Changes to the resource structures are again mostly aimed at better adapting the newly established resources with these of the organizations that they interact with in the industrial network to create efficiencies. Digitally transformed organizations and their industrial network are now vertically and horizontally integrated, and they are freely sharing data across their cyber physical systems. They also produce significantly more value with more efficiency and sustainability than the pre-transitional phase (Ungerman et al., 2018; Westerman et al., 2014). However, the ideal stage is such that it is an ideal for the industrial network. It may very well fail at unlocking the full potential of digital transformation and exit the transitional stage before reaching that level of value creation. The industrial network may reach the limit of what the resource context can afford in metamorphic changes. The actors within the network may also fail to recognize the frictional forces that may negatively affect value creation, fail to embed the newly developed changes into the resource context, or fail to identify the limitations resulting from economically heavy established resource structures. Finally, when in the ideal stage, the industrial network is on an incremental course towards the next initial stage of the next cycle of metamorphic change. Incremental changes may move the network towards the next critical event triggering a metamorphic stage.

Contribution to IMP Theory
The INM is a novel way of studying complex change processes in the industrial network. This change theory is built from IMP theory and empirical observations from the digital transformation of two industrial networks. However, it can be used to interpret other similarly complex change phenomena, given that these present similar conditions of application as the digital
transformation, and concern a network of interacting organizations with constructive changes unfolding across their resource context, articulated in a few distinct stages. While other studies of change in the industrial network have derived their theoretical lens from the ARA model, to study change within the business relationship (Abrahamsen et al., 2007; Butler and Purchase, 2020), the INM focuses on the resource context and mechanisms related to resource interactions. The INM is explicitly built upon the RIA, thus providing descriptions of changes specific to resource structures and how these affect technological development driven and related changes (Håkansson and Waluszewski, 2002b). It builds on a theoretical approach, the RIA, that studies the particulars of resource interactions, and that has been developed in multiple empirical studies of technological development within the industrial network across the resource context (Håkansson and Waluszewski, 2002a, 2018; Prenkert et al., 2019).

To concepts from the RIA, the INM adds and develops the concept of metamorphic change in the context of the complex and relatively novel change process that is digital transformation. The INM describes non-incremental changes during a revolutionary period in the industrial network (Halinen et al., 1999), as metamorphic changes, to address changes unfolding in the resource context of an industrial network introducing conflict with established resource structures. The INM defines metamorphic changes from the fundamental structural effects that they are causing. The INM also bridges confined and connected changes from the node to the network (Halinen et al., 1999), by using the RIA to define the unit of change, as the resource context, which reflects change mechanisms taking place within and across organizational boundaries, from the single firm to the industrial network. The use of RIA concepts further allows illustrating the inertia and change forces in the industrial network, by introducing relating friction forces with change in the industrial network, as a product of resource interface tensions, both driving and hindering changes to economic outcomes. By taking an RIA approach, the INM illustrates the relation between metamorphic change with the notion of path dependency, as resulting from resource embeddedness, and from structural characteristics of resource structures, of heaviness and variety, giving a direction to the developments in the resource context while seeing metamorphic changes taking a nonlinear and unpredictable path.
Conclusions

This dissertation studied the empirical phenomenon that is the digital transformation change process. Across two cases of large manufacturing industrial network, Sandvik Manufacturing and Machining Solutions and the Cibes Lift Group, studied with four qualitative research papers, it illustrated how digital transformation affects the manufacturing industry, and more specifically went into the details of the type of changes that occurred during this complex transformation process, and how they affected value creation in the respective industrial networks. All four papers are based at least partially on the resource interaction approach. It was at first combined with theoretical lenses allowing to focus on certain specific managerial aspects related to change management and innovation, and later as main theoretical framework to study first value creation opportunities, and frictional forces resulting from structures embedded within different resource contexts.

The general motivation for writing so extensively on Industry 4.0 and digital transformation is the observation that both concepts suffer from the same general lack of understanding over what they really concern. This issue was addressed through both an extensive literature review of the concepts to differentiate them and to better focus on the phenomenon of digital transformation, and through empirical qualitative studies of digital transformation. The theory entitled in this dissertation the Industrial Network Metamorphosis Change Theory of Digital Transformation, or INM, presents how metamorphic changes may unfold during the digital transformation change process across the resource context of an industrial network. The INM highlights the type of changes during such a complex change process, metamorphic changes, and relates them to the fundamental structures that are transformed during the change process that constitute the resource context. The INM illustrates the relation between change and value creation during the digital transformation change process, as an irreversible, interactive, and nonlinear change sequence unfolds across the resource context of the industrial network to develop value creation opportunities, and where an orientation that results from the resource context path dependence, with friction forces both hindering and driving changes.
Findings and Contributions

This dissertation presented a number of findings specific to the digital transformation change process. The process appeared in both CLG and SMMS to be started with the introduction of digital technologies into traditional product or service types of resource structures. In other words, the critical event here is the accessibility of digital technologies to industrial firms for enacting structural changes. It was illustrated in both cases, as both SMMS and CLG started to implement changes and to articulate goals for their digital transformation following the introduction of digital technologies. In both cases the digital technologies had potential for changes that could challenge the established status quo. The leadership at both organizations recognized the potential changes that could challenge the established processes and structures, so goals for changes were articulated. The digital transformation's initiation was accompanied by conflict, from conflicting cognitive perceptions over what goals and changes should be pursued. Generally, the digital transformation appears to operate some adjustments into the power dynamics in place within the industrial network before the change process started, as certain actors in the network saw in the changes a threat to their own resources and revenues, while other actors would be removed from the interaction patterns as a result of the disintermediation from digital technology implementation.

Digital transformation in the industrial network in both cases involved a number of changes to organizational resources across the network. The studies illustrated the important interplay between technical and organizational resource types during the digital transformation. To articulate goals and a plan, firms may develop new organizational units, such as recruiting managers with competencies from the digital industry to establish new business units with new business models reflecting affordances of digital innovations. They may also develop their competencies, to a lesser extent, by recruiting single consulting developers or consulting firms to work closely with them on the development of digital transformation-related projects. At SMMS, the newly established unit had ambitious plans for fostering a new culture, new ways of working and new ways of thinking across the group of traditional tool manufacturing organizations. Organizational resources were an equally important source of hindrances or limitations. Traditional business practices resisted change for the CLG smart product, and a lack of business relationships with end customers hindered the efforts of managers at AMT. Using the RIA made it possible to highlight the importance (or even dominance) of organizational and social elements of organizations for digital transformation, a somewhat paradoxical characteristic of a technological trend. Although central objects around which to articulate change, technology was not necessarily the bottleneck of digital transformation at the industrial networks studied. The commoditization of digital technologies, their widespread accessibility to most industrial firms,
means that developing your own IoT technology no longer provides a sustainable competitive advantage. The present studies highlight how important it is for firms undertaking a digital transformation to implement changes across the resource context, by developing new roles, new organizational units, new competencies, and new digital ways of thinking and working. It is the unique combination of all these changes that creates value beyond the simple technical incremental innovations.

Eklinder-Frick et al. (2019) and Fremont et al. (2018) focused on the interaction process using boundary object and liminality lenses. The first investigated how individuals interact with resources, the boundary objects, introduced for a digital transformation. It investigated how the actors may develop different perceptions and how firms could manage and coordinate these different perceptions. Therefore, it also changed by managing the resources' characteristics (Star and Griesemer, 1989; Wagner et al., 2012). The paper creates a connection between cognitive perceptions of individuals of resources and change, with the tangible economic friction effects from the resource interaction approach. This addition of the boundary object lens to the RIA to study digital transformation resources brings nuance to the rainforest picture of an industrial network bound with interdependencies. Firms may experience individual cognitive conflicts while interacting and producing changes within their resource structures. The digital transformation introduces changes to conflict with certain established structures, creating controversies and destabilizing negative friction effects (Fremont et al., 2018). The second paper presents how firms may develop liminality to initiate such changes by separating embedded resources or establishing new ones in separation from the embedded resource context (Eklinder-Frick et al., 2019). Although not entirely, resources may be separated from their settings and from the mutual orientations that have been developed over time, accumulating investments by different organizations interacting with each other.

At SMMS and CLG, the critical event that started digital transformation was introducing technical resources into established resource structures. The changes were followed by changes in organizational resource structures, where goals for the original technical changes were developed. Firms may therefore cope with change by establishing organizational unit resources that will develop specific goals for the change to be undertaken. Firms’ leadership may develop a vision based on the technical changes but will need to establish the organizational resources to support the changes. When initiating the digital transformation, the industrial network enters a constructive change phase, where actors need to face uncertainty over their decisions’ potential positive and negative outcomes. They will see controversies arise as different perspectives conflict as actors discuss certain abstract long-term goals, and as tangible and technical resources are introduced negative frictions may arise. Liminality
may be used to circumvent these controversies and friction effects to develop new resources with new benefits. However, the firm will need to balance the degree of freedom, culture, and community in the established liminal space, as liminality itself may create further challenges when reintroducing the developed resources into the setting where they are meant to create value. The digital transformation-specific changes target resource structures as fundamental structures. The resource context from its characteristics creates a path dependency for the changes taken, meaning that it will offer certain opportunities and limitations to value creation, and firms will need to cope with the path dependency. More opportunities may be captured in the resource context, if firms introduce changes for their digital transformation, such as digitalization projects, that may lead to increased variety in resource interactions. Firms should seek changes such as establishing new resource interfaces that may conflict or compete with the established resource structures to seize opportunities in variety and circumvent limitations resulting from the heaviness in certain resource structures. The embedded resource context, characteristics, and path dependence for developments imply that the digital transformation will always take a unique nonlinear path. Furthermore, firms will always need to cope with friction forces creating predictable and unpredictable effects because of the changes that they implement in different locations of the resource context. The effects will both spur and resist the changes. When implementing their digital transformation-related changes, managers will need to create goals for their changes based on recognizing established opportunities and limitations for value creation in their resource context and based on reactionary friction effects that may help or hinder their efforts.

The study of digital transformation in the industrial network highlighted several implications for value creation. Within manufacturing industries, the digital transformation introduces opportunities for new value, new process improvements, and business models that make use of digital technologies. The findings in this dissertation do seem to indicate that overall digital transformation led to an increase in value creation opportunities at both the CLG and SMMS networks. Digital technologies allow firms to create connections between previously unconnected or non-interacting resources. These connections are sources of data and information for actors who interact with them. Therefore, value creation is increasingly related to the efforts taken by companies with data, for example to help the customer’s productivity or improve the user experience. The new value creation opportunities require changes across the resource context to both technical and organizational resources. The shift in value creation from tangible to intangible also means that certain hardware manufacturing firms such as SMMS or CLG will, by helping their customers be more efficient, possibly produce and sell less hardware. However, digital transformation introduced business models and solutions that sometimes conflicted with the established resources used for value creation. The
empirical observations uncovered several negative friction effects, negatively affecting costs, efficiency, and efficacy, because of the changes undertaken by both organizations. The findings in this dissertation suggest that digital transformation will always cause negative friction forces to appear, because of changes taking place in the resource context characterized by tensions across resource interfaces. Friction forces may cause a number of negative effects to value creation, in reaction to the changes implemented, at directly and indirectly related locations. Therefore, the changes may lead to a net value creation from efficiencies, cost reductions and growth opportunities, while sources of value creation may be destroyed at other locations in the industrial network in response to the initial changes. The overall balance of value creation from digital transformation in the industrial network may be a net positive as the market is made overall more efficient.

Considerations for Practitioners

The present dissertation contains contributions for industry practitioners. The first being that the study of digital transformation doesn’t allow prescribing a specific path of change, a specific technology, organization form, or business model to implement. Instead, the results support that digital transformation follows a unique path of change for each organization that is context dependent. Furthermore, digital transformation may not lead to observably radical and industry disruptive changes for firms, because industry disruption is itself a unique outcome that may not be achieved because of the resource context dependence of digital transformation. Both cases show that firms could undertake a digital transformation that sees metamorphic change across the resource context, the unique resource combinations interacting across the industrial network. Managers should identify opportunities and limitations from the resource context, including both what the firm hierarchically controls, what can be accessed directly by interacting with other organizations, what is not accessible and what will conflict with the desired changes. Managers should then develop value creation goals towards which they will set the direction of their change path, and analyze the effects of and reactions to their changes across the industrial network. Managers should use the findings in this dissertation for their own inspiration and reflect on the changes they need to undertake that may have similarities with the ones undertaken by SMMS and CLG. Without being in the same industry, managers operating in a similarly complex industrial network context can take cues from both cases. Besides developing smart products with IoT, practitioners should pay close attention to the resource network spanning beyond their own organizational boundaries and the opportunities and limitations it offers. They should pay close attention to organizational issues, competencies, ways of working and culture, as essential to creating value with digital technologies. They should also consider the
importance of potentially conflicting perceptions of individuals as an im-
portant source of controversies and how these may later affect value creation
from digital transformation. They could use certain IMP theoretical tools to
drive these reflections, such as the 4R model to map their digital transfor-
mation projects' resources and resource interfaces. And of course, they may
also use the INM to increase their knowledge of their own digital transfor-
mation. The INM may help practitioners take a network perspective on the
change process and understand the nature of metamorphic changes during the
transitional phase of the change process. It may also help managers articulate
a digital transformation process by describing it in a few distinct phases, with
their own specific content. For example, the INM should help managers better
describe the phase their own digital transformation is in and create a vision for
the ideal state of value creation they would like to reach.

Research Limitations and Avenues for Future Research

The research in this dissertation has taken an IMP approach, which tends to
favor in-depth detailed empirical case descriptions over quantitative “hard
facts.” It should be noted that there has been the temptation to complement
this research with quantitative methodology. The temptation still exists, but a
study where quantitative methodology would be a good fit has yet to present
itself. Qualitative case study research was used in this dissertation to draw a
detailed picture of a relatively new and loosely defined phenomenon; the dig-
ital transformation change process in industrial networks. The main empirical
findings remain highly contextual to the digital transformations undertaken at
two complex industrial networks. This dissertation doesn’t present any fact
that can be totally generalized to other digital transformation cases, although
it does offer suggestions for future research. Instead, the focus has been on
theory building to better describe the phenomenon from an IMP perspective.
Future quantitative research should test certain assumptions made in some of
the studies, such as regarding friction forces and the type of resource with
which they tend to be most associated. Furthermore, future research should be
done to effectively study value creation from digital transformation across in-
dustrial networks. There is an assumption in digital transformation literature
that a successful digital transformation will have a net positive effect on firm
revenues and profits (Björkdahl, 2020; Westerman et al., 2014). However,
value can really take different forms, and may be difficult to effectively meas-
ure. The present studies investigated value creation opportunities resulting
from digital transformation, without taking the measure of revenues and prof-
itability of the actors involved, although the number of opportunities of value
creation created from digital transformation was looked at. If feasible, a quan-
titative financial analysis of industrial networks undertaking a digital transfor-
mation should probably be done. Taking an IMP perspective questions the use
of financial criteria to measure the success of a digital transformation as appropriate to reflect value increase because of the change process, and instead calls for criteria that better reflect value created across the industrial network.
Epilogue

Much is still unanswered about digital transformation, and more time will still be needed to reflect on the full impact of digital transformation for industrial networks and society at large. There seems to be a dominant utilitarian view of Industry 4.0 and digital transformation. The general understanding is that it is a net good for society. 2020 as the first year of the COVID-19 pandemic made me think about the nuances.

The pandemic started after the data collection for this dissertation was completed, and it naturally doesn’t appear as a topic in the findings. The pandemic had a significant impact on almost all aspects of our societies, and on industries everywhere. In addition to costing numerous human lives, it acted as an important obstructive force to interactions, as well as a driving force for the adoption of digital technologies replacing human-to-human interactions everywhere. It has been arguably the most important critical event since the Second World War. The pandemic has changed so many perspectives and attitudes towards digital technologies. Its impact has probably already led to many studies in social sciences, and many of them are probably addressing the topic of digital technologies and digital transformation.

Therefore, as anyone who writes about digital technologies, I had a lot to reflect on during this time. This year, we have all been isolating ourselves, working mostly remotely with digital tools as the sole point of interaction with our colleagues. Digital transformation is meant to change work by increasing the number of digital tools and by decoupling work and production locations. Remote working can be very cost and time efficient if done with the right digital solutions, employees can spend less time commuting and can instantly go from one meeting to another without breaks. Companies can operate vast cost reductions by diminishing the amount of facilities that they occupy and worry less about recruiting employees who live in the geographic vicinity of their offices.

However, this last year has shown the importance of what we have been missing, the human and social interactions that we have in the office. Like many others, I haven’t been especially happy not to need to take the train to work every week, because I have realized the importance of these social contacts.
These, however, are almost never addressed in digital transformation. They are instead removed, as people are interacting less with other people and more with digital solutions. I don’t believe that remote work is sustainable as the sole mode of work forever. I do think that organizations need to think of social interaction spaces and systems, to be as important as their cyber physical systems. I believe that it will require rethinking the work environment and re-thinking how individuals interact in it to both socialize and build a purpose for what they do.
Svensk sammanfattning

medföra. Baserat på denna beskrivning så presenterar avhandlingen en teori om metamorf förändring i det industriella nätverket, en teori som syftar till att beskriva komplexa förändringsprocesser såsom den digitala ovandlingen.
References


A doctoral dissertation from the Faculty of Science and Technology, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology. (Prior to January, 2005, the series was published under the title “Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology”.)