Tampere University of Applied Sciences

Industry 4.0 impact on business models of Finnish Industries

Muhammad Irshan Khan

MASTER’S THESIS
November 2022

Master's Degree Programme in International Business Management

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Master's Degree Programme in International Business Management

KHAN MUHAMMAD IRSHAN
Industry 4.0 impact on business models of Finnish Industries

Master’s thesis 75 pages, appendices 3 pages
November 2022

Industry 4.0 deployment has been enabling new opportunities for industries to extend their traditional businesses. However, less research has been done to analyze industry 4.0 impact on industries’ business models. The thesis project analyzed the impact of industry 4.0 deployment on Finnish industries.

The research used a qualitative research method using a combination of primary and secondary data. The primary data was collected from seven interviews conducted with industries’ solution providers, of ports and terminals, mining, pulp and paper, agriculture industries, industrial manufacturers, and system integrators. The secondary data was used from the literature and public resources of the industries. The research results highlighted that industry 4.0 has been changing the market structure, creating integrated value-creation networks and ecosystems which are significantly impacting industries’ business models and strategies. Industries have been analyzing their role in the new environment created by Industry 4.0. The new market structure is changing the competition among industries. On one hand manufacturers, partners, suppliers, and customers are collaborating for the creation of an ecosystem. On the other hand, this collaboration could be a source of affecting competitive forces of bargaining power of buyers and suppliers, rivalry among competitors, and threats of the new entrant. Industries have been observing significant changes in five business model components of value propositions, customer relationships, revenue streams, key partners, and key resources.

Moreover, research results highlighted connectivity and computation networks as key enablers and areas for future development for the deployment of I4.0 in Finnish industries. The connectivity and computation need has been growing for industries especially the need for private wireless networks for connectivity and hybrid computation networks consisting of embedded computing, edge computing, and cloud for industrial applications. The areas of future development are identified in improved security solutions, standardization, and availability of human resources capable of working in I4.0 enabled environment. Industries see a key role of the Finnish government in contributing to areas of future development by working with different organizations in Finland and working with other European countries.

Keywords: Industry 4.0, business model, Porter’s five forces, Network and service providers, Business model canvas

CONTENTS

GLOSSARY

3GPP	Third Generation Partnership Project for Cellular technologies
4G	Fourth Generation of mobile wireless technology
5G	Fifth Generation of mobile wireless technology
AI	Artificial Intelligence
BM	Business Model
CapEx	Capital Expenditure
CBRS	Citizen Broadband Radio Service
CPS	Cyber-Physical System
I4.0	Industry 4.0
ICT	Information and Communications Technology
IT	Information Technology
MaaS	Manufacturing as a Service
ML	Machine learning
OpEx	Operating expense
OT	Operation Technology
PaaS	Production as a Service
PSS	Product service system

1 INTRODUCTION

Industry 4.0 (I4.0) has gained increasing attention in various industries. The I4.0 term was first introduced for the digitalization of the industry in Germany in 2011 (Ibarra et al., 2018). I4.0 has now become a concept for obtaining production and operational efficiencies with the latest technologies in many industries all around the world. I4.0 deployments have obtained government-backed strategic initiatives from global manufacturing giants such as Germany, France, the U.S., Japan, and Mainland China (*Industry 4.0* | *Statista*, 2022, p. 2). I4.0 has been extensively researched in both academia and industries from technological and business perspectives since its introduction.

I4.0 spread followed the previous three industrial revolutions that started from the focus on production and operational efficiencies (Pereira & Romero, 2017); the first industrial revolution focused on the use of mechanical production lines and equipment powered by steam and water. Mass production lines and electrical energy powering industries were emphasized during the second industrial revolution. The third revolution is also called the digital revolution and introduced computers, advanced electronics, and automation of operations which is followed by the fourth industrial revolution also called Industry 4.0 focused on digitalization, intelligent automation, and self-behavior of the machines (Oztemel & Gursev, 2018). Figure 1 depicts the industrial revolutions with their timelines.

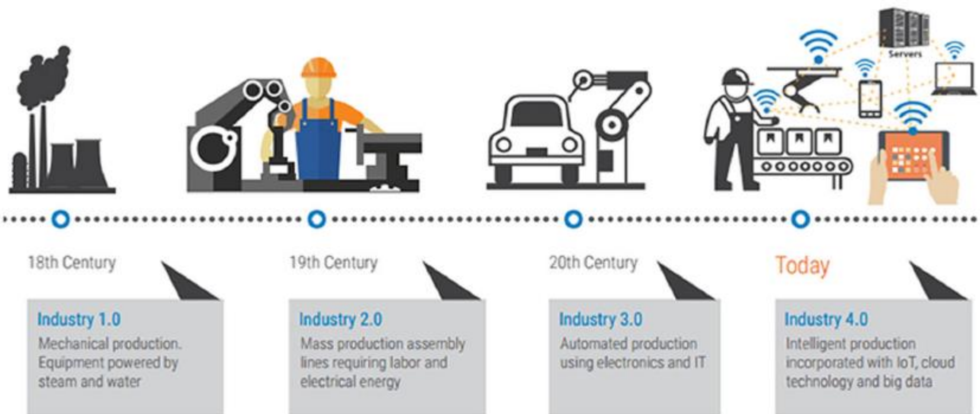

FIGURE 1. Industrial revolutions with their timelines and key enabler (Oztemel & Gursev, 2018, p. 133)

1.1 Research topic/phenomenon

A considerable amount of research has focused on the development of I4.0 technologies. However, less attention has been paid to the impact of these technologies on business models. As a result, companies deploying I4.0 technologies are not obtaining the significant benefits of the technologies and there is very little adoption of new business models. I4.0 implementation and its impact on business models have been discussed by (Frank et al., 2019; Ibarra et al., 2018; Müller, 2019; Müller et al., 2018; Weking et al., 2020). However, more research is required for understanding the impact of I4.0 on businesses and business models.

I4.0 technologies implementation without updating traditional business models is not helping industries to obtain significant economic benefits. The traditional business models are unable to capitalize on new environments created by I4.0. This provides opportunities for business model innovation for companies to increase their share for value creation, value delivery, and value capture using I4.0 technologies.

The thesis project aims to investigate I4.0 technologies' impact on business models, identify challenges in adopting new business models, and find gaps and opportunities that come with the deployment of I4.0. The research was done using the empirical research method by conducting and analyzing interviews from industries deploying I4.0 and companies providing I4.0 technologies in Finland. Nokia was the commissioner of the thesis project.

1.2 Research Questions

The thesis project was guided by research objectives from the commissioner. Answers to the questions will be useful for the commissioner to refine the value propositions for I4.0 for industries and could create opportunities for the development of new products and services. Furthermore, the thesis project will also contribute to academic research by enhancing an understanding of the business model impact with the deployment of I4.0. The following are the main research questions and sub-questions for the thesis project.

1. How are industries adopting Industry 4.0 (I4.0) in Finland?
    a. How are the companies seeing an effect on business models with the deployment of I4.0?
    b. What are the challenges in adopting I4.0?
    c. How could the Finnish government help industries with the deployment and adoption of I4.0 technologies?
2. What role communication and network service providers could play in the implementation of I4.0

1.3 Research approach

The research was designed to use qualitative research methods. The research questions were used to collect the research data by organizing semi-structured interviews. The interviews of people working in higher management roles in industries adopting and providing I4.0 solutions were conducted. The participants for the interviews were located in Finland. Additionally, the secondary data was also used from available literature, and companies' websites and social media channels.

1.4 Structure of the thesis

The structure of the thesis is as follows, Chapter 2 provides a theoretical framework of business model theories, I4.0 technologies impact on business models, and factors affecting the adoption of new business models. Chapter 3, describes the methodology of the research and research plan used for the thesis project. Empirical research results are discussed in Chapter 4. Lastly, Chapter 5 provides a discussion of the result and its implication for future research.

2 THEORETICAL FRAMEWORK

Theories in business models and Porter's five forces are relevant viewpoints when studying the impact of I4.0 impact in Finnish industries from a business perspective. Porter's five forces model is widely used to understand industry structure and the nature of competitive interaction within an industry (Porter, 2008). Business models' theories help to understand the technological potential of innovation and technologies and the creation of strategies.

2.1 I4.0 definition

I4.0 technologies have been changing the environment of industries. The I4.0 technologies are disrupting value chains and forcing companies to rethink nearly everything they do from product design, their manufacturing and service needs, and working with different partners to fulfilling the demands of I4.0 enabled manufacturing environment. The deployment of the latest technologies is creating new activities such as collecting large amounts of data from machines, enabling new values from the data in the form of analytics and intelligence, using the analytics and intelligence for improving operations, and even enabling automation to operations and creating an integrated value network. The efficient transmission of information in the integrated network has been turning into economic benefits through shorter delivery times, reduced inventories, and smaller amounts of working capital (*Renewal in the Manufacturing Industry*, 2020).

I4.0 technologies have gained increasing intention in industries and academia. The technologies are digitalizing industrial infrastructure and connecting them. The connectivity has made the possibility to collect data from the resources and extract intelligence from the data using machine learning and artificial intelligence algorithms. Furthermore, connectivity technologies have been connecting the value chains of industries, partners, and customers. I4.0 technologies for the thesis project were focused on connectivity technologies, computation technologies, and their usage for collecting data and processing data for extracting intelligence and for decision-making. Figure 2 depicts enabler technologies for I4.0 for the thesis project.

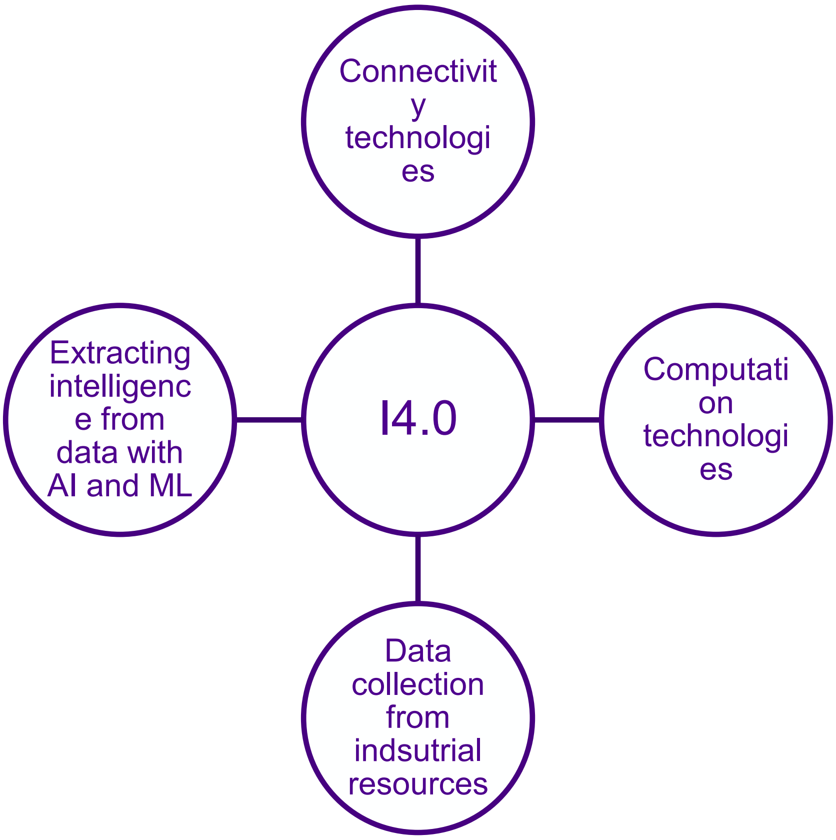

FIGURE 2. Enabler technologies of I4.0

Connectivity and computation technologies are two key enablers for the implementation of I4.0. I4.0 has been connecting the whole value chain of industries, businesses process, supply chains, and even customers as shown in Figure 3. The connected value chain is producing large amounts of data which needs communication and computation networks. Several researchers have agreed on the essential role of computation and connectivity technologies in enabling I4.0(Ibarra et al., 2018; Lee et al., 2015; Wang et al., 2016; Weking et al., 2020). The use of the cloud for enabling digital business ecosystems and interoperable digital supply chains is discussed by (Korpela et al., 2016). Furthermore, high-capacity wireless networks (e.g., 5G) and edge computing (on-premise servers) have been playing a key role in enabling mission critical applications of industrial automation and autonomous operating vehicles and drones, augmented and virtual reality, etc. (*Private Wireless Market Report*, 2022), (*Edge Computing | Statista*, 2022).

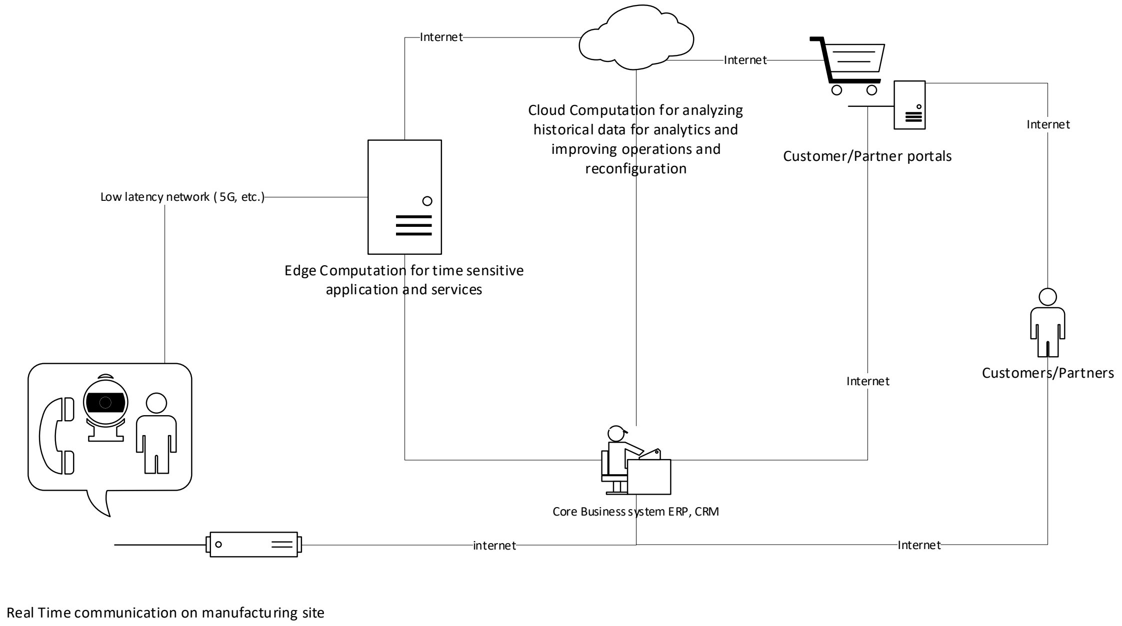

FIGURE 3. I4.0 deployment with enabler technologies created by the author

The interconnectivity of industrial infrastructure and the value chain has enabled several key features. The connected industrial infrastructure has enabled features of industrial automation, making machines capable to learn about their environments, perform self-diagnoses, know their service needs, and adapt user preferences (Porter & Heppelmann, 2014), remote operation control,(Xu et al., 2018) (Ibarra et al., 2018),(*Renewal in the Manufacturing Industry*, 2020). Moreover, the interconnection of the value chain is helping industries for tracking and monitoring the supply chain operations and improve customer interaction and understanding of customer requirements (Lee et al., 2015; Porter & Heppelmann, 2014; Rao & Prasad, 2018).

2.2 Porter's Five forces model

Porter's five Forces help organizations, to understand the industry structure, the intensity of competition in an industry, and its attractiveness and profitability level (Porter, 2008) (Schilling, 2013). Moreover, it helps to understand the structure of the industry and stake out a position that is more advantageous and less vulnerable to attacks from competitors (Schilling, 2013). (Porter & Heppelmann, 2014) presented analysis for smart products using Porter's five forces model that has many resemblances with I4.0 market forces. Porter's five forces based on their explanation in (Schilling, 2013) are described in Table 1.

TABLE 1. Porter's five forces model

Competitive rivalry	Determines competitiveness and profitability of the industry. It is affected by the number of competitors, their strengths and weaknesses, and their operational efficiency in doing activities.
Threat of substitute product or services	Determines the ability of customers to find substitutes. This is influenced by several substitutes in the market, their quality, price, availability, and switching cost.
Bargaining power of buyers	Power of the customers to influence product prices and quality. It is influenced by the number of buyers in the market, the size of the orders, the buyers' position in the market, and the switching cost of the buyer to a substitute.
Bargaining power of suppliers	Determines the power of suppliers and how they could influence prices and quality which could affect products or services. The supplier power is affected by the number of potential suppliers in the market, availability of their offering, switching cost, and availability of substitute offering.
The threat of new entrants	The threat of new entrants determines the barrier to entering and establishing a business in the industry. The barrier is affected by finances and resources needed for entering the market, rules and regulations, and access to suppliers and distributors.

2.3 Business models

Business models' theories are helpful for understating the technological potential of innovation and technologies and creation of the strategies. Several researchers have defined the business model differently, business model converts technological characteristics and potentials through customers and markets into economic outputs (Chesbrough & Rosenbloom, 2002); the business model specifies a firm position in the value chain to do business (Chesbrough & Rosenbloom, 2002; Rappa 2004; Weking et al., 2020) and business model defining strategy (Morris et al., 2005; Zott et al., 2011).

The business model definition and business model canvas presented by (Osterwalder, 2010) was used as a theoretical framework for the understanding of the deployment of I4.0 on the business model. The framework defines a business model as the rationale of creating, delivering, and capturing value by an organization. Figure 4 depicts key elements of a business model canvas.

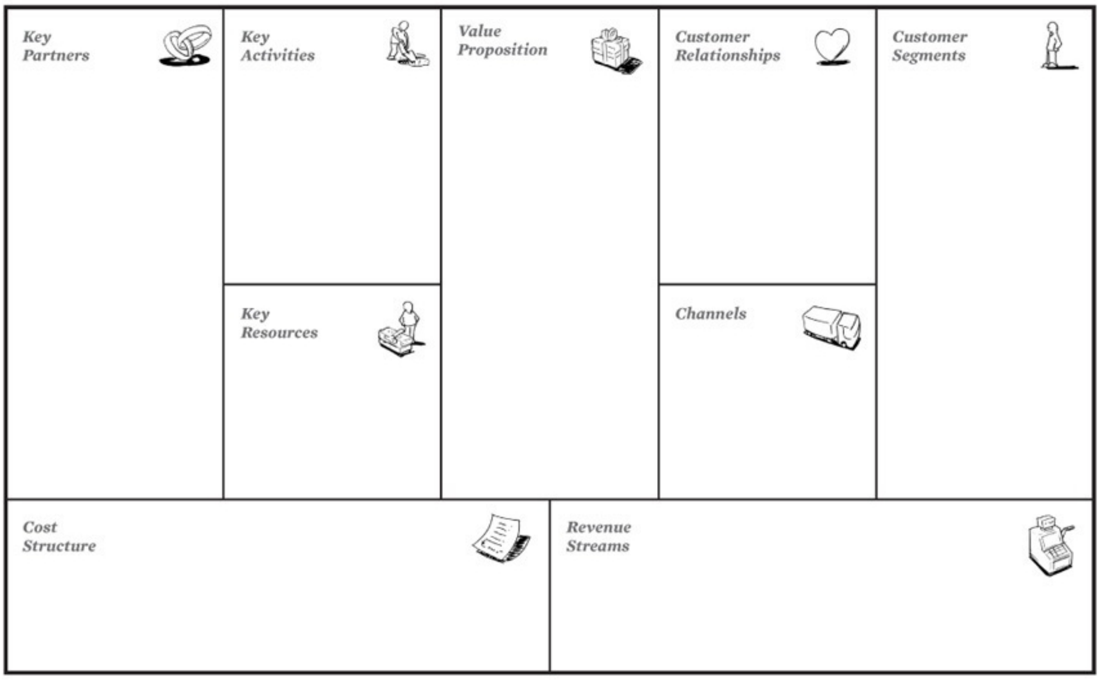

FIGURE 4. Key elements of the business model canvas (Osterwalder, 2010, p. 42)

(Osterwalder, 2010) describes the business model canvas with nine building blocks that show the logic of the company's intention to make money. The nine building blocks are defined in Table 2.

TABLE 2. Business model canvas nine building blocks

Customer Segments	Customer segment an organization will serve
Value Propositions	Organization seeks to solve customer problems and satisfy customer needs with value propositions
Channels	Delivery of value proposition to customers through communication, distribution, and sales channel
Customer Relationships	Establishing and maintaining relationships with each customer segment
Revenue Stream	Revenue from the value proposition offered to customers
Key Resources	Assets required to offer and deliver the value proposition, developing customer relationships and channels and revenue sources
Key activities	Key activities of the organization
Key partnership	Partnership for acquiring resources and performing activities outside the enterprise
Cost structure	Business model elements result in cost structure

2.4 Business model for I4.0

I4.0 has enabled new capabilities for industries that have started to change their business models of the industries. Several authors have studied business models for the deployment of I4.0(Ibarra et al., 2018; Müller, 2019; Müller et al., 2018; Pereira & Romero, 2017; Weking et al., 2020). (Ibarra et al., 2018) identifies three of I4.0s' business model innovation patterns: (1) service orientation, (2) networked ecosystems, and customer orientation by analyzing the business model literature of I4.0. (Weking et al., 2020) defined a taxonomy to characterize I4.0 enabled business models with three patterns of integration, servitization, and expertization using case studies. (Müller et al., 2018) have done qualitative research on I4.0's business model impact on SMEs in Germany and identified key resources and value propositions that are the most affected business model elements. Table 3 summarizes the available literature on I4.0 for business models with a business model canvas.

TABLE 3. Business model effect with the deployment of I4.0

BM component	Changes with the Implementation of I4.0
Key resources	New types of production equipment, human and intellectual resources, and IT competencies(Ibarra et al., 2018; Müller, 2019) Value creation networks (Kiel et al., 2016)
Value proposition	New, data-driven products or services.(Ghobakhloo, 2018; Ibarra et al., 2018; Müller, 2019). More flexible and individual production (User-driven offering) (Ibarra et al., 2018; Müller, 2019; Müller et al., 2018; Weking et al., 2020). Service orientation, an increase in service offerings (Cavalieri & Pezzotta, 2012; Frank et al., 2019; Guinard et al., 2010; Ibarra et al., 2018; Müller, 2019; Weking et al., 2020). Integration of value chain offering (network offering) (Ibarra et al., 2018; Weking et al., 2020) Platform offering(*Digital Business Models for Industrie 4.0*, n.d.; Weking et al., 2020)
Customer relationships	Co-creation: Customers are part of the value-creation process. Direct relationship: between the firm and the customers(Cavalieri & Pezzotta, 2012; Ibarra et al., 2018; Kiel et al., 2016; Müller et al., 2018)
Key partners	Intensified partnerships between customer and supplier, new partners with IT or data expertise (Ibarra et al., 2018; Müller, 2019) third parties (Weking et al., 2020)
Cost structure	Large investments for a new production system (Müller, 2019) Creation of new competencies
Revenue streams	Pay-per-use (Ibarra et al., 2018, p. 9) (Müller, 2019). Dynamic pricing, performance-based revenues, etc. (Ibarra et al., 2018, p. 9) subscription, revenue sharing rent/lease (Weking et al., 2020) pay per use MaaS and PaaS (Ghobakhloo, 2018)
Customer segments	New customer segments can be identified through data collected from products and their usage by customers(Kiel et al., 2016; Müller, 2019; Porter & Heppelmann, 2014).
Key activities	New activities that build upon collected data, optimization, etc. (Müller, 2019) Customer integration (Kiel et al., 2016)
Channels	Direct channels and integrated channels with the customers and indirect channels through partners (Nagy et al., 2018)

2.5 Business Model innovation Patterns for I4.0

I4.0-enabled business models have been focusing on the following themes, service orientation, changes in key partnerships, network effect in value creation and value capture, and new revenue streams and value offerings. The patterns are defined in the following sections.

2.5.1 Service orientation

There has been an increasing pattern of including services with products using I4.0 technologies. The services inclusion is expanding the role of the manufacturers in the value chain by capturing more value with the services and they don’t have to compete on manufacturing costs only (Guinard et al., 2010) (Ibarra et al., 2018). I4.0 enabled services to include, supplementary services of remote monitoring, predictive maintenance, system upgrade, etc. (Ghobakhloo, 2018). The services help industries to increase revenue and differentiation in the marketplace, provide higher profit margins and recurrent sources of revenue and allow a higher shareholder value (Cavalieri & Pezzotta, 2012).

2.5.2 Ecosystem and integrated value network

Ecosystem and connected value network which is one of the features of I4.0 (Ibarra et al., 2018) (Weking et al., 2020). Traditional Industries are making partnerships with key enabler providers of I4.0 to create new combined offerings beyond their value chains (Ibarra et al., 2018) and increase the value capturing share with I4.0. The new integrated value network has the potential of optimizing production processes, enhancing the quality of products, strengthening the relationship between all stakeholders, and offering new business models and new ways of operating (Pereira & Romero, 2017). The integrated value network requires effective collaboration and well define value propositions from the stakeholders.

2.5.3 Increase in customization of value propositions

Industries are offering flexible value propositions in response to customer requirements with the help of reconfiguration of operations and improved customer interface enabled by I4.0 (Ibarra et al., 2018) (Müller et al., 2018). The improved customer interfaces are connecting industries with customers and understating their requirements. The new capabilities are also helpful for industries serving new customer segments who are not served yet by understanding their need and providing customized value propositions to fulfill their needs.

2.5.4 New method for revenue streams

I4.0 has enabled effective monitoring and control of operations which is useful for enabling new methods for revenue streams, value capture, or monetization expects of business models. Industries are offering new methods of value offering such as pay-per-use, dynamic pricing of resources, performance-based revenue, and pay-per-result. Moreover, Production-as-a-Service (PaaS) and Manufacturing-as-a-Service (MaaS) business models have been also used by the industries (Ghobakhloo, 2018).

2.6 Challenges in the adoption of I4.0

Several authors have found challenges with the deployment of I4.0 technologies. The three most common challenges are the lack of widely accepted standards, the competence gap in human resources, and cyber security threats(*Digital Business Models for Industrie 4.0*, n.d.; Horvath & Szabo, 2019; Müller, 2019; Nagy et al., 2018). The standardization of I4.0 technologies is required for interoperability of I4.0 enabled equipment from different vendors; human resources require new competencies for the implementation and use of I4.0 technologies and cyber security is essential for securing industries' operations and business data. Furthermore, issues of developing sustainable digital business models are identified in developing supportive ecosystems, scaling the business models, assessing and monetizing data, and issues around platform governance (*Digital Business Models for Industrie 4.0*, n.d.).

2.7 Industry 4.0 initiatives in Finland

I4.0 is one of the focus areas for both industries and the Finnish government. The Finnish government is playing a key role to drive the implementation of I4.0. The government has been providing funded projects to industries and different stakeholders for creating I4.0 solutions. Industries are collaborating with other companies and research institutes and universities for accelerating the implementation of I4.0. following are some examples of the collaboration project of these collaboration Reboot IoT Factory (Reboot Iot Factory - Reboot IoT Factory, 2022), focusing on manufacturing industry adoption of Industry 4.0; Sustainable Industry X (SIX) program for implementation of digital industry (*Sustainable Industry X*, 2022) and Industry 4.0 Hotspot providing a collaboration platform for Tampere based companies for the implementation of I4.0 (*Industry 4.0 Hotspot*, 2022).

2.8 Synthesis of the theories

Industry 4.0 (I4.0) has gained increasing attention in various industries and academia. I4.0 technologies have been enabling new functionalities to industries which both increase operation efficiencies and help to introduce new services with traditional products. A summary of key concepts and their definition and relationship with each other is summarized in Table 4.

Despite the importance of business model innovation for businesses, few researchers have studied the impact of I4.0 technologies on business models. As a result, companies have been facing hindrances to obtaining significant economic benefits from the I4.0 deployments. I4.0 implementation and its impact on business models have been discussed by (Frank et al., 2019; Ibarra et al., 2018; Müller, 2019; Müller et al., 2018; Weking et al., 2020). Understanding the impact of I4.0 on businesses and business models requires more research.

I4.0 technologies impact with theoretical frameworks for Porter's five forces model (Porter, 2008) and Business model theories defined by (Osterwalder, 2010) are relevant frameworks for the analysis of I4.0 on businesses. I4.0's impact on business models using the (Osterwalder, 2010) framework has been used by (Ibarra et al., 2018) with a literature review and (Müller, 2019) using qualitative research methods for SMEs in Germany. The author could not find any researcher using Porter's five forces model for analyzing the impact of I4.0 deployments on businesses. However, the author finds Porter's five forces model on smart products (Porter & Heppelmann, 2014) very helpful as connectivity and computation resources are also key enablers for smart products and smart products are one of the outcomes of I4.0.

As a result of analyzing the literature, the author found the analysis of I4.0 using Porter's five forces model is the biggest area for further development. Moreover, empirical research on the impact of I4.0 on business models of Finnish industries using business model canvas (Osterwalder, 2010) could be also developed further to obtain a better understanding of I4.0's impact on business models. The thesis project could contribute to the identified areas as a gap in the existing literature.

TABLE 4. Summary of I4.0 key terms and their relationships

Key constructs	**Definition**	**Key concept**	**Relationship between key constructs**
I4.0	A very broad term that is used to describe the use of the latest technologies especially digital technologies in industrial sectors	Use of I4.0 technologies for modernization of industries.	A phenomenon where many industrial companies are adopting, implementing, and collaborating for extending their traditional business and improving their operation and business performances
Business model	The business model describes how an organization does business by creating, delivering, and capturing value.	Essential for extracting the potential of the latest technologies to serve humanity.	Business model innovation for industries for extracting potential benefits of the use of I4.0 technologies for the businesses

Connectivity networks	Use of connectivity technology for exchanging information	Networks for providing communication and connectivity between humans and machines in industries. Connecting supply chain and customers with industrial operations.	A key enabler for I4.0 technologies for exchanging information and widely used for the implementation of I4.0 in industries.
Computation technologies	Provide capabilities of storing, processing, and using data collected from the machines	Essential for processing data and decision-making.	A key enabler for I4.0 mission-critical applications which require low latency decision on-site and long-term use of data for business
I4.0 in Finland	Activities for the implementation of I4.0 in Finland	Impact of change in industries with the implementation of I4.0 in Finland	Finland is a forerunner in providing connectivity and computation technologies which are key enablers for I4.0 implementation

3 METHODOLOGY

As the industry 4.0 business environment is evolving an exploratory approach with qualitative research was chosen. The qualitative research method was selected instead of quantitative research as the author wanted to learn from industry experts by conducting in-depth interviews on research questions. Data for the qualitative research was collected by semi-structured interviews and thematic analysis was done on the data. Throughout the research process, interview questions were adapted using a reflective and interrogative process described in (Agee, 2009) to shape the qualitative research based on an increased understanding of the problem.

Thematic analysis was done for analyzing the qualitative data collected through interviews. Thematic analysis was also done on the literature to identify the relevant themes for the research. The questions were designed based on theoretical research and thematic analysis. However, questions were not considered themes which is a common pitfall (Maguire & Delahunt, 2017). The themes for analyzing the data were created after analyzing the interviews. Semi-structured interviews were conducted where questions were asked on relevant areas but were open so that the interviewees could express their opinions and predict the future of industry 4.0, challenges, and opportunities which could help the research. There are different positions regarding when the research should engage with the literature relevant to your analysis. Some argue that early reading can narrow your analytic field of vision, leading the focus on some aspects of the data at the expense of other potentially crucial aspects. Others argue that engagement with the literature can enhance your analysis by sensitizing you to more subtle features of the data (Braun & Clarke, 2006, p. 86). In qualitative research, the researcher is trying to discover meaning throughout the inquiry process (Agee, 2009).

The methodological approach used during the thesis is described in Figure 5. The main themes of the research were research questions. However, during data collection and analysis of the data latent themes were also touched on. Qualitative analytical methods were chosen as a research methodology. The thematic analysis provides a flexible and useful research tool that can potentially provide a rich and detailed yet complex account of data (Braun & Clarke, 2006). The themes are, topics, ideas, and patterns for meaning that come up repeatedly, they are used to address the research or say something about an issue (Maguire & Delahunt, 2017). Themes represent some level of patterned response or meaning within the data set. (Braun & Clarke, 2006, p. 82).

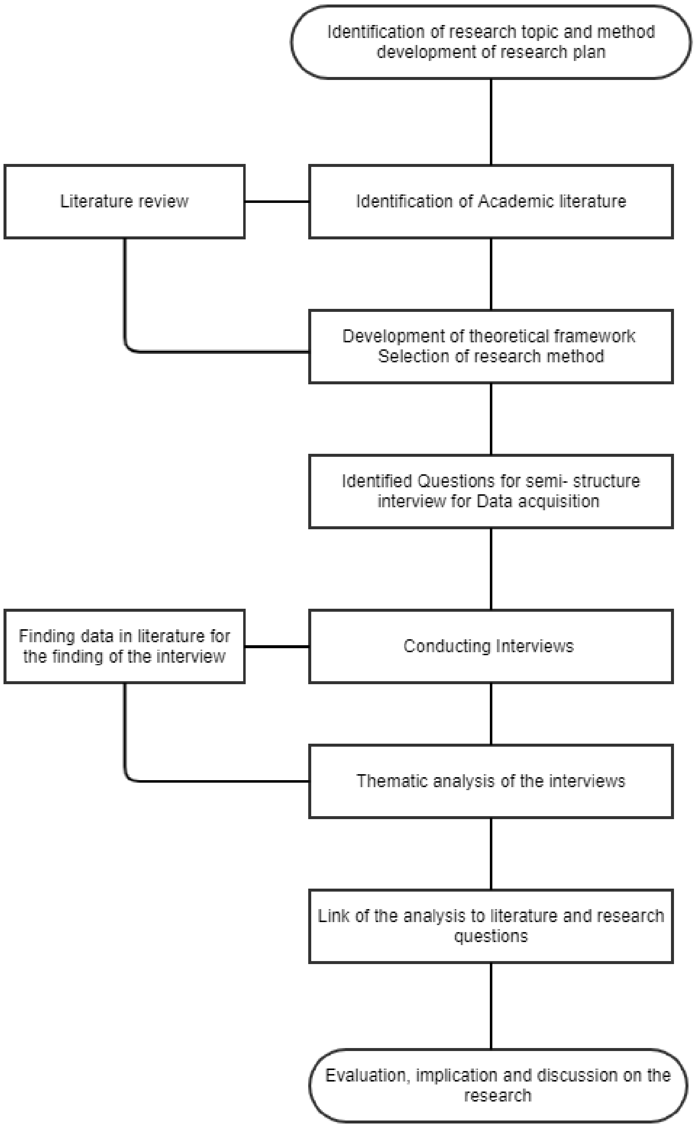

FIGURE 5. Methodological approach for the thesis

3.1 Methodological approach and methods

The author aimed for a theoretical and thematic framework to guide the data acquisition process. An iterative process was used for the data acquisition, analysis, and reflection on the research process. For each iteration questions were modified to obtain a better response from the participants. Theoretical research was done after each interview to relate primary data with secondary sources.

3.2 Interviews

The primary data was collected by conducting interviews with industry experts. The interviews were conducted in two iterations for each iteration two interviews were conducted, and data were analyzed. For the next iteration questions were adopted. The interview helps to refine the themes and collect more data from the literature for the themes. The process helps to give answers to the research questions. Additionally, more sub-themes were identified based on answers for opportunities and threats related to the implementation of industry 4.0 implementation. The participants were all working in the industry for the deployment of I4.0. The research method was chosen to learn from the people involved in the deployment of I4.0.

Qualitative research involves a series of questions, and there is a need to be clear about the relationship between these different questions which drives the research (Braun & Clarke, 2006). Semi-structured interview requests were sent to nine companies and eighteen representatives to get answers to the research questions with key contacts of industries. Business executives and R&D managers were targeted for the interview requests.

Research about industries in Finland was conducted by collecting primary and secondary data on the industries in Finland. Industries in Tampere were given more focus as the author is based in Tampere and it was easy to approach companies in Tampere for the interviews for conducting interviews. Valmet, Kalmar, Sandvik, and AGCO were chosen for the research and collection of primary and secondary data. Primary data was collected by conducting interviews with the employees of the selected companies and secondary data was collected from the company websites and other public resources.

3.3 Interview plan

The author planned to have interviews with higher management who are working in decision-making positions and managerial roles for the collection of primary data. Additionally, the target audience was covering both roles of research and development managers and business managers to get perspective on the operational ad technological of I4.0 technologies and business perspective. The author wanted to cover multiple stakeholders of I4.0 in the interviews for example industries who are deploying I4.0 solutions, system integrators, research institutes, and companies providing a solution, with I4.0 to other industries. Table 5 provides the list of companies whose interviews were planned.

TABLE 5. Interviews plan

S. No	Companies	Industry
1.	Kalmar	Logistics, port, and terminal
2.	AGCO	Agricultural, machines
3.	Sandvik	Mining, machines
4.	Valmet	Pulp and paper, Energy I4.0 Solution provider
5.	Tietoevry	Software services integration
6.	Digita	Private wireless networks deployment
7.	Siemens	I4.0 solution providers
8.	Business Finland	A government funded organization provides government funds for projects
9.	VTT	I4.0 R&D

Interview questions and their mapping to research questions are described in Table 6. More detail on the questions and explanation of the terms of the definition of business model, I4.0 technologies were given specifically to get relevant input from the interviews. The details are presented in Appendix 1.

TABLE 6. Research Questions Mapping with Interview Questions

Research Question	Interview Questions
1. How are industries adopting Industry 4.0 (I4.0) in Finland?	What initiatives are being undertaken in your own organization to fully or partially implement I4.0 in its operations?
a. How are the companies seeing the effect on business models with the deployment of I4.0?	What is the role of I4.0 in current industrial business activities? How does the implementation of I4.0 influence an organization's current business model? What opportunities or threats would arise in terms of offering new products or services, should an organization implement I4.0?
b. What are the challenges in adopting I4.0?	What opportunities or threats would arise in terms of offering new products or services, should an organization implement I4.0?
c. How could the Finnish government help industries with the deployment and adoption of I4.0 technologies?	How could the Finnish government help industries with the deployment and adoption of I4.0 technologies?
2. What role could communication and network service providers play in implementing I4.0?	What are the benefits of digitalization, automation, scalable networks, and cloud computation for Industry 4.0?

3.4 Practical and ethical issues

The research was planned to be done based on public data of companies and with interviews where the purpose of the interview will be described. The approach will not raise issues of access to specialist databases. Research questions were designed on a level that confidentiality or property rights are not violated especially in the collection of primary data with the participants working in industries. Ethics was considered to design the questions so that participants do not feel any risk by answering those. And answering the questions does not affect participants' personal or professional lives

The concern about GDPR (General Data and Privacy Regulation) was addressed by informing interviewees working in the industries and how the collected data in the interviews will be used. Additionally, to address the data, the personal information of the interviewee will be anonymized, and the purpose of the interview and use of the interview will be clarified. The main purpose of the researcher is the advancement of the business perspective in I4.0.

3.5 Research method and analysis of the data

The following six-step framework for performing thematic analysis defined by (Braun & Clarke, 2006) was used for analyzing the data collected from the interview and the literature.

- Step 1. Become familiar with the data,
- Step 2. Generate initial codes,
- Step 3. Search for themes,
- Step 4. Review themes,
- Step 5. Defining and naming themes, and
- Step 6. Producing the report

The first step was to become familiar with the data at this stage, interviews were conducted, and notes were taken during the interviews, videos of the interviews were also recorded with participants' permission. Microsoft Teams was used as a tool for recording the interviews which is very helpful as it also created the transcript of the interviews with the recording. The author also used transcripts and videos after the interviews to develop a good understanding of interview responses. The collected research data from interviews and literature were analyzed with the six steps thematic analysis framework defined in (Braun & Clarke, 2006). Step 1 and step 2 were used to create initial codes by combing and organizing all data from the interviews. The responses to the interviews were combined to summarize the main ideas collected during the interviews and which were relevant to the research questions. First themes were created with Step 3 by collecting all data relevant to each theme together. The data was associated with the identified themes. The following questions presented by (Maguire & Delahunt, 2017) were used to review the themes for step 4

- Do the themes make sense?
- Does the data support the themes?
- Am I trying to fit too much into a theme?
- If themes overlap, are they separate themes?
- Are there themes within themes (subthemes)?
- Are there other themes within the data?

Step 5 was the final step of the creation of the themes and aim to identify the essence of what each theme is about (Braun & Clarke, 2006), identify any sub themes, and make a relation how the themes interact with the main theme and how the themes relate to each other (Maguire & Delahunt, 2017).

4 EMPIRICAL RESEARCH RESULTS

The impact of I4.0 technologies deployment on industries was analyzed by qualitative research, using seven interviews from Finnish companies. Four interviews were done from industries of port and terminal, mining, factory automation, and agriculture solution providers: Kalmar, Sandvik, Valmet, and AGCO respectively. Additionally, three interviews were done with industrial segment solution providers, Siemens, software service providers Tietoevry and private wireless as a service provider Digita. The industries are in different phases of deployment of I4.0 technologies from Proof of concept to offerings of products and services using I4.0. The interview requests were sent to nine companies and eighteen representatives working as Business executives and R&D managers. The acceptance ratio for interviews was 39%. Interview questions are presented in Appendix 1.

4.1 Analysis of the interviews

Interview responses were analyzed with quantitative methods and thematic analysis. Interview responses were combined, and the ratio was calculated to know the most important trends in the responses which are shown in Table 7. Additionally, the thematic analysis was done on the responses for further analysis of interview data which is presented in the next sections.

TABLE 7. Summary of interviews

I4.0 current industrial business activities	**Re-spo nse**	**Ratio**
Efficiency increase of product and operation	5	38 %
Increasing sales with I4.0 enable features	5	38 %
Investing modernization of the operation	3	23 %
I4.0 initiatives being undertaken by organizations		
Digitalization and connectivity	5	45 %
Autonomous machines development	5	36 %
Development of services	2	18 %
I4.0 opportunities and threats		
Challenges		
Cyber security	4	36 %
Lack of expertise, need for new workforce	3	27 %
Lack of standards	3	27 %
Return of investment	1	9 %
Opportunities		
Improve worker safety	2	33 %
Increase productivity	3	50 %
Emergency services	1	17 %
I4.0 influence an organization's current business model		
Value propositions	5	26 %
Customer relationships	4	21 %
Revenue streams	4	21%
Key Partnerships	3	16 %
Key resources	3	16 %
Finnish government's role in driving I4.0 in Finland		
Helping in creating a workforce for I4.0	5	45 %
Working with other countries for defining Regional (EU) level standards and regulations	3	27 %
Providing funds for collaboration work between industries	3	27 %
Communication and computation resources for I4.0 implementation		
Fast and reliable communication and computation network	4	67 %
Possibility of customization of capacity for uplink and downlink	1	17 %
Offering based on pay per usage	1	17 %

4.1.1 Thematic analysis of the interviews

Thematic analysis of the interviews was done to identify themes from the interview. The thematic analysis framework presented by (Braun & Clarke, 2006) was used for the analysis. Initial themes were created by coding interview data for important terms and creation of themes which are shown as a mind map in Figure 6.

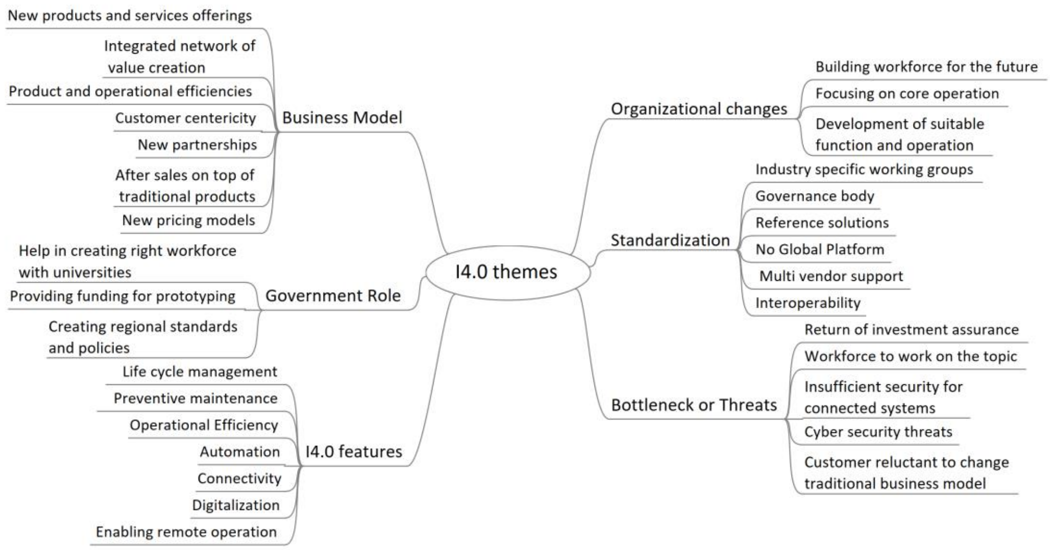

FIGURE 6. Thematic map I4.0 from the interviews' data

The themes were then connected with the research questions and sub-themes to create a thematic map. The thematic map for the analysis is shown in Figure 7. The themes of the interview are discussed in the following sections.

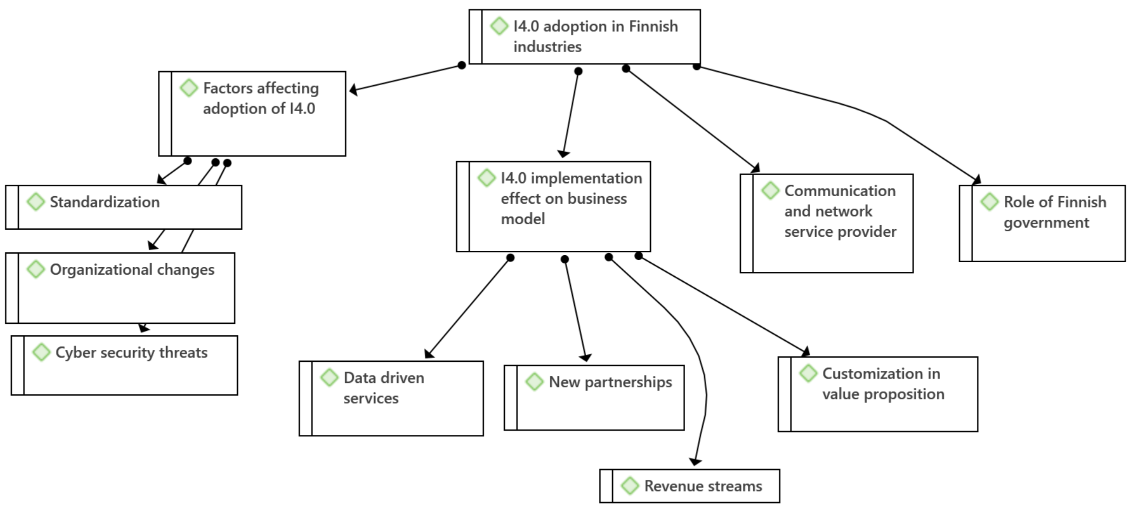

FIGURE 7. Thematic map I4.0 from analysis of the result

4.2 Industries' adoption of I4.0 in Finland

Finnish industries have been deploying I4.0 technologies. The industries are in different stages of deployment and are engaged in different business activities for the deployment of I4.0. The business activities of increasing product and operation efficiencies, increasing sales with I4.0 enable features, and investing in the modernization of operations. Moreover, organizations are also in different stages for the implementation of the features from the development of proof-of-concept systems with the enabler technologies to the offering of advanced automation solutions for industrial operations. The following pie chart in Figure 8 summarizes the relative proportion of three key business initiatives in industries for the implementation of I4.0.

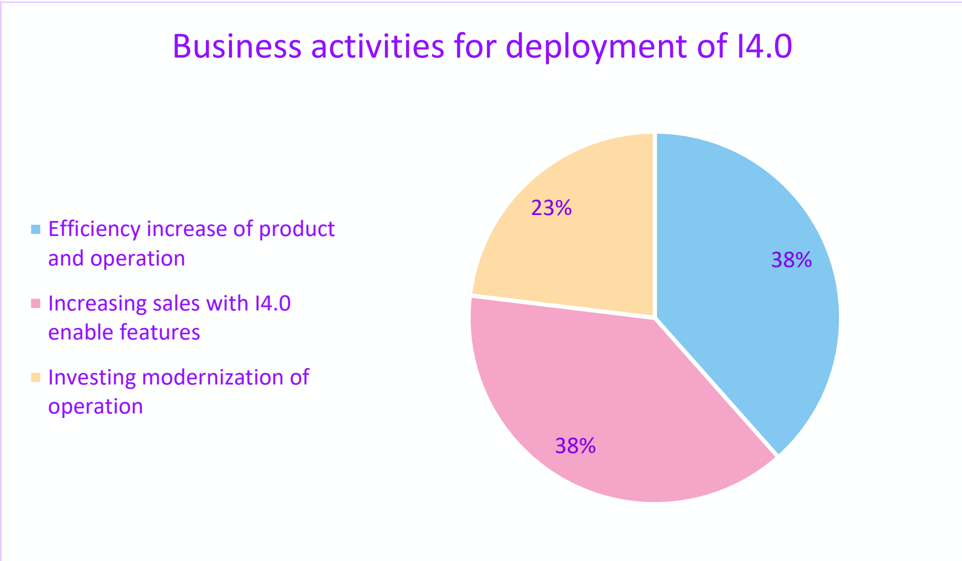

FIGURE 8. Business activities for deployment of I4.0

Finnish industries have been developing I4.0 for different purposes, the relative proportion of the activities is shown in the following pie chart. Interviewees mentioned that their industries have ongoing initiatives for digitalization and connectivity of operations. Industries are developing automation features for mobile machines and operations which was a 36% share in the responses. Furthermore, companies are developing services for targeted preventive maintenance by collecting and analyzing data from the machines. Figure 9 provides more details on current initiatives of I4.0 deployment in Finnish industries.

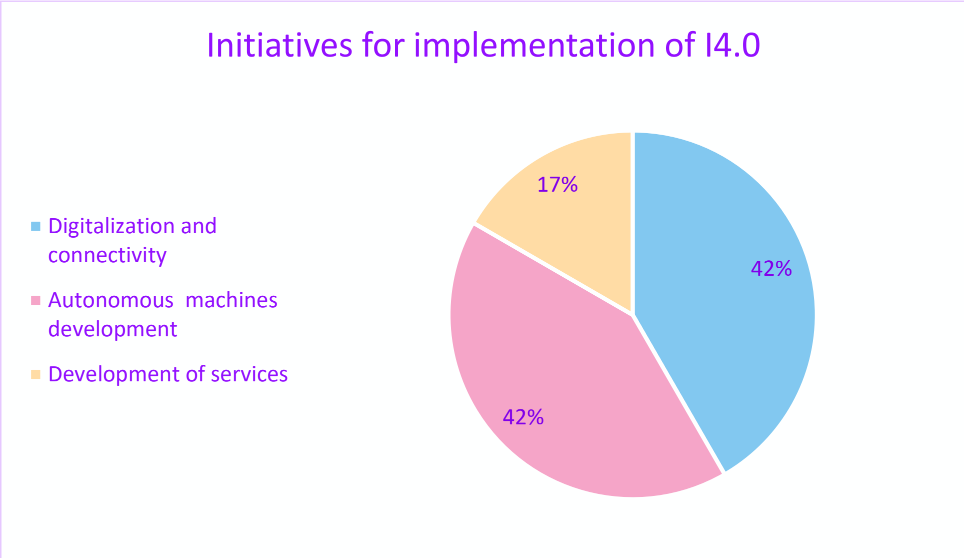

FIGURE 9. Initiatives for implementation of I4.0

Industries are focusing on different I4.0 features to improve operational efficiencies which are summarized in Table 8. In port, and container handling industries, Kalmar wants to optimize the loading, unloading times, and transfer of vessels to the next destination with key enablers of I4.0, that is digitalization, automation, and remotely operated equipment such as cranes, and straddle carriers. This will allow them to manage fluctuating demands, and volumes of containers entering and leaving the port with the least disruption, and highest efficiency while maintaining the safety of any personnel on-site. (*Kalmar Explores Digital Transformation of Ports*, 2021) . The interviewee provides an example of I4.0 implementation at Kalmar: “We are connecting our operation which will enable automation and collaboration of machines for handling the next coming job at the port”

TABLE 8. Implementation of I4.0 in Finnish industries

	Industry	Value driver	I4.0 Features
1.	Mining, Port, and terminal/logistics Agriculture	Operational efficiencies, the safety of human resources by reducing interactions with heavy machinery, and working in difficult environments	Remote operation control, Autonomous mobile machines, and Digitalization
2.	Manufacturer of factory automation solution System integrator	Differentiation of solution, operational efficiency, and the possibility of using collected data for improving operational, and business outcomes Value-added services for connected operations	Digitalization, end-to-end connected value chain, Deep integration with customers, Service

Sandvik is transforming the mining industry, with the automation of mines, self-driving autonomous machines, electrification, and connected equipment. The transformation result is a huge productivity boost that also benefits the surrounding environment and employees' situation. (*Sandvik Group*, 2020). A very good example of I4.0 deployment is the remote, and autonomous operation of Agnico Eagle Finland at the Kittilä gold mine in northern Finland. Sandvik's AutoMine® system and Nokia's 5G stand< private wireless network are key enablers for the automation operation at the mine, which is successfully running since 2021 and has surpassed the targeted operational efficiency for the initiative. (*Agnico's Kittilä Autonomous Haulage*, 2021) (*Nokia 5G - Industry 4.0 Adoption*, 2022).

Valmet is a leading global developer, and supplier of process technologies, automation, and services for the pulp, board, paper, tissue, nonwovens, energy, marine, and process industries. Additionally, Valmet serves process industries with automation systems, and flow control solutions.(*Valmet*, 2022 August-2022). Valmet is providing solutions, and services for automation, maintenance of machines, cyber security, connectivity, and which have an important role in the implementation of industry 4.0.

Siemens Digital Enterprise provides offerings of automation and industrial software to many industries. In the food and beverage industries “Nestlé’s plant in Juuka, Finland” (*Nestlé Juuka Digitalization | Siemens Global*, n.d.) is a very good example of the implementation of I4.0 in industries. In agriculture industries AGCO is using, I4.0 for connecting machine fleets, collecting data from the fleet, optimization of machines, and providing additional services using data from the machines. Tietoevry provides different software services for I4.0 collected data from system integration to extracting intelligence from data. And Digita has an offering for private wireless services in Finland which is one of the enablers of I4.0.

4.3 Effect of business model with the deployment of I4.0

I4.0 deployments have been impacting value creation, delivery, offering, and value capturing aspects of business models. Five areas were mentioned more during the interviews: (1) Value proposition, (2) Customer relationships, (3) Key partnerships (4) Revenue streams, and (5) Key resources. Figure 10 shows the relative proportion of the business model components mentioned during interviews that have been impacted by the implementation of I4.0. The business model canvas for industrial solution providers is summarized in Table 9 which was a result of combining Interviews responses and analysis with the theoretical framework of the business model canvas defined by (Osterwalder, 2010).

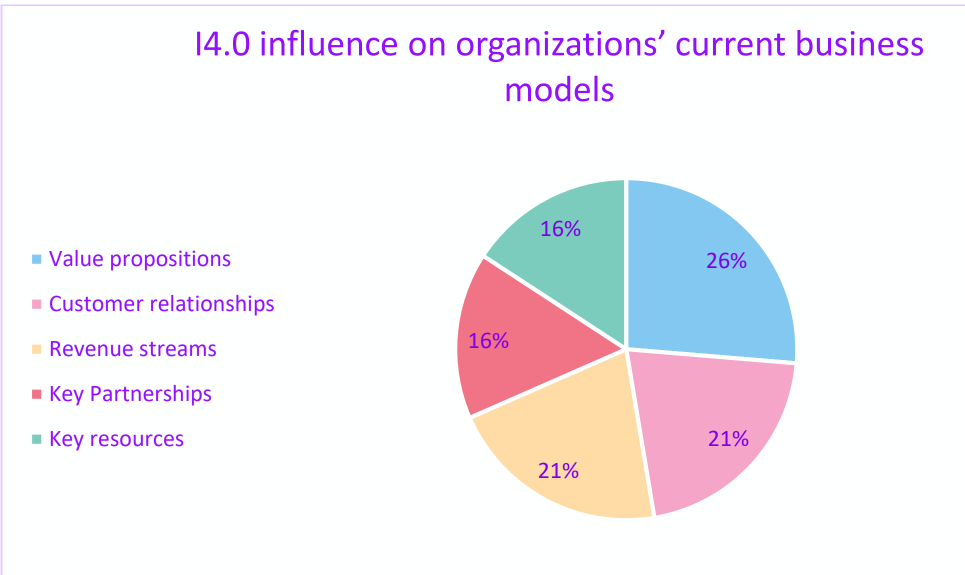

FIGURE 10. I4.0 influence on organizations’ current business models

TABLE 9. Business model canvas for Industry 4.0 industrial solution providers

Key Partners	**Key Activities**	**Value Proposition**	**Customer Relationships**	**Customer Segments**
Connectivity and computation resources providers Supply chain partners Universities Third-party solution providers and Customers as a partners	Development of production facilities with I4.0 technologies Creation of integrated value creation networks with partners Creation of new value propositions enabled by I4.0	Autonomous mobile machines and autonomous factory operations Valued added service using data collected from machines Flexibility for customized production and products Close-loop manufacturing Self-organizing operations	Co-creation with customers Long-term Partnership	Several Industrial companies working in different industries segments deploying I4.0 solutions
	Key Resources		**Channels**	
	I4.0 enabled manufacturing facilities Integrated value network I4.0 enabled workforce Key partnerships R&D		Integrated channels of suppliers, Partners, and customers	

Cost Structure	**Revenue streams**
Initial costs for research and development of I4.0 enable products and solutions Cost for licensing different solutions from third parties Initial investments required for the creation of integrated value network	Increasing share of service revenue using data collected from machines Charging high premiums for customized products Revenue sharing, pay-per-result, and pay-per-use

Furthermore, one participant also mentioned that “ I4.0 is changing the whole organizations’ operations, products, marketing and sales, etc. and organizations need to rethink the business models with the implementation of I4.0”.

4.3.1 Value proposition

One of the biggest effects of I4.0 technologies was identified in the value proposition. The I4.0 technologies have enabled data-driven services that have been created with the collected data from the machines. The data-driven services of preventive maintenance, health check of machines, and consultation services have been developed in mobile machine industries. One interviewee gave the example of targeted preventive maintenance as follows.

> “I4.0 has enabled us to collect data from our machines. We are using AI and data analyses on the collected data to learn about what is happening in our machines, the lifetime of machines, and what happens during the lifetime and plan machines' maintenance“

Additionally, I4.0 technologies play an essential role in machine and factory automation, a key value proposition for the industries. Many value propositions were found in the interviews such as close-loop manufacturing, integration of value chain, individual mass production, and self-organizing manufacturing. One interviewee explains close-loop manufacturing as:

> " The close loop manufacturing is combining PLM (Product life cycle management) the ERP (Enterprise Resource Planning) and manufacturing operations. The close loop manufacturing allows you to rotate from product design to manufacturing and tracking of what is happening in the factory shop and introducing new products”

Furthermore, the integration of the value chain, individualized mass production, and self-organization manufacturing was also mentioned in the interviews. An integrated value network is one of the key value propositions mentioned in one interview as “ Many customers consider I4.0 deployment for their operations for enabling advanced level integration of value chain.” Interviews revealed that individualized mass production and the need to bring new products more rapidly into the market are key drivers for the implementation of I4.0 technologies in manufacturing. Furthermore, self-organizing manufacturing has been increasing the demand for the value proposition of automated guided vehicles that moves materials and manufactured products in self-organizing manufacturing.

4.3.2 Customer Relationships

I4.0 technologies have improved the customer relationships customer are connected as part of the value chain. The connection with customers in the early phase of production has enabled taking customer requirements early and developing value propositions that meet customers' demands. Customer relationships have been key in enabling co-creation and individualized mass production based on customer needs.

Furthermore, I4.0 has enabled co-creation with customers where the customers are involved in designing the product with the manufacturer. An interviewee mentioned that customer focus in one of our strategic directions for developing new machines and indicated the increasing role of customers in designing products "Our marketing, sales, and product design teams are increasingly involving customers for designing new machines for their needs, this enables us to be closer to customers and serve them better and support their strategies"

4.3.3 Revenue Stream

I4.0 has been changing the revenue stream of the solution providers. A reason for the change is to tackle the need of initial large investment needed for the installation of I4.0 technologies. Companies are providing different pricing models for offering value and value captures to reduce the initial cost of deployment, it was mentioned in an interview as "New pricing models of pay-per-result and as a service model is giving the possibility to the small to medium size enterprises and even startups to start utilizing the technologies because the initial investment is not so significant"

Industries have been using pay-per-use, pay-per-result, profit-sharing, and as a service models. As a service model is widely used for software services. One interviewee stated that "We are moving away from the traditional kind of software business into a subscription or software as a service type of models -- in conjunction with possible services and integration and implementation work". Profit sharing model is identified as one of the key pricing models for deployment of I4.0 it was identified as "a profit-sharing model where solution provider gets paid by the output of the work. So, I think that's the ultimate where you can go that you change the whole business logic and the model “.

4.3.4 Key Partnerships

The interviews mentioned key partnerships with communication and computation network providers and third parties with AI and ML. An interviewee described key partnerships are essentials for an integrated value chain created with the deployment of I4.0.

> “Business models will be merging into joint value creation modes and ecosystems. Industry 4.0 is bringing the bits and pieces together. It is rather obvious that no company can do it alone, and I think it's then joining forces with the best possible ways to maximize the needed capabilities from there.”

Third parties will play a key role in creating value added services from the collected data from the machines. One interviewee explains the role of third parties in creating additional value: “We see opportunities to work with third parties who have the right competence and resource to drive new values from the data. We could not create all possible values with data ourselves. “

4.3.5 Key resources

The new capabilities created by I4.0 requires a workforce that could operate and get benefits with new enhanced capabilities. One of the essential needs of industries for the implementation of I4.0 is to upgrade the existing workforce by training and hiring new employees for the new capabilities.

Secondly, interviewees mentioned that they see the role of IT (information Technologies) and OT (Operation technologies) departments getting merged with the deployment of I4.0. The increasing use of digital technologies in operation have been demanding skills of IT organization in the workforce working with production equipment.

4.4 Communication and Network service providers for I4.0

I4.0 is driving the digitalization of industries and growing demand for a highly reliable and fast communication network in the industries. The network and computation resources were identified as enablers for I4.0. Wireless connectivity technologies demand is growing for enabling autonomous operations of mobile vehicles in port and terminal, mining, and agriculture industries. Additionally, the demand for private wireless networks and edge computation were also mentioned for mission and business critical applications which require low latency communication and computation and high security of the mission and business critical data. One interviewee described the need for private wireless as: “The industrial companies prefer to have their private networks so that their activities are not visible outside. As an example, information, are they producing or not? is sensitive --.” The response for the role of communication and network service providers is shown in Figure 11.

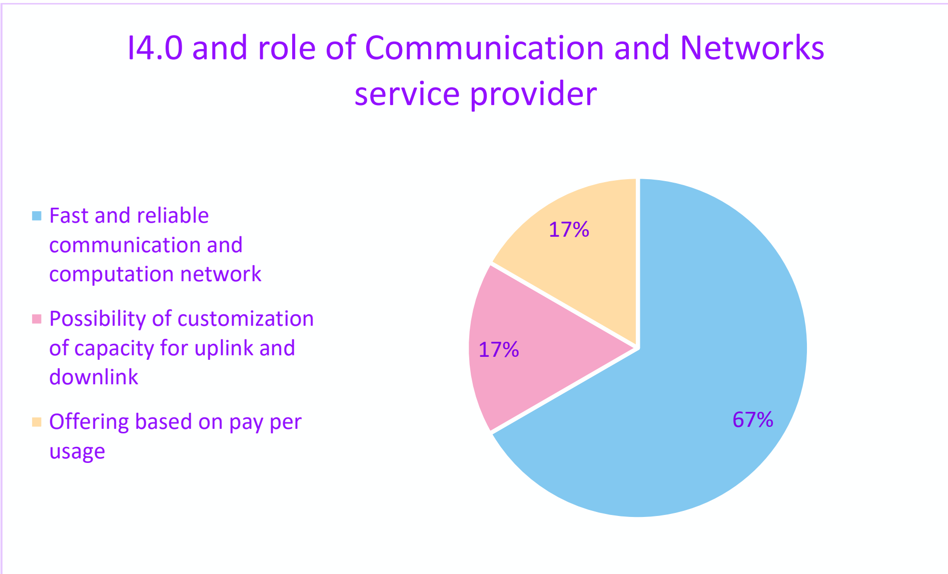

FIGURE 11. I4.0 and the role of communication and network service providers

Interviews also identified the need for computational resources for the deployment of I4.0 and computation technologies of embedded computing, edge computing, and clouds all have their role for I4.0 deployment for different purposes. One interview explained the role of computation resources as:

"Hybrid approaches with a combination of embedded computing/sensors, edge computing, and clouds are a way forward. One great example is machine learning topics where you need to generate the models within the cloud. But then you typically deploy the model into runtime running closer to the machine because. Not everything needs and should go to the cloud on the data, but really. It's all about finding the balance that you can achieve the topic for your need with a combination of cloud and edge. So, these are key components in there, but it's not everything, it's a combination of the topics."

4.4.1 Business model of Network service providers

I4.0 applications have different needs for network and computation. The application need requires different capabilities from the communication and computation resources. Real time communication and high security of data are key requirements for mission critical and business critical applications where edge computation has been the first choice for industries to make sure data is not leaving the premises. On the other hand, for non-critical applications cloud infrastructure has been the first choice for computation networks. Table 10 provide the summary of resource needed for the I4.0 applications.

TABLE 10. Communication and computation network application for I4.0

Application types	**Connectivity network**	**Computation**	**Example**	**Additional Requirement**
Mission Critical application	High speed networks e.g., cellular networks 4G, 5G, etc. Real-time communication > 10 milliseconds	Edge computing Real-time computation	Autonomous machines, factory automation, operation safety	Security of mission critical data, Skilled workforce
Non mission critical application	Low power cellular network IoT etc. Delays of more than 10 milliseconds	Cloud infrastructure Delays of more than 10 milliseconds	Analytics of the historical data, SW upgrade, reconfigurations, etc.	Flexibility of scaling infrastructure, Flexible workforce

I4.0 has been evolving as an ecosystem and network and services providers have a key role in providing digitalization and connectivity infrastructure. However, digitalization and connectivity only represent a fraction of the ecosystem. The network service providers should invest in capabilities beyond connectivity, to get a larger market share in the ecosystem (*Edge Computing* | *Statista*, 2022). The ecosystem will be more focused on customer relationship management, service orientation, and focusing on the economy of scope that is offering services and applications suitable for enterprise customers and partnership with third party application providers to provide new innovative solutions focused towards industrial and enterprise customers. I4.0 mission critical applications have been increasing focus for industries for enabling autonomous operation which provides an opportunity for network and communication service providers for developing their value offering.

I4.0's needs for networks and edge computation are very different from the network provided by telecom operators. The traditional business model for network service providers is providing network infrastructure and network management which is focused on the economy of scale (Osterwalder, 2010). The private wireless network and edge computation provide opportunities for a network provider to not just provide digitalization and connectivity infrastructure for industries but also provide capabilities for running mission and business critical applications on edge servers. Network and service providers must focus on Key partnerships with solution providers of I4.0 for industries, to become part of the integrating value creation network of industries and creates value propositions complementing the mission and business critical application of I4.0. Furthermore, the main cost structures of network and service providers could be developing new capabilities for providing edge platforms and working with third-party application providers for using their capabilities to enable new value added services along with connectivity. The network service provider could provide private wireless networks with unlicensed bands and Citizens Broadband Radio Service (CBRS). They don't need to partner with public mobile operators for obtaining access to spectrum in some markets. Table 11 describes a business model canvas for network and service providers for I4.0 industries based on interviews, and the author's experience working in the I4.0 industry.

TABLE 11. Business Model for Network and Service Providers

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Proposition</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">Partnership with I4.0 enabled industrial solution providers and third parties with competence in AI and ML for enabling new applications with data collected from the connected value network
Customers as partners</td><td>Network maintenance, application and service provisioning platform, research, and development for providing value added applications and services to I4.0</td><td rowspan="3">Value proposition providing private wireless, edge computing platform and portfolio of I4.0 mission and business critical applications</td><td>Co-creation
Long-term Partnerships for meeting individual industries' requirements
Self-service for third parties' partners</td><td rowspan="3">Several industries deploying I4.0 solutions</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td>Private wireless network and Edge computing platforms to run mission and business critical applications
Service provisioning platform
R&D and Human resources</td><td>Become a key partner of industries' value creation network and ecosystem
Direct</td></tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue streams</th></tr>
<tr><td colspan="2">Edge platform development
Cost for developing mission critical application portfolio
Cost for licensing of third party applications</td><td colspan="3">Increasing service revenue with mission critical applications and services
Revenue from value added services from the collected data from the machines
Pay per use, and as a service business revenue model</td></tr>
</table>

4.5 Challenges with the adoption of I4.0 deployment

The challenges of lack of expertise, need for a new workforce, lack of standards, cyber security, and slow adoption of new business models was identified during the interviews. The distribution of identified challenges is described in Figure 12 which is described in the following sections.

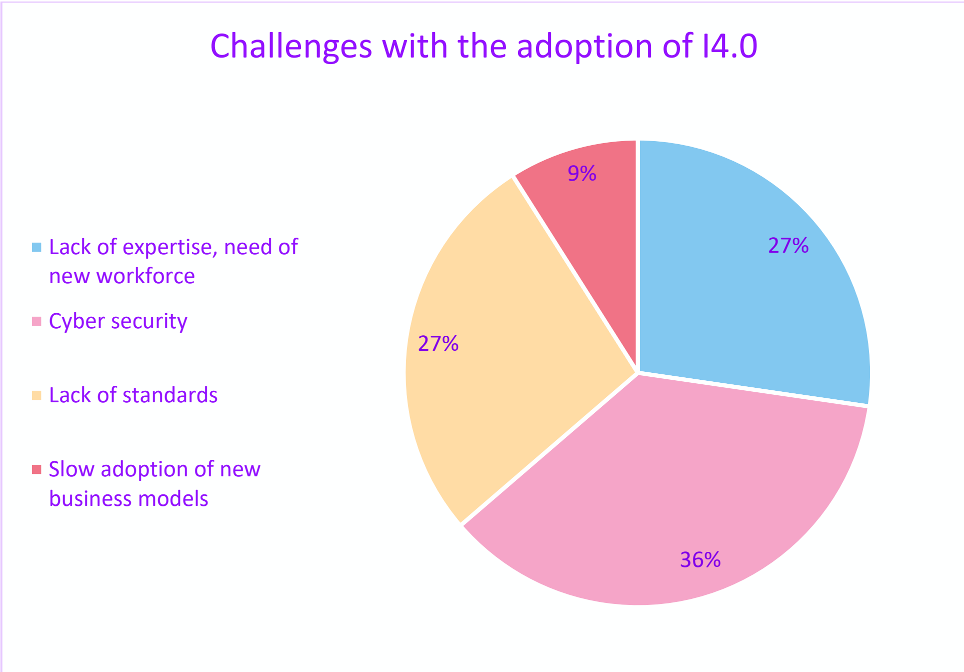

FIGURE 12. Challenges with the adoption of I4.0

Firstly, the new capabilities enabled by I4.0 technologies require the transformation of the workforce. The industries see the lack of a suitable workforce and the long time for training existing employees as a challenge for the deployment of industry 4.0. Furthermore, another challenge is the lack of the I4.0 implementation strategy of the company by higher management.

Secondly, I4.0 technologies are still evolving, and there are no widely accepted standards for the industries. The standards' nonavailability is caused by the high level of customization of the I4.0 solutions for individual industries, the absence of a common platform for facilitating standardization of I4.0, and the culture of big solution providers of industries to focus on proprietary solutions. One participant identified the availability of a common platform for collaboration and culture of big industrial solution providers companies as:

> “One of the reasons for the slow standardization of I4.0 is the culture of big industrial companies of not collaborating actively. -- mobile manufacturers collaborate actively in the 3GPP platform for the standardization of technology which results in the availability of multiple vendors, and cheap price of the technology compared to the technology used in industrial segments”

Industries have been participating in industry-specific platforms for the standardization of I4.0 technologies and the creation of reference solutions for their segment which are present in Table 12.

TABLE 12. Workgroup for standardization of I4,0

Industry	I4.0 Workgroup
Agriculture	**AEF**, Agriculture Industry Electronics foundation, (*AEF - AEF Online*, 2022)
Ports and Container handling industry	**TIC 4.0**, Terminal Industry Committee 4.0, iTerminals 4.0, Eu funded project for application of I4.0 technologies towards digital port container terminal (*ITerminals 4.0*, n.d.)
I4,0 solution providers	**Industrial communication Protocol** **OPC UA**, Open Platform Communication Unified Architecture, (*Unified Architecture - OPC Foundation*, n.d.) **RAMI 4.0,** Reference Architecture Model Industry 4.0 **5g-acia**, (*5G Alliance for Connected Industries and Automation*, n.d.) MQTT, (*MQTT - The Standard for IoT Messaging*, n.d.)

Finally, the security of information is a key requirement for the deployment of I4.0 technologies that have been connecting value chains and increasing the stakeholders who have access to critical information. The need for high security for industries was identified in an interview as: “Security of our system is very important we aim to use very advanced security methods to secure our machines “. The connectivity of the value chains is increasing exposure to cyber security threats.

4.6 Role of the Finnish government

The Finnish government could play a key role in the adoption of I4.0 by working with other governments for EU-level standardization and policies for I4.0. One interviewee sees the role of the Finnish government in defining regional policies as:

> "Finnish government is helping us with the Finnish market, but the help is very little if we consider the global market, it should play a role in defining global phenomena of I4.0 by working with other countries".

Additionally, the government should work with the universities to the creation of workforce of I4.0 to meet the demands for I4.0 deployments in Finland. The distribution of the responses is described in Figure 13.

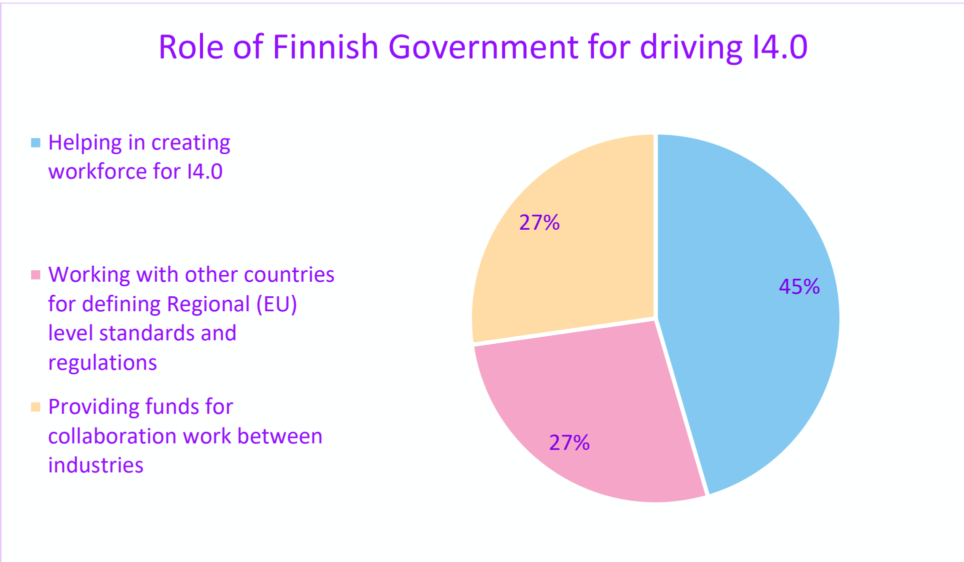

FIGURE 13. Role of Finnish Government in driving I4.0 initiatives

Finally, government-funded projects are also important to bring together companies with complementary capabilities and create I4.0 solutions for the industries. (Müller et al., 2018) also found government funded projects are important to bring together companies with complementary capabilities.

4.7 Synthesis of the result

I4.0 have been a key area for future business development for Finnish industries. Finnish industries are forerunners in I4.0 enabled solutions for port and terminal logistic and mining industries. I4.0 has been one of the growth areas for industries and industries already have some solutions enabled with I4.0 technologies and there are ongoing initiatives for investing in developing I4.0 products and services.

Industries have identified the impacts of I4.0 on business models. The biggest impact on business models with the deployment of I4.0 was found in five areas (1) Value proposition, (2) Customer relationships, (3) Key partnerships (4) Revenue streams, and (5) key resources. Value propositions for industrial solution providers are focusing on enabling autonomous operation for different industries. Each industry has different requirements for machines and operations, so solution providers are focusing on developing solutions and machines for specific industries. Kalmar is developing autonomous mobile machines for port and terminal industries, Sandvik for mining industries, and AGCO for agriculture industries. Industries have been seeing the increasing role of customers in value networks and the development of network value chains and I4.0 ecosystems.

For the area of future developments need for improved security solutions and network infrastructure for mission and business critical applications was identified. The mission and business critical applications require low latency decision making and high security and critical data not leaving the premises. The high-speed private wireless network and edge computations could play a key role to meet the requirements of mission and business critical applications. (Edge Computing | Statista, 2022).

Network and service providers are key enablers for I4.0 applications. The mission and business critical applications require an enabler of private wireless and edge computing for meeting the low latency and security requirements. The edge computing platform is a key opportunity for network and service providers to extend their value proposition beyond connectivity. The edge computing platform for running mission critical applications and enabling value added service with data collected from the machine using AI and ML could be a key role as a network and service provider for I4.0.

Industries have been seeing challenges with the adoption of I4.0 as well. The challenges of lack of expertise for I4.0 technologies need for a new workforce and lack of standards I4.0 are found. The lack of standardization of I4.0 technologies has been seeing the biggest challenge for the widespread adoption of I4.0. The standardization is facing hindrances due to the non-availability of a global platform for discussing the standardization of I4.0 solutions.

The Finnish government could play a key role in the adoption of I4.0 by working with other governments for EU-level standardization and policies for I4.0 and working with Finnish universities for creating a workforce that has the competence of I4.0 technologies for meeting the future demand of Finnish industries.

5 DISCUSSION

I4.0 is reshaping the industry boundaries, changing the dynamics of competition, and creating new opportunities, threats, and markets for both established players and new entrants. Industrial companies must think beyond the technical capabilities of I4.0 and define their role in the new boundaries. I4.0 deployment is changing the value creation, value capturing, and value offering of industries and making them rethink their strategy in the new environment and innovating business models with the new capabilities. The connectivity and computational resources are key enablers of the I4.0 capabilities which are making the industrial segment a key customer segment for network and service providers.

The author attempted to analyze the impact of I4.0 deployment on Finnish industries. The research was focused on three areas of impact of business model impact on the industries, the role of network and service providers for the deployment of I4.0 technologies in Finland, and the role of the Finnish government in driving the I4.0 deployment. The research result is summarized in the following sections, the effect of I4.0 on industries using Porter’s five forces, an analysis of the impact on business models with the implementation of I4.0, and challenges with the implementation of I4.0 in the following sections.

5.1 Effects of I4.0 on industries

The industry 4.0 deployment is changing the industries’ structures, which is increasing the role of I4.0 to enable technologies in both value creation and value capturing. The new structure is changing the competition between the traditional players in the market who are providing traditional products specific to their industries but also for new features and value-added services providers which are created through a network of partners, suppliers, and customers. The companies whose offerings of products and services have the greatest impact on overall system performance will be in the best position to drive the process and capture the disproportionate value and the companies that fail to adapt may find their position very weak in the value proposition with system integrators in control (Porter & Heppelmann, 2014).

5.1.1 Creation of ecosystem and integrated value network

From the research result, it was found that I4.0 deployments have been promoting an ecosystem and culture for network value creation for the industries. The ecosystem has been developing with the increasing collaboration of industries, partners, and customers for value creation. The finding of the ecosystem and value network support the pattern of innovation discussed by (Ibarra et al., 2018) in the association of radical change of business model components. It was identified that the traditional business models of suppliers will be merging into joint value creation models and the creation of ecosystems. The ecosystems have been increasing the need for cooperation between companies for joining forces for the needed capabilities and it is becoming almost certain that no company can enable the ecosystem of an industry alone. The industries have been making strategic choices about what part of the value creation network they want to position and create competencies for and what competencies they will rely on partners.

Interviewees classified mainly two competencies for I4.0 deployments (1) core competencies of industries and (2) foundation or enabling competencies for I4.0 deployment. The core competencies are the research and development of products and solutions for specific industries. On the other hand, foundational or enabler competencies are needed to work with enabler technologies of I4.0 connectivity, computation, and application running on top of these technologies for example AI and ML. Industries tend to focus on core competencies and develop further for their core products new features by analyzing the data collected from the machines. On the other hand, industries developing key partnerships for acquiring the foundation capabilities of I4.0 connecting their operation, value networks, and customers, and network and service providers and third parties enabling value added service with data collected from the machines are key partners for the industries.

5.1.2 Bargaining power of buyers

The empirical results reveal that the I4.0 deployment has been creating new opportunities for industries. The new opportunities have been increasing revenues as a result of product differentiation of I4.0 enabled features, new services derived from collected data, and customization of products for customers. The new opportunities have been moving competition away from only competing for the price of the same offerings. The collected data from the connected value network has been helping industries to learn about customer usage patterns of their offering, which is enabling them to create better customer segments and improve the value proposition for each customer segment and eventually improve customer satisfaction. The improved customer satisfaction increases the buyers' cost of switching to a new supplier and mitigates or reduces the bargaining power of buyers (Porter & Heppelmann, 2014) (Cavalieri & Pezzotta, 2012, p. 279).

On the other hand, the deployment of I4.0 is also making customers closer to the value chain which makes them more knowledgeable about the value propositions of the suppliers and reduces their dependencies on consultation and support services. More knowledgeable customers will have more bargaining power which enables them to find alternate solutions and obtain better prices. Finally, extensive partnerships for I4.0 deployment can also make partners more knowledgeable about the value propositions and potential of appearing the same value offerings from the partners. The availability of more options will increase the bargaining power of buyers for switching to a new manufacturer and negotiations on features and pricing.

5.1.3 Rivalry among competitors

I4.0 has been changing the competitive environment for industries, and the use of the latest technologies has been changing the competitive landscape for suppliers. The competitive landscape has been increasing the role of foundational enablers of I4.0 such as connectivity and computational resources and third parties for enabling new servicing using data collected from the industries. It was found from the interviews that the rivalry has been increasing among the traditional competitors for enabling new features for creating differentiation in the offerings, providing new value-added services, after-sales services for the products, and making their manufacturing capable of handling very customized products.

On the other hand, new capabilities may also make companies compete for features and functions race with rivals and give away too much of the improved performance for free. This is a dynamic that escalates costs and erodes industry profitability (Porter & Heppelmann, 2014). Additionally, the increasing role of network partners in value creation could also change the role of manufacturing companies altogether and the new main competition between the offerings could be between the new capabilities' providers for example connectivity and computation technologies providers.

5.1.4 Threat of new entrants

I4.0 deployments have been creating networks of value creation for industries. The network value chains have been increasing barriers for new entrants to invest heavily to enable the creation of the network and working with partners. The integrated networks are complex due to the involvement of multiple partners, and the complexity of understanding the network value proposition will also deter new entrants to enter the market. Furthermore, I4.0 technologies have been useful for improving customer relationships. The improved customer relationship has been increasing barriers to competitors (Cavalieri & Pezzotta, 2012, p. 279) and thus reducing threats of new entrants.

On the other hand, there will be a threat of new entrants from one of the partners of the integrated value chain. The partner being part of the value network will have a good understanding of the network value proposition which will reduce the barrier to entry. The barrier of entry has been going down with the increasing need for complementing capabilities by the traditional players. The providers of complementing capabilities have been increasing their understanding of the value chain of industries and increasing reliance on industries for complementing capabilities could increase the threat of new entrants.

Furthermore, I4.0 has been enabling flexible manufacturing operations which could be used for producing customized value propositions, this has also decreased the barrier to entry for new entrants in the industry and opportunities for manufacturing companies to enter other industries. For example, the increased use of automation in vehicles has been a focus for both mobile machine manufacturers for industries and passenger car manufacturers. Although the mobile machine manufacturing industry is very different from car manufacturing and is highly customized based on customer requirements for their operations. The automation capabilities provided by car manufacturers could potentially make them enter mobile machine industries by providing automation capabilities for industrial mobile machines.

5.1.5 Threat of substitute

Many industries have been focusing on operational excellence with I4.0 deployment and still using traditional business models for their business. The reliance of industries on traditional models has been increasing threats of substitutes in the form of new business models replacing traditional models which could affect the industries' businesses. The new business models of providing Product-as-a-Service (PaaS) and Manufacturing as a Service (MaaS) could increase threats of substitutes for the industries. Industries must focus on business model innovations while implementing I4.0 technologies in their operations to reduce the threat of substitutes for their industries.

5.1.6 Bargaining power of suppliers

Industries have been observing the increasing power of partners providing enabler technologies, connectivity providers, computational resource providers, and third parties for enabling new value-added services. The use of these technologies has been increasing in the manufacturing industries. The increasing use of the technologies has been increasing the bargaining power of these suppliers and allowing them to capture a large share of the value. This could reduce the profitability of industries. Moreover, the supplier has opportunities to increase bargaining power with the consolidation of digital offerings needed by industries.

5.2 Impact of I4.0 on Business models of industries

I4.0 deployment has been changing the business model of industrial companies. Industries have been identifying the need for business model innovations that provides opportunities for upscaling businesses and gaining strategic positions (*Digital Business Models for Industrie 4.0*, n.d.). I4.0 deployment is changing the value creation, value propositions, and value capturing of industries which are resulting in innovative business models with the new capabilities. Table 9 summarizes the effect on the business model of industries with a Business model canvas for industrial solution providers. The interviews revealed that the main factors influencing the business models are value propositions, customer relationships, Key resources, and Key partnerships which are discussed in the following sections.

5.2.1 Value Proposition

The value propositions got the highest relative proportion of business model components in the interviews which has been influenced by the deployment of I4.0. This is understandable, the first consideration of deployment of industry 4.0 is solving industries' current problems and satisfying customer needs with the help of the latest technologies. Industries see opportunities for several new products and services in their portfolio with the deployment of I4.0 along with performance improvements, customization, and accessibility for new customer segments such as start-ups with innovative pricing models. One of the most discussed values propositions is new services enabled by collecting and analyzing the data from the operations(Cavalieri & Pezzotta, 2012; Frank et al., 2019; Guinard et al., 2010; Ibarra et al., 2018; Müller, 2019; Weking et al., 2020). Example of new services includes targeted preventive maintenance, real-time health check of the operation; condition-based monitoring (Müller, 2019). Secondly, optimization services such as closed-loop manufacturing were mentioned in the interview collected data is used for learning and reconfiguration of operations for improving operation performances. Lastly, the customization of products enabled by I4.0 technologies which are enabling of individualized production (Ibarra et al., 2018; Müller et al., 2018; Müller, 2019).

Conversely, it was also found that some customers are not willing to move to the new service-based model due to a lack of a clear value proposition. (Cavalieri & Pezzotta, 2012) pointed out the issue of under-designed and inefficient services as a problem of the adoption of the Product service system. The adoption of service-oriented business models by customers could be increased by using systematic methods for service design and delivery presented in (Goldstein et al., 2002) that could help clarify value propositions and how the value proposition is meeting customer needs.

5.2.2 Customer Relationship

The empirical research results highlighted, industries' relationships with customers have been improving with co-designing with customers and new methods for communications enabled by I4.0. The role of the customer during the design could be explained as I4.0 enabled production systems are capable of manufacturing products that are tailored to individual customers' requirements. The possibility of supporting customized requirements has increased the engagement between customers and industries. The industries are engaging with customers in the early phase of design for understanding their requirements and developing customized solutions. The increasing role of customers in designing is in line with finding in the literature by (Ibarra et al., 2018, p. 9)(Müller et al., 2018). Furthermore, customer relationships have been improving as a result of co-creation and obtaining very customized products and services that are meeting their demands. The improved collaborations with customers are the results of the increasing use of new methods and concepts of social media, online communities, open source, and open innovation (Kiel et al., 2016).

5.2.3 Revenue Stream

Interviewees mentioned different revenue models that have been used with the deployment of I4.0 in operations and their impact on business models. Reasons for different revenue models include helping customers to remove the barrier of initial heavy investment for the deployment of I4.0 technologies and the possibility of recurring revenues enable after I4.0 deployments. The revenue model of pay per result (Weking et al., 2020), pay per use (Ibarra et al., 2018; Müller, 2019), and as a service model is giving the possibility to small to medium size enterprises and even startups to start utilizing the technologies because the initial investment is not so significant.

5.2.4 Key Partners

I4.0 technologies have broadened the technological landscape used in industries. The landscape has produced a competence gap for the industries which is needed to effectively implement I4.0 in the operation. Industries are making strategic partnerships with other companies to reduce the gap. The partnerships are essential for network value creation enabled by I4.0. The industries have been focusing on the core operation and looking for partnerships for exploring new opportunities through partners.

Empirical research emphasizes partnerships with communication networks and computation providers, customers and third parties with AI and ML capabilities. Communication and computation network providers were identified as key partners for providing enabler technologies for the deployment of I4.0 and their role is also key for enabling mission and business critical applications of I4.0. Table 11 summarizes the influence of industry 4 on network services providers. Industries have become an additional key customer segment for network service providers. Secondly, collaboration with third parties for creating new value with collected data was mentioned. The finding of third parties is in line with data expertise as a key partnership found (Müller, 2019). Moreover, industries have been seeing customers as collaborative partners and co-designers. The concept of open source or open innovation processes has been used for integrating customers as partners (Kiel et al., 2016).

5.2.5 Key resources

The adoption and implementation of I4.0 require new key resources of modernized manufacturing equipment, a value creation network, and human resources. Modernized manufacturing equipment has been increasing production and operational efficiencies. The value creation networks are enabling flexible value propositions and accelerate time to market (Kiel et al., 2016). Furthermore, value creation networks have been enabling manufacturers to get better visibility of how end-users are using their offerings and adapt their value propositions accordingly. The new capabilities enabled by I4.0 deployments will benefit manufacturers to access the information which was traditionally kept by delivery chain vendors. Finally, human resources are needed to operate and develop the infrastructure with I.40 technologies, enabling new values with collected data and creating new value propositions will be key resources for the deployment of I4.0 technologies. (Müller, 2019) found key resources of new production equipment and a new workforce with IT and data expertise as key resources of I4.0-enabled business models.

Interviewees mentioned the challenges of the lack of human resources and emphasized universities and the Finnish government's role in meeting the demand of the workforce. One of the challenges for the deployment of I4.0 and competition between companies will be acquiring the right skills and resources. The workforce demand could be met by training the existing workforce, hiring new employees for new capabilities, and redesigning existing jobs to leverage complementary capabilities of people and machines (The Social Enterprise and Technology at Work | Deloitte Insights, 2020). Organizations should think about reskilling the employee not only for the employee to be relevant in the market but also to help the transformation of the organization and business.

The transformation of the workforce should be given similar importance as the usage of the technologies. Managers and policymakers should look beyond individuals to the entirety of the organization and ecosystem. They should evaluate the implementation of I4.0 technologies with multiple perspectives of sustainability, economic, environmental, social, and people for successful technology adoption and diffusion (Bai et al., 2020). Human resource managers have a very key role in the defining I4.0 implementation strategy of the company. The management must take the first step in defining the strategy and evaluating the need for I4.0 technologies and training of a workforce for their operation.

5.3 Challenges with the adoption of I4.0 technologies

Industries have been observing challenges with the adoption of I4.0 as well. Interviewees mentioned the challenges, lack of standards, cyber security, slow adoption of new business models, and the need for a new workforce.

Lack of standardization got the highest proportion of identified challenges in the interview. The result ties well with (Horvath & Szabo, 2019; Müller et al., 2018; Nagy et al., 2018) who identified as a barrier to the adoption of I4.0 technologies. The lack of standardization is creating the problem of interoperability among different vendors and slowing down the adoption of I4.0 technologies. One of the reasons for slow standardization is, industries have different requirements for I4.0 solutions. Additionally, the standardization efforts are done in industry-specific workgroups which are shown in Table 12.

Secondly, insufficient security and lack of human resources obtained the second highest proportion of 27% in identified challenges. Security of information is a key for integrated value networks which have been increasing the stakeholders of value networks. The cyber security threats for I4.0 deployments are pointed out by(Corallo et al., 2020; Ghobakhloo, 2018). One of the reasons for increasing cyber security threats is associated with the increased use of cloud technology which has been seeing an increasing trend of threats in recent years (*Network Infrastructure Report 2021 | Statista*, 2021) (*Data Center 2021 | Statista*, 2022). There is a need for further development of security mechanisms for meeting the demand for security by industries. The government-funded program of Digital Trust Finland (*Digital Trust Finland*, 2022) and other research in academia such as cyber security proposals for production monitoring and maintenance service use cases by (Flatt et al., 2016) could help to secure the information of I4.0 industries.

Industries are observing a lack of suitable workforce for the deployment of industry 4.0. Industries need to upgrade the existing workforce with training and redesign of existing jobs by leveraging complementary capabilities of people and machines to get maximum benefits. Furthermore, human resource managers have a very key role in the defining I4.0 implementation strategy of the company.

The management must take the first step in defining the strategy and evaluating the need for I4.0 technologies and training of a workforce for their operation. Furthermore, change resistance was another barrier identified by (Cavalieri & Pezzotta, 2012). I4.0 deployments have been changing the operation of industries significantly which has been affecting the existing workforce of the organization and the reason for change resistance. Moreover, concern over the ethical use of technologies is another reason for the change resistance. The new technologies will bring capabilities that could be used in ways that could create social issues. The main objective of using the technology should be enhancing the existing workforce, improving life, and serving humanity. Instead of unethical use of technologies that could adversely affect the employees by spying and monitoring of employees. (*Technology at Work | Deloitte Insights*, 2020).

Lastly, the slow adoption of new business models is in line with the findings of (Cavalieri & Pezzotta, 2012, p. 279) who identified the slow adoption as a barrier and provided the reason for slow adoption as a lack of trust between providers and customers, low level of maturity of the model, concern about increasing risks due to the adoption of new pricing policies and lack of expertise of suppliers in designing and delivering services.

5.4 Role of network services providers

Network and service providers have big opportunities for providing enabling technologies for the implementation of I4.0 and enabling value added service by analyzing collected data from the industries. The connectivity and computational technologies have been identified as essential enablers for I4.0 deployment. Table 11 summarizes the role of network service providers and understands their role with the business model canvas for the deployment of I4.0. The private wireless network and edge computing have a key role in meeting the requirements of industries for securing mission and business critical data. The demand for private wireless networks has been acknowledged by secondary sources who have predicted that private wireless could overtake public wireless networks in the future (*Network Infrastructure Report 2021 | Statista*, 2021) (*Private Wireless Market Report*, 2022) (Drahos et al., 2018).

However, the opportunities for growth in private wireless networks for network and service providers also carry an inherent risk of cannibalizing infrastructure management business with mobile operators. Mobile operators and network service providers could be competing for providing a private wireless network to industries. The use of unlicensed bands and CBRS has provided opportunities for expanding their market without the cooperation with mobile operators for the deployment of the network in some markets. However, the traditional cooperation of the network service provider will still be needed in territories where unlicensed bands are not available. Access to spectrum will be a key competitive force for the deployment of private wireless networks in some markets. It can affect whether, when, and where existing service providers and potential entrants will be able to expand capacity or deploy networks. (*Mobile Wireless Competition Report*, 2022)

5.5 Key research finding

Key research findings of the thesis projects are summarized in the following sections by answering the research questions with the key findings.

1. How are industries adopting Industry 4.0 (I4.0) in Finland?

Industry 4.0 has been enabling integrated value-creation networks and ecosystems for different market segments. The ecosystems have been changing the market forces and competitive environment of the companies working in them. The new environment has been providing new opportunities for companies for growing and capturing value and obtaining sustainable competitive advantages. The integrated value network has made industrial companies think about their strategic role in the integrated value chain and the selection of suitable partners for the creation of an ecosystem for their market segment.

The new market structure is changing the competition among industries. On one hand manufacturers, partners, suppliers, and customers are collaborating for the creation of an ecosystem. On the other hand, this collaboration could be a source of affecting competitive forces of bargaining power of buyers and suppliers, rivalry among competitors, and threats of the new entrant. I4.0 have been a key area for future business development for Finnish industries. I4.0 has been one of the growth areas for industries there are ongoing business initiatives for investing in developing I4.0 products and services and selling solutions to some industries.

a. How are the companies seeing an effect on business models with the deployment of I4.0?

Business model innovation has a key role to obtain economic benefits and competitive advantage by replacing used outdated traditional business models. Industries have been developing a new business model in five key areas of (1) Value proposition, (2) Customer relationships, (3) Key partnerships (4) Revenue streams, and (5) Key resources.

- The value propositions for industrial solution providers is focusing on increasing operational performance with close-loop manufacturing, enabling autonomous operations for different industries and customized value propositions. Additionally, industries have been developing services by collecting and analyzing data from machines. Some examples of the services in mobile machine industries are targeted preventive maintenance, health check of machines, and consultation services.

- I4.0 deployments have been playing a key role in improving customer relationships by providing opportunities for co-creation and individualized mass production based on customer needs. Moreover, improving customer relationships could increase barriers for new entrants in the markets.

- Industries have been offering innovative revenue models for tackling need of initial large investment need for the installation of I4.0 technologies and increasing the share of recurring revenues with value-added services. For example, value propositions have been offered with innovative pricing models of pay-per-results and profit sharing which are very effective for meeting customer requirements and are suitable for the adoption of I4.0 for all customers from start-ups to big enterprises.

- The partnerships have been increasing with other stakeholders for enabling network value creation. The industries have been focusing on core operations and looking for partnerships with technologies providers, connectivity providers, computational resources providers, and third parties for enabling new value-added services

- The adoption and implementation of I4.0 require key resources I4.0 enabled manufacturing facilities, integrated value network, key partnerships, and human resources.

b. What are the challenges in adopting I4.0?

Industries have been identifying areas of future development for improved security solutions, standardization, and human resource capable of working with I4.0 technologies. The standardization is facing hindrances due to the non-availability of a global platform for discussing the standardization of I4.0 solutions and the high customization need from customers. The lack of human resources was identified as another challenge for the deployment of I4.0 and companies could compete for acquiring the right skills and resources. Additionally, companies have identified the need for transformation of the existing workforce with training, the importance of I4.0 implementation strategy from higher management, and redesigning of jobs for example combining IT and OT departments and combing competencies of technologies and human effectively

c. How could the Finnish government help industries with the deployment and adoption of I4.0 technologies?

The Finnish government could play a key role in the adoption of I4.0 by working with other governments to the creation of EU-level standardization and policies for I4.0. Additionally, the government should work with the universities to the creation of workforce of I4.0 to meet the demands for I4.0 deployments in Finland

2. What role could communication and network service providers play in implementing I4.0?

The network and computation resources were identified as key enablers for I4.0. Wireless connectivity technologies demand has been growing for digitalization of industries and enabling different uses cases of autonomous operation, self-organizing manufacturing, etc. The demand for the private wireless network and edge computation was also mentioned for mission and business critical applications which require low latency communication and computation and high security of the mission and business critical data. However, the opportunities for growth in private wireless networks for network and service providers also carry an inherent risk of cannibalizing infrastructure management business with mobile operators. Mobile operators and network service providers could be competing for providing private wireless networks to industries.

5.6 Critical evaluation of the research design and implementation

The author used eight key markers of quality in qualitative research a model presented by (Tracy, 2010) for critical evaluation of the research design and implementation of the thesis project which is described in Table 13.

TABLE 13. Critical evaluation of the research design and implementation

Criterion	Reflection
Worthy topic	The thesis project investigated the impact of I4.0 deployment on industries' business. The I4.0 deployment has been ongoing in Finnish industries. The impact of the deployment on business is a key topic for industries. The result could provide a useful perspective of different industries on the business impact of the I4.0 deployments and business model adoption.
Rich Rigor	The topic was approached from different perspectives literature was read and analyzed to understand the phenomenon, data was collected from the industries working on the topic, and the use of systematic approach combing quantitative tools and qualitative research methods of thematic analysis to ensure adequate rigor for the project.

Sincerity	The author has been sincerely using the available literature, public sources, and data collected from the field and was open to the improvement of the writing based on feedback
Credibility	The author has tried to use reliable references available on the topic by combing research journal conference papers which are cited by many reliable authors in the field, analysis of consumer and market from reliable companies, and primary data collected from the key players of the market.
Resonance	This work resonates with both researchers and practitioners in the field working on the topic of the research.
Significant contribution	The research contributes to the field of industry 4.0 business models and understanding of industry 4.0 market forces. It also contributes to explaining the role of network and service providers in providing key enablers of connectivity and computation networks.
Ethical	The research followed strict ethical guidelines. The research was designed on a level that confidentiality or property rights are not violated in the collection of primary data with the companies working in industries.
Meaningful coherence	The author gave his best effort to provide meaningful coherence through many iterations of writing the content of the thesis. Each iteration followed the reading, writing to improve coherence, and working on the feedback from the supervisor to work on the next iteration of the writing.

The author reflects based on the criteria above that the thesis attempts to summarize the key elements that fulfill the requirements of the master thesis.

5.7 Contribution to previous research

The objective of the thesis project was to : (1) investigate I4.0 deployment's effect on the change of industries in Finland, (2) identify challenges in the adoption of a new business model, and (3) find gaps and opportunities that come with the deployment of I4.0. The author believes that research results are of interest not only for designing a business model for industry 4.0 solution providers but also for network and services providers which are key enablers for industry 4.0 deployments. The research identified the business model of industries for the deployment of I4.0 from empirical research results in Table 9 by using the business model canvas for solution providers of Industry 4.0. Furthermore, the research identified business models for connectivity and computation services providers for the deployment of I4.0 technologies in Table 11. Moreover, the research also analyzed industry 4.0 with Porter's five forces model which the author considers as a gap and could contribute to the author who wants to use the model for analyzing industry 4.0 with the framework. Finally, the empirical research result also identifies challenges to the adoption of I4.0 of lack of standardization, the need for new human resources and improved security, and the role of higher management, governments, and I4.0 solution providers in addressing these challenges.

5.8 Practical Conclusions

The author acknowledged several limitations concerning methodology and findings. First, the qualitative nature of the research is not suitable for the generalization of the findings. Second, the single informant bias can be a concern as the author interviewed only one senior Research manager or head of product management from one company. The author was able to use the business model framework for combining data from the interviews and using statistical tools for analyzing the data. However, the quantification of results could be improved by conducting surveys with more participants using the findings of the research results. Finally, the research was focusing on Finnish industries and companies that have offices in Finland, which is another limitation of the findings, it could be useful for analyzing and comparing the research on other countries on the topic.

5.9 Future avenues for research

The thesis provides four perspectives (1) competitive market forces and the creation of ecosystems and integrated value networks with the deployment of industry 4.0 (2) I4.0 impact on industries' business models and (3) the role of network and service providers in the deployment and (4) challenges of deployment of industry 4.0. All four areas are avenues for further research to quantify the research results using quantitative research methods for example use of surveys for data collection and the use of quantitative research tools. Furthermore, it would be interesting to validate the defined business models canvas for industrial solution providers and network and services providers from the companies. The refinement of results by conducting more interviews with other companies in Finland is another avenue for research. Furthermore, it would be interesting to conduct research outside Finland as well to understand the global impact of I4.0 deployments on businesses.

Moreover, another future avenue for research could be focused on focusing on industry-specific business models for example which are discussed in the work group of trade unions and contribute to investigating how business models are changing for a vertical industry for example farming industry, port industry, mining industry, and factory automation solution, etc. Moreover, the research also identified opportunities for detailed case studies of business models of successful deployments of I4.0 in Finnish industries. Two case studies were identified of the autonomous operation of Agnico Eagle Finland at the Kittilä gold mine in northern Finland (Agnico's Kittilä Autonomous Haul-age, 2021) and food and beverage industries "Nestlé's plant in Juuka, Finland" (*Nestlé Juuka Digitalization* | *Siemens Global*, n.d.). The research could provide further perspective on what business models have been used for the deployment of these operations and what new values have been enabled by them and their impacts on the industries' business.

REFERENCES

5G Alliance for Connected Industries and Automation. (n.d.). Retrieved 27 November 2022, from https://5g-acia.org/

AEF - AEF Online. (2022). https://www.aef-online.org/about-us/about-the-aef.html#/About

Agee, J. (2009). Developing qualitative research questions: a reflective process [Article]. *International Journal of Qualitative Studies in Education*, *22*(4), 431–447. https://doi.org/10.1080/09518390902736512

Agnico's Kittilä autonomous haulage. (2021, July 8). https://im-mining.com/2021/07/08/agnicos-kittila-clocks-full-year-autonomous-haulage-sandvik/

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective [Article]. *International Journal of Production Economics*, *229*, 107776. https://doi.org/10.1016/j.ijpe.2020.107776

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology [Article]. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Cavalieri, S., & Pezzotta, G. (2012). Product–Service Systems Engineering: State of the art and research challenges [Article]. *Computers in Industry*, *63*(4), 278–288. https://doi.org/10.1016/j.compind.2012.02.006

Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies [Article]. *Industrial and Corporate Change*, *11*(3), 529–555. https://doi.org/10.1093/icc/11.3.529

Corallo, A., Lazoi, M., & Lezzi, M. (2020). Cybersecurity in the context of industry 4.0: A structured classification of critical assets and business impacts [Article]. *Computers in Industry*, *114*, 103165. https://doi.org/10.1016/j.compind.2019.103165

Data Center 2021 | Statista. (2022). Statista. https://www-statista-com.libproxy.tuni.fi/study/107178/data-center/

Digital business models for Industrie 4.0. (n.d.). Retrieved 26 November 2022, from https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/Digital-business-models.html

Digital Trust Finland. (2022). https://www.businessfinland.fi/en/for-finnish-customers/services/programs/digital-trust-finland

Drahos, P., Kucera, E., Haffner, O., & Klimo, I. (2018). Trends in industrial communication and OPC UA [Proceeding]. *Proceedings of the 29th International Conference on Cybernetics and Informatics, K and I 2018*, *2018-*, 1–5. https://doi.org/10.1109/CYBERI.2018.8337560

Edge Computing | Statista. (2022). Statista. https://www-statista-com.libproxy.tuni.fi/study/82641/edge-computing/

Flatt, H., Schriegel, S., Jasperneite, J., Trsek, H., & Adamczyk, H. (2016). Analysis of the Cyber-Security of industry 4.0 technologies based on RAMI 4.0 and identification of requirements [Proceeding]. *2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA)*, *2016-*, 1–4. https://doi.org/10.1109/ETFA.2016.7733634

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective [Article]. *Technological Forecasting & Social Change*, *141*, 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0 [Article]. *Journal of Manufacturing Technology Management*, *29*(6), 910–936. https://doi.org/10.1108/JMTM-02-2018-0057

Goldstein, S. M., Johnston, R., Duffy, J., & Rao, J. (2002). The service concept: the missing link in service design research? [Article]. *Journal of Operations Management*, *20*(2), 121–134. https://doi.org/10.1016/S0272-6963(01)00090-0

Guinard, D., Trifa, V., Karnouskos, S., Spiess, P., & Savio, D. (2010). Interacting with the SOA-Based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services [Article]. *IEEE Transactions on Services Computing*, *3*(3), 223–235. https://doi.org/10.1109/TSC.2010.3

Horvath, D., & Szabo, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? [Article]. *Technological Forecasting & Social Change*, *146*, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

Ibarra, D., Ganzarain, J., & Igartua, J. I. (2018). Business model innovation through Industry 4.0: A review [Article]. *Procedia Manufacturing*, *22*, 4–10. https://doi.org/10.1016/j.promfg.2018.03.002

Industry 4.0 | Statista. (2022). Statista. https://www-statista-com.lib-proxy.tuni.fi/study/66974/in-depth-report-industry-40/

Industry 4.0 hotspot. (2022). https://www.businessfinland.fi/en/do-business-with-finland/invest-in-finland/business-opportunities/ict-digitalization/tampere-hotspot-of-industry-4-0

iTerminals 4.0. (n.d.). Retrieved 10 November 2022, from https://iterminalspro-ject.eu/

Kalmar explores digital transformation of ports. (2021). https://www.kalmar-global.com/news--insights/articles/2021/20211028_wireless-connectivity/

Kiel, D., Arnold, C., Collisi, M., & Voigt, K.-I. (2016). The impact of the industrial internet of things on established business models [Proceeding]. *IAMOT 2016 - 25th International Association for Management of Technology Conference, Proceedings: Technology - Future Thinking*, 673–695.

Korpela, K., Mikkonen, K., Hallikas, J., & Pynnonen, M. (2016). Digital Business Ecosystem Transformation -- Towards Cloud Integration [Proceeding]. *2016 49th Hawaii International Conference on System Sciences (HICSS)*, *2016-*, 3959–3968. https://doi.org/10.1109/HICSS.2016.491

Lee, J., Bagheri, B., & Kao, H.-A. (2015). A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems [Article]. *Manufacturing Letters*, *3*, 18–23. https://doi.org/10.1016/j.mfglet.2014.12.001

Maguire, M., & Delahunt, B. (2017). Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars. *. In *ojs.aishe.org* (Issue 3). http://ojs.aishe.org/index.php/aishe-j/article/view/335

Mobile Wireless Competition Report. (2022). https://www.fcc.gov/20th-mobile-wireless-competition-report-quick-facts

Morris, M., Schindehutte, M., & Allen, J. (2005). The entrepreneur's business model: toward a unified perspective [Article]. *Journal of Business Research*, *58*(6), 726–735. https://doi.org/10.1016/j.jbusres.2003.11.001

MQTT - The Standard for IoT Messaging. (n.d.). Retrieved 27 November 2022, from https://mqtt.org/

Müller, J. M. (2019). Business model innovation in small- and medium-sized enterprises: Strategies for industry 4.0 providers and users. *Journal of Manufacturing Technology Management*, *30*(8), 1127–1142. https://doi.org/10.1108/JMTM-01-2018-0008

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132*, 2–17. https://doi.org/10.1016/j.techfore.2017.12.019

Nagy, J., Oláh, J., Erdei, E., Máté, D., & Popp, J. (2018). The role and impact of industry 4.0 and the internet of things on the business strategy of the value chain-the case of hungary [Article]. *Sustainability (Basel, Switzerland)*, *10*(10), 3491. https://doi.org/10.3390/su10103491

Nestlé Juuka Digitalization | Siemens Global. (n.d.). Retrieved 16 November 2022, from https://new.siemens.com/global/en/markets/food-beverage/references/nestle.html

Network Infrastructure Report 2021 | Statista. (2021). Statista. https://www-statista-com.libproxy.tuni.fi/study/84963/network-infrastructure-report/

Nokia 5G - Industry 4.0 adoption. (2022). https://www.nokia.com/about-us/news/releases/2021/11/25/nokia-5g-standalone-private-wireless-network-to-support-industry-40-adoption-at-agnico-eagle-finland-mining-operations/

Osterwalder, Alexander. (2010). *Business model generation a handbook for visionaries, game changers, and challengers* (Yves. Pigneur & T. Clark, Eds.) [Book]. John Wiley & Sons.

Oztemel, E., & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies [Article]. *Journal of Intelligent Manufacturing*, *31*(1), 127–182. https://doi.org/10.1007/s10845-018-1433-8

Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept [Article]. *MANUFACTURING ENGINEERING SOCIETY INTERNATIONAL CONFERENCE 2017 (MESIC 2017)*, *13*, 1206–1214. https://doi.org/10.1016/j.promfg.2017.09.032

Porter, M. E. (2008). The five competitive forces that shape strategy [Article]. *Harvard Business Review*, *86*(1), 78–137.

Porter, M. E., & Heppelmann, J. E. (2014). How Smart, Connected Products Are Transforming Competition [Article]. *Harvard Business Review*, *92*(11), 64.

Private Wireless Market Report. (2022). https://mindcommerce.com/reports/private-wireless-market/

Rao, S. K., & Prasad, R. (2018). Impact of 5G Technologies on Industry 4.0. *Wireless Personal Communications*, *100*(1), 145–159. https://doi.org/10.1007/S11277-018-5615-7

Reboot Iot Factory. (2022). https://rebootiotfactory.fi/

Renewal in the manufacturing industry. (2020). https://www.businessfinland.fi/en/whats-new/blogs/2020/the-pressures-for-renewal-in-the-manufacturing-industry-are-intensifying

Sandvik Group. (2020). https://www.home.sandvik/en/stories/articles/2020/11/stefan-widing-on-industry-4.0/

Schilling, M. A. (2013). *Strategic management of technological innovation* (4th ed.) [Book]. McGraw-Hill.

Sustainable Industry X. (2022). https://www.six.fi/

Technology at work | Deloitte Insights. (2020). Deloitte. https://www2.deloitte.com/us/en/insights/focus/human-capital-trends/2020/technology-and-the-social-enterprise.html

Tracy, S. J. (2010). Qualitative Quality: Eight "Big-Tent" Criteria for Excellent Qualitative Research [Article]. *Qualitative Inquiry*, *16*(10), 837–851. https://doi.org/10.1177/1077800410383121

Unified Architecture - OPC Foundation. (n.d.). Retrieved 27 November 2022, from https://opcfoundation.org/about/opc-technologies/opc-ua/

Valmet. (2022). https://www.valmet.com/about-us/

Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination [Article]. *Computer Networks (Amsterdam, Netherlands : 1999)*, *101*, 158–168. https://doi.org/10.1016/j.comnet.2015.12.017

Weking, J., Stöcker, M., Kowalkiewicz, M., Böhm, M., & Krcmar, H. (2020). Leveraging industry 4.0 – A business model pattern framework [Article]. *International Journal of Production Economics*, *225*, 107588. https://doi.org/10.1016/j.ijpe.2019.107588

Xu, L. da, Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends [Article]. *International Journal of Production Research*, *56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research [Article]. *Journal of Management*, *37*(4), 1019–1042. https://doi.org/10.1177/0149206311406265

APPENDICES

Appendix 1. Interview Questions

In the interview request Industry 4.0 (I4.0) is defined as use of digitalization, automation, Artificial Intelligence (AI), robots, scalable networks, and cloud computation by the industries. And the Business model is defined as a heuristic logic that connects technical potential with the realization of economic value. Following were the questions sent for the interview request invite.

In the interview, the author defined the business model as defined by "the heuristic logic that connects technical potential with the realization of economic value" (Chesbrough & Rosenbloom, 2002b, p. 529). Questions were asked about the technical potential of Industry 4.0 with the realization of economic benefit. The question was focusing on Business model innovation for I4.0.

The business model innovation is innovating key components of the business to gain more operating profit or future growth. Business model innovation results from one of four objectives: (1) Satisfy existing but unanswered market needs, (2) Bring new technologies, products, or services to market, (3) Improve disrupt or transform the existing market with a better business model and (4) Create entirely new market. (Osterwalder, 2010)

Interview Questions

1. How do you describe your organization's business?
2. In your opinion, what is the role of I4.0 in current industrial business activities?
3. What initiatives are being undertaken in your own organization to fully or partially implement I4.0 in its operations? Please give some examples in your answer.
4. In your opinion, what opportunities or threats would arise in terms of offering new products or services, should an organization implement I4.0?
5. In your opinion, how does the implementation of I4.0 influence an organization's current business model?

6. Would you share your own thoughts in terms of how the Finnish government could drive industries towards I4.0 in Finland?

Additional Questions

1. How do you see the role of low latency communication networks (e.g., 5G) and computation networks (e.g., cloud and edge computing) for I4.0 implementation?
2. How do see the maturity of existing standards for the implementation of I4.0?
3. In your opinion, how does the implementation of I4.0 influence an organization's current business model (e.g., in terms of value creation, value delivery, and value capturing)?

Appendix 2. Interview dates and roles

	Dates	**Title**	**Organization**	**Industry**
1.	27-06-2022	Research manager	Valmet Automation	Automation and services for the pulp, energy, marine, and process industries, Factory automation
2.	29-06-2022	Senior Manager, Research and Advance Engineering, Volume tractors	AGCO Corporation	Farm management, Precision farming, and Smart agriculture Manufacturing of agriculture equipment and autonomous robots and crane logistics
3.	01-07-2022	Director, Automation Research	Cargotec	Container handling at ports, Heavy machinery, Mobile machines, logistic
4.	15-06-2022	System Manager	Sandvik	Mining in an ever-changing environment, the Mobile machine industry
5.	14-10-2022	Head of R&D	Tietoevry	System integrator, software development competence, competencies in AI and machine learning
6.	01-11-2022	Director, Business Development	Digita Oy	System integrator, deployment of communication networks in industries
7.	16-11-2022	Director of Digital Enterprise	Siemens Osakeyhtiö	Digital industries, industrial manufacturing, a Solution provider of I4.0
8.	No interview	Business Finland	Government-organizations provide	Business Finland

			Govern-ment funds for projects	
9.	No interview	VTT	I4.0 R&D	VTT