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Challenges in implementing Industry 4.0 technologies in manufacturing companies

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Abstract

Industry 4.0 originates from the German wording "Industrie 4.0" and it was introduced publicly for the first time at the Hannover Fair 2011. The German government produced a report of Germany's future actions regarding Industry 4.0 and after that, the research and buzz around the fourth Industrial revolution has been substantial. Many areas of the subject remain merely unresearched. This research will cover a service provider's perspective on the different challenges of implementing Industry 4.0 technologies.

The Industry 4.0 technologies are divided into base technologies and front-end technologies as in the framework by Frank *et al.* (2019). The base technologies are: (1) Internet of Things, (2) Cloud, (3) Big Data and (4) Analytics. The base technologies enable the concept of Industry 4.0 and the front-end technologies. These technologies can be used for different kinds of optimization, predictive maintenance etc. The implementation of these technologies includes various challenges, which are in this research, categorized in the following way:

- Managerial
- Business-related
- Technological

The primary data for this thesis is interviews with case company X. X is a Finnish startup specializing in end-to-end IoT-systems for the manufacturing industry. They have experience from different kinds of projects such as hydro plants and heavy industry machinery. I interviewed two members of X's board which are both experienced in their own fields of specialization. New aspects to the existing research will be achieved with a semi-structured interview.

Case company X's successful sales process usually starts from preliminary discussions and leads to a Proof of Concept (PoC). A proof of concept is the best and most common way for the implementation of their solutions, but that is usually where the problems occur in the above-mentioned categories. Key challenges of implementation of Industry 4.0 technologies include communication, lack of a clear business case and security issues. New innovative Industry 4.0 solutions mix the digital and physical worlds and enable new business- and revenue models.

The implementation process of Industry 4.0 solutions isn't yet comprehensively researched and there are many interesting research topics for the future in all of the three categories named in this research. In addition to the named challenges, politics and legislation effect the future of Industry 4.0. Global challenges such as sustainability and labour supply can also be more thoroughly handled with the Industry 4.0 framework in the future.

Keywords Industry 4.0, challenges , IoT, Big data, smart manufacturing, implementation

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1 Introduction

The term Industry 4.0 originates from Germany, and the German wording “Industrie 4.0” was used for the first time publicly in 2011 at the Hannover Fair. Industrie 4.0 is part of the German government's High-Tech Strategy 2020 action plan. It comprises various automation technologies such as IoT (Internet of Things), Big data, cloud computing, CPS (cyber-physical systems) and blockchain. With the technologies above, industrial companies work among things like smart manufacturing, real-time capability and interoperability to increase their efficiency and to even create entirely new business models. Although this trend has been around for years, industrial companies around the world are facing many challenges in implementing these new technologies. Through this paradigm shift in the industrial sector, companies will eventually have to adapt to these technologies in order to keep up with the competition.

Such an industrial change has various problems, such as financial capability, data security, IT maturity, and knowledge competencies. At the moment, world-class manufacturers are most likely to put Industry 4.0 technologies successfully to operation (Ghobakhloo, 2018). Industry 4.0 is now no longer only a hype and big industrial companies are in the process of developing and applying their software and hardware solutions. A “digital twin” of a factory can be created with Cyber-physical systems, which merge the virtual and physical worlds to implement agile and efficient production for example. This level of Industry 4.0 is still just a theoretical concept.

Digital transformation is a complex task for companies, and it requires a lot of resources, a strategy, etc. Change management has been researched for many years, but there isn’t a unified strategy to manage such complex projects. The implementation of Industry 4.0 technologies also depends on the groundwork done in the company’s ICT architecture. According to Zimmermann *et al.* (2015), “excellence in IT is both a driver and a key enabler of the digital transformation.” An Industry 4.0 transition team helps the whole organization to execute the planned strategy regarding Industry 4.0 (Müller, Kiel and Voigt, 2018). Schneider, 2018, has created a theoretical framework to asses the managerial challenges of implementing Industry 4.0 solutions.

The case company X in my research is an SME (small and medium-sized enterprise) from Finland. They offer complex end-to-end IoT-systems for industrial companies. These solutions are within the theoretical framework of Industry 4.0 technologies presented in

Chapter 2. The case company's experiences will be analyzed together with the existing literature and research to find common ground and possible patterns between research and practice in the implementation of Industry 4.0 technologies. For this research, two partners of case company X were interviewed to gain a new perspective on the implementation process of Industry 4.0 technologies. Both of the partners are experienced in their own industries, which include ICT, technology and banking. X's customers are usually big industrial companies from Finland and Germany. Interviewing a smaller company provides this study with an exceptional view of the whole process from sales to a working solution.

In recent years, Industry 4.0 has emerged as a promising technology framework for enhancing manufacturing processes. (Xu et al., 2018). The number of IoT-devices in the world is growing at a huge rate and there is a growing demand for research regarding Industry 4.0 (Xu et al., 2018). This is why I decided to choose an innovative case company from the technology sector and to conduct interviews with industry experts from the case company X. Their organization is hierarchically low, and both of the interviewees have an exceptional understanding of their previous projects and day-to-day operations. The technological challenges of implementing Industry 4.0 technologies are only slightly discussed due to the complexity of the technologies.

Bischoff; *et al.*, (2015) note that company-specific efforts in developing Industry 4.0 solutions are generally assumed to result in isolated solutions, which fail to leverage the whole potential of the concept of Industry 4.0. This implicates, that smaller technology-providers can be of high importance to large industrial companies, and together companies of different sizes can find success through jointly developed services and collaborative business models (Geissbauer *et al.*, 2014; Kagermann *et al.*, 2013). Case company X is a great fit to analyze this occurrence within the manufacturing industry due to its size and diverse experience from Finland and Germany.

1.1 Research questions and scope of research

The main research question of this research paper is “What are the biggest challenges in implementing Industry 4.0 technologies in industrial companies?”. The goals of this study are to define the different challenges in implementing Industry 4.0 in industrial companies. These challenges are divided into managerial-, business- and technological challenges. Other research questions include “How can the process of implementing new technologies be streamlined” and “What are the stages of successful implementation of Industry 4.0 technologies”.

Much of the research and terminology around Industry 4.0 is still quite fuzzy, and there isn’t a universal definition among both researchers and practitioners (Hofmann and Rüsch, 2017). What researchers and practitioners agree on is that Cyber-physical systems are the technological driver of Industry 4.0 (Schneider, 2018). This research is not about achieving Industry 4.0 level of technology in manufacturing in all of the processes in a company. It is to observe the process of implementing some of the technologies within the Industry 4.0 framework. The nuances of IoT and Industry 4.0 technologies will be presented later in the theoretical background.

1.2 Structure of the research

The thesis will begin with an introduction of the topic and proceed with the research question and scope of the study. After this chapter, the thesis will cover the theoretical background of Industry 4.0 technologies, change management in a digital context and the commercial side of the applications. Industry 4.0 technologies are divided into base- and front-end technologies according to a theoretical framework by Frank *et al.*, (2019). The theoretical background of the thesis will preface the methodologies of my research.

The methodologies of my research include an interview with executives from case company X and examining significant research regarding the research questions. The third chapter starts with presenting the case company X. In chapter 3.2, the qualitative research methods of this research and its data collection methods are presented. This chapter will also include references to previous literature about using qualitative interviews as a data collection method in research.

After the methodology chapter, I will present my findings from the interview in Chapter 4. This chapter begins with a description of the case company's sales process. After that, the answers of the case company's interviewed persons are presented. The challenges that company X has faced while implementing their solutions can be divided into managerial-, business- and technical challenges. The interview answers will be analyzed together with previous research findings across the whole chapter. In Chapter 4.2, I will focus on the technological-, industry-wide problems and a general view of implementing Industry 4.0 technologies.

Chapter 5 includes discussion and implications which discuss the relevance of the research. It also considers the limitations of the research and future research possibilities. Chapter five will be divided into two subchapters, which are implications to research and practice and limitations to future research. In this chapter, the key findings of my research will be concluded and discussed.

2 Theoretical background

With industry 4.0, companies will achieve more flexibility simultaneously with the highest quality standards in planning as well as operating the factories. The concept of Industry 4.0 will lead to more dynamic, real-time optimized and in some cases mass-personalized production, which is optimized based on criteria such as cost efficiency, availability and resource allocation (Kagermann et al., 2013). Industry 4.0 is a very current topic, and there has been a lot of research around the subject recently, even though there isn't an explicit agreement about the term Industry 4.0 among researchers and practitioners (Hofmann and Rüsch, 2017). Vital for this thesis is also the previous research in change management in organizations and especially in cases of digital transformation in industrial companies. The technicalities of Industry 4.0 technologies will only be opened to the extent, which is necessary to understand the commercial aspect of implementing these technologies. This chapter will be finalized by shortly explaining the projected challenges of Industry 4.0, and it's technologies and commercial details.

2.1 Industry 4.0 technologies

As introduced in Chapter 1, the term Industry 4.0 originated from the German governments' strategic action plan for the year 2020. The term represents the current trends of automation technologies in the manufacturing industry and researchers have named many key technologies such as Cyber-physical systems (CPS), Internet of Things (IoT), cloud computing and big data analytics. (Hermann, Pentek and Otto, 2016; Jasperneite, 2012; Kagermann *et al.*, 2013; Lasi *et al.*, 2014;). Researchers and industry experts acknowledge CPS as the technological driver of Industry 4.0. This research is going to focus on the Industry 4.0 technologies that the case company X is mostly familiar with. These technologies are IoT, big data analytics, edge- and cloud computing. Apart from technologies, enabling these technologies rely on concepts such as information integration, automation and interoperability between systems.

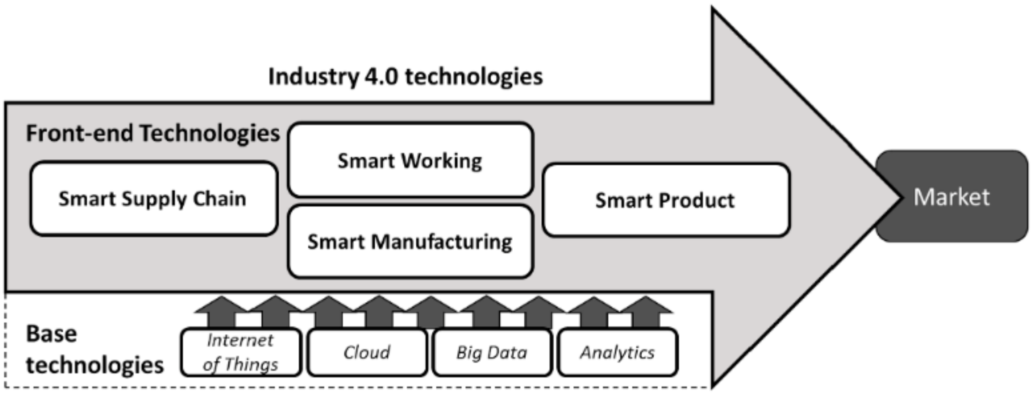

Figure. 1. Theoretical framework of Industry 4.0 technologies. (Frank, Dalenogare, & Ayala, 2019, Fig 1. page 16)

In this research, I have decided to use the framework in Figure 1. to help understand the general view of Industry 4,0 technologies. The combination of the base technologies presented above in Figure 1. (Frank et al. 2019) is needed to implement the front-end technologies. Frank et al., 2019 research suggests, that the stronger the base technologies of a company are, the more advanced the company will be in the front-end technologies such as smart manufacturing.

2.1.1 Base technologies

IoT itself embodies various technologies, and the definitions of IoT and Industry 4.0 technologies overlap in some research. The basic concept of IoT is a global network of machines and devices that can interact with each other (Lee & Lee, 2015). Both physical products and services are needed to implement IoT applications. IoT in Industrial companies can further be divided into Industrial Internet of Things (IIoT). It's projected that in 2020, there will be over 20 million connected IoT units in the world (Gartner, 2017). Around 8 million of these devices will be in use by businesses around the world.

The base technologies combined with artificial intelligence and other technologies within the Industry 4.0 framework, enable a new generation of manufacturing systems that are able to combine the virtual and physical worlds with real-time data (Xu, Xu, and Li, 2018). The sensors used in IoT solution vary greatly from microphones to more standardized radio frequency identification (RFID) tags. In 2015 Lee & Lee identified three IoT categories for enterprise applications: (1) monitoring and control, (2) big data and analytics, and (3) information sharing and collaboration. All of the three categories named above are essential for the implementation of IoT solutions (Lee and Lee, 2015).

Cloud computing is a term to describe the delivery of computational services over the internet. Cloud services enable shared access to multiple connected devices that can communicate with each other without being in the same physical location. With cloud computing, the implemented IoT-solutions are easily scalable and can be integrated with different systems. Cloud computing is necessary for all of the three IoT categories for enterprise applications by Lee & Lee, 2015. Case company X perceives edge computing as one of its core technologies in addition to cloud computing. The network infrastructure and the computational capacity can limit the implementation of solutions with real-time data etc. To tackle this problem, the data is processed near the sensor before entering the cloud. This technology is called edge-computing.

Big data describes the vast amounts of data gathered from different systems or sensors for example. The data alone is not useful, but through big data analytics, it is possible to build a "digital twin" about a factory or a process. The volumes of data are enormous and so is the variety of it. A digital twin is a cyber-physical system, which combines the virtual and physical worlds. Creating a digital twin of a factory currently remains as more of a dream and such Industry 4.0 solutions might be implemented in the future.

2.1.2 Front-end technologies

The base technologies enable the whole concept of Industry 4.0. Smart manufacturing and smart products describe the transformation due to new technologies in manufacturing activities and the ways that new products are offered. Smart supply chain and smart working, on the other hand, consider the whole supply chain and the new way of organizing work (Frank et al. 2019). Figure 1. describes this front-end layer as essential to a complete solution that can be offered to the market.

Smart manufacturing is the core of the front-end technologies since it is also the core business for a manufacturing company. The role of smart working and smart supply chain is enhancing efficiency in other operational activities than manufacturing. The concept of a smart factory isn't mentioned in Frank et al. 2019 research and it is desirable to know that concepts such as IoT, CPS, and IoS (Internet of services) are very close to each other (Hofmann and Rüsch, 2017). By adapting the theoretical framework for

Industry 4.0 technologies (Figure 1.), a smart factory can be seen as a combination of all the front-end technologies.

2.2 Implementation and management of new technologies

Change management has been researched for a lot longer than the term Industry 4.0 has existed. Many of the principles of management and strategy have remained the same, but the globally evolving economy with its technologies poses a new set of challenges for industrial companies.

The IT of a company is a driver and a key enabler of digital transformation. The diversity of new IoT technologies and products extend the previous efforts in enterprise architecture as companies try to create business value and manage these systems and concepts (Zimmermann *et al.*, 2015). The current research does not have an understanding of Enterprise Architecture (EA) for the Internet of Things. Digitalization has been a topic in organizational research since the 1950s. Most organizations have, for long, had to include digital transformation as one of the core strategies to keep up with the competition (Heavin and Power, 2018). Nowadays in an industrial company, that would mean naming an Industry 4.0 transition team to help the organization in executing the chosen strategy (Müller *et. al.*, 2018).

Schneider (2018) recognized six interrelated clusters in his literature review of managerial challenges of Industry 4.0. The research focused on the managerial aspect because of the technology-driven existing research, a possibility for a higher level of analysis on the company level, and to provide a more practical and normative framework around managerial challenges of Industry 4.0. The recognized clusters represent manageable issues, which company managers can directly address.

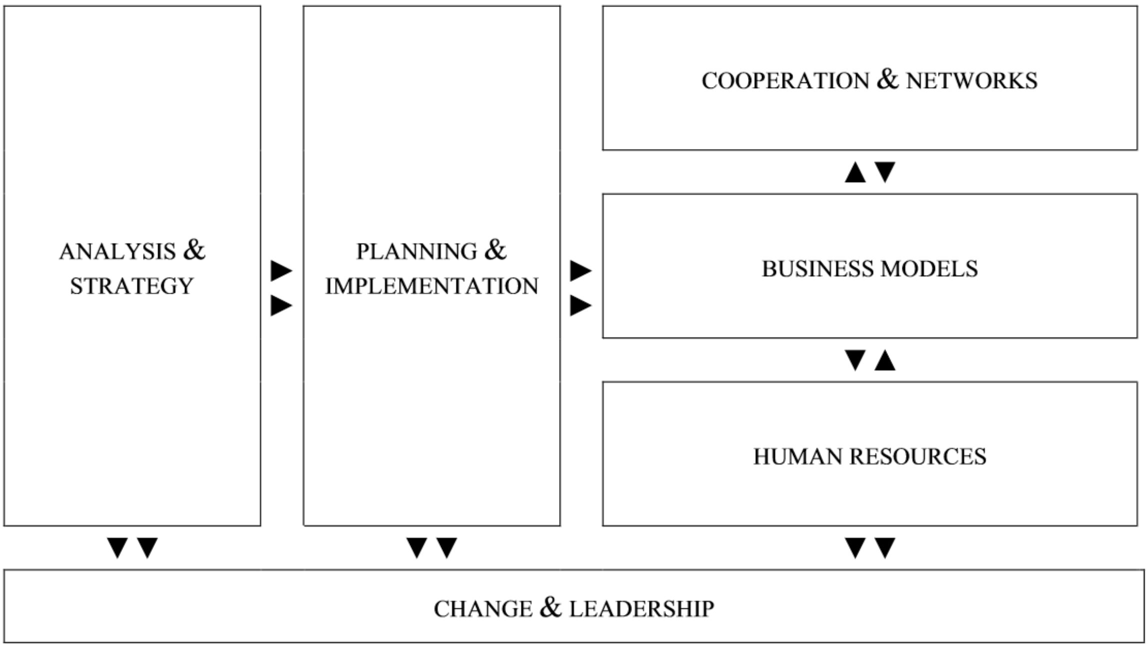

Figure 2. Six interrelated clusters of managerial challenges of Industry 4.0 (Schneider, 2018, Fig. 3, page 816)

As noted by Zimmermann *et. al.* (2015), “excellence in IT is both a driver and a key enabler of digital transformation.” This citation is in line with Schneider’s research that suggests that assessing the maturity and readiness of the company is a good starting point for the strategy of implementing Industry 4.0 technologies. Early adopters of the technologies, even in a small way, seem to profit in ways such as standard-setting and networking effects. After deciding on the strategic path regarding Industry 4.0, managers still usually struggle in finding tangible use cases for their companies (Schneider, 2018). The non-linearity of the transformation generates even more problems and, notably, assessing the overall effect regarding investments to Industry 4.0 is one of the most significant implementation barriers in management practice (Heng, 2014; Bischoff; *et. al.*, 2015)

Cooperation and networks, business models and human resources form a separate unity on the right side of the model. Bischoff *et al.* (2015) point out that company-specific efforts with Industry 4.0 technologies may not be able to leverage their full potential due to the lack of networking and cooperation regarding the technologies. Collaborative business models have their risks, even though they might be more innovative technology-wise. Managers struggle with make-or-buy decisions because it isn’t desirable to source differentiating technologies to third-party providers (McKinsey Digital, 2016). New value propositions emerge with implementing Industry 4.0 technologies and high individualization, integrated product-service combinations and innovative digital service solutions will primarily characterize these value propositions (Iansiti and Lakhani, 2014).

The possibilities of Industry 4.0 are endless, and Rudtsch *et al.* (2014) emphasize the importance of industry-specific solutions. The impact of Industry 4.0 on human resources is likely significant, and Kagermann et al. (2013) suggest that higher demands will be placed on the capability of the workforce in managing complexity, abstraction and problem-solving. Simpler jobs will be automated and digital skills within the company will become even more critical as key sources for the company (Porter and Heppelmann, 2015). Concerning my research, the main challenge regarding human resources is recruiting or educating skilled workforce. Such a paradigm shift in the industry will involve various challenges in the change and leadership cluster. Since the transformation process is usually non-linear, there are many possibilities to choose from in managing transformation organizationally. Organizations with a so called zero-defect principle are more likely to be risk averse and miss out on learning from early mistakes (The Economist, 2015)

2.3 Known business challenges of Industry 4.0

In the Final report of Industrie 4.0 (Kagermann et.al., 2013) a survey of the trends of Industrie 4.0 was presented, conducted by The Mechanical Engineering Industry Association (VDMA), Germany's digital association Bitkom and Germany's Electrical and Electronic Manufacturers's Association (ZVEI). The three biggest challenges connected to the implementation of Industrie 4.0 in the survey were standardization, process/work organization and product availability. Fourth on the list was new business models. Standardization mostly concerns the technological challenges and productization of technology solutions. Process/work organization and business models can both be found in Schneiders' six clusters for managerial challenges in Industry 4.0 in Figure 2.

Regarding the commercial side of challenges, the Working Group (Kagermann et al., 2013) points out, that processes in the manufacturing industry are often static and implemented through inflexible legacy systems. Due to the inflexibility, implementation of new business models, such as service-oriented systems, becomes even harder. The second major notice was that, in order to successfully transition to Industrie 4.0 someday, the more traditional industries such as machinery and plant manufacturers etc. need to work closely with the ICT industry, which is accustomed to much faster innovation cycles (Kagermann et al., 2013).

McKinsey, 2016, conducted a similar survey where they asked manufacturers about the major barriers which to overcome in the implementation of Industry 4.0. The top 5 barriers aren't surprising: (1) Difficulty in coordinating actions, (2) Lack of courage, (3) Lack of necessary talent, (4) Concerns about cybersecurity and (5) Lack of a clear business case. The first four barriers are already somewhat discussed in this chapter, but the fifth barrier , "Lack of a clear business case," isn't. In the core of the fifth barrier is the challenge of formulating and proving a justification for the investments needed within the organization to implement Industry 4.0 solutions (McKinsey, 2016).

As already discussed, the effects of Industry 4.0 on enterprise architecture hasn't yet been researched. Fleisch et al., 2014, say that the importance of digital business model patterns is clear also in the physical industries**.** The question is whether the customer whose premises are the source of data owns the data or the supplier who owns the sensors and smart containers, that generate the data (Fleisch et al., 2014). The adapted Value-creation Layers in an Internet of Things Application (Fleisch et al., 2014) will be presented later to visualize how the digital- and physical layers mix in case company X's solution.

The effect of cooperation and networks was introduced in the previous chapter regarding managerial challenges. Companies need to decide which parts of their process value chain are strategically important for them regarding their competition when developing Industry 4.0 solutions (McKinsey, 2016). Losing a strategical part of the process to an intermediary might force the company to a low-margin business, because the system connecting the physical parts might serve as the core advantage (Porter and Heppelmann, 2015). Industrial companies should focus on building partnerships and gathering third-party technology providers to their portfolio, to handle the transition to a model with multiple technology providers (McKinsey, 2016).

3 Methodology

This research includes an interview with a case company specializing in end-to-end IoT solutions for industrial companies. The interview and its results are anonymous, and all of the names have been changed. In addition to interviews, previous research will be reviewed to find similarities between research and practice. The concept of Industry 4.0 is still quite new, and it has been researched a lot lately. As researchers aren't unanimous on the definition of Industry 4.0, there are still many unexplored or mildly researched areas that would benefit from theory extension and -refinement.

3.1 Case company

Case company X is a Finnish start-up specializing in complex end-to-end IoT systems. X's representative describes their end-to-end system with the following three stages: (1) gathering data from sensors and systems, (2) edge-processing of the data and transferring the data into the cloud (3) further processing the data in the cloud and transferring it back to the edge. They have utilized Artificial Intelligence to make the system self-learning. X has substantial experience from working with industrial companies both in Finland and globally. Their team of about ten workers or partners have different backgrounds academically and are experienced especially in the technology sector. The company's' revenue for the last fiscal year (2018) was over 1M€. X also has experience in utilizing external consultants within their projects.

This research focuses on finding and examining the challenges in the implementation of Industry 4.0 technologies from a service provider's (X) point of view. X has an extensive product & service offering and it's able to provide tailored solutions for its' customers. The algorithms and sensors are designed to suit the specific customers' needs. Some buzzwords regarding their offering on their website include cloud-based learning, signal processing and tailored audio algorithms. By interviewing a case company this size, it is possible to have a closer look at the implementation process of new technologies.

In the interview, the case company X says that they focus on deploying and developing smart connected industrial solutions based on sensor analytics including audio. "The perception that is gained by examining deviations from an exact point of reference can have many uses e.g. in predicting and proactively preventing equipment failures in a manufacturing plant" says Seppo Teollisuus, partner of X, about their solutions.

3.2 Qualitative research

The primary data of my research is collected through the interviews with case company X. The secondary data for my research is the existing research and empirical data. The term Industry 4.0 was used for the first time in 2011, and therefore most of the secondary data is published quite recently after the year 2011.

Qualitative interviewing and especially the semi-structured format are probably the most common form of interviewing. Semi-structured interviews can achieve new angles to the topic in question by giving the interviewee more freedom. The interviewer can direct and comment on the topics along the interview to find the desired angles (Leavy and Brinkmann, 2014). The implementation of Industry 4.0 technologies doesn't have that much thorough research. I have formulated the interview questions in a way that the interviewee doesn't directly answer the research questions. This ensures that I have a proper research question which can be answered through careful analysis of the interview questions (Glesne, 1999).

I interviewed X's operative partner and chairman of the board Matti Meikäläinen. He has a degree in Electrical and Electronics Engineering from Helsinki University of Technology. He had a remarkable career at a Finnish technology company in various executive positions during the peak times of the Finnish technological industry. Matti also has previous experience from board positions in Finnish companies. He has an excellent overview of the company's operations, and he is aware of the practices and trends in the technology sector. In addition to Matti, I also interviewed Seppo Teollisuus, a partner of company X. He has a master's degree from the Helsinki School of Economics. He has made a career in banking and later as an entrepreneur in the ICT-sector.

Table 1. Summary of interview participants

Interviewee	Details
Matti Meikäläinen	• Male • Chairman of the board and partner • Experienced in technology • M.Sc. in Electrical and Electronics engineering
Seppo Teollisuus	• Male • Member of the board and partner • Experienced in business and banking • M.Sc in Economics

The goal of the interview questions is to gain an understanding of X's core business and to receive data for answering the research questions presented earlier in Chapter 2. X offers a wide range of solutions and their customers are usually from the industrial sector. Since X is a startup, they likely face additional challenges in comparison with bigger solution providers. The case data was collected through one-on-one semi-structured interviews with the interviewees. Prior to the interviews, the interviewees were provided with relevant themes of the interview to increase the credibility of the interview data. The interview questions proceeded depending on the interviewees' previous answers. I received the interview data on paper, per telephone and from face-to-face interviews with the interviewees. In addition to the eight questions, the interviewed persons were cooperative and directed the interview towards exciting topics. The interviews were conducted at X's office.

In a semi-structured interview, I have to be especially careful with covering all of the topics in my research questions (Eriksson and Kovalainen, 2011). The style of the interview questions also varies to answers different topics, that I am interested in hearing about. Silvermann, (2001) provides a typology where interviews are divided into three different categories which are positivist, emotionalist and constructionist. My interviews are positivist and aim to receive accurate information from the interviewees. By combining the interview data with existing literature about the subjects, a more true picture of the process can be formed. Yin (1994) suggests that case study research is most efficient on the "how" and "why" questions. In interview research, positivist and optionalist approaches are usually associated with "what" questions and the contructionist approach with "how" questions (Eriksson and Kovalainen, 2011). Holstein and Gubrium (2011) point out that interviews are usually a combination of the two questions. This can be clearly seen in my interview questions.

The first questions one and two are formulated to form an overall picture of X's operations and the different stages of implementing their solutions. The "how"-questions five and eight are designed to find out the preparedness of Industrial companies for new technologies and suggestions for the customers from a service providers point of view. The questions 2-8 can all be refined with the categories of challenges used in this research (managerial-, business-, and technological challenges) and by using the semi-structured interview, new angles to the research were achieved.

4 Results

To understand the different challenges faced by case company X, we need to understand their processes and the general flow of events that usually leads to a complete solution for the customer. The process starts with sales, and that is already where the first challenges occur. Based on previous research presented in Chapter 2, and case company X's interview answers, it was explicit to categorize these challenges in the three following categories: Managerial-, business and technology challenges. Managerial challenges can be analyzed with Schneider's (2018) framework for managerial challenges. The business challenges, that X has highlighted, are in line with the existing research. However, they provide a new aspect to the topic regarding existing research.

Description of the sales process

Seppo says that the process of implementing their solutions begins from preliminary discussions where they try to understand the customer's business case. The key question in this part of the process is, "What is assumed measurable added value that digitalization could bring?" says Matti Meikäläinen. In the negotiations, X must focus on the possible economic impacts that their solutions might bring, before getting into the technical details. Usually, the customer places a question on a specific problem, that they are interested in solving or enhancing. The case company X is a small company compared to its clients, so they need to see to their credibility from early on.

"In most cases the customer places a question regarding areas in which digitalization might bring more understanding/ added value. Most customers are large multinational corporations having corporate digitalization programs and various activities on-going. However, often such projects are slow-moving and complex – we bring agility by having more focused, stand-alone projects with fast impact."
-Matti Meikäläinen

When the sales process proceeds to implementing physical solutions on customers' premises, certain things are also expected from the customer to enable the building of a Proof of concept (PoC). According to Seppo, a successful PoC is the best way to convince the customer to buy a complete solution, since a working prototype eases the investment decision made by the customers' management. The goal of the sales process is simply to provide the customer with a view of the possible added value. The possibilities include many improvements in production performance e.g. quality, quantity, higher availability, plant optimization, and predictive condition-based maintenance cost. The length of the sales cycle depends on the various challenges within the process and these challenges will be named and discussed in the following chapters.

“The length of our sales cycle is usually 6-12 months and the rough of stages of the complete project are PoC, pilot solution and a productized solution”
-Seppo Teollisuus

4.1 Case company’s challenges

In the theoretical background, some of the general challenges in implementing Industry 4.0 technologies were already introduced. A explained before, this analysis focuses on the managerial- and business aspect of the challenges named by case company X, and therefore the technology challenges are dealt on the face of it to limit this research to the business field of study with a glance to the technology aspect. The findings are presented categorically and they are derived from interviews with case company X’s representatives. Some frameworks and figures, that were brought up by the interviewees, are presented and further discussed in Chapter 5.

Managerial challenges

One of the biggest managerial challenges in implementing their solutions is overall communication with the customer. The problems range from small on-site difficulties to communication with the customers' decision making executives about the results of the PoC. The people working in the environments, where the sensors are placed, usually have relevant information, that hasn’t been put into operation. Help from these floor-level workers is therefore important and might result in new innovations, shortcuts and overall shorter development processes. According to X’s experience, customers would sometimes like to have a technical representative around the premises to communicate with them on a daily basis, but this kind of a contribution to the project is usually too pricey for X and doesn't really speed up the development process.

"Relevant data from the floor-level workers is usually hidden and unexploited. A person might have mastered a heavy industry machine for decades and their "gut feeling" about the state of the machine can shorten the development process."
-Seppo Teollisuus

X's observation about the unexploited usage of the knowledge of floor-level workers and machine operators suggests, that manufacturing companies often ignore this hidden knowledge. Seppo points out, that even the AI built in the solutions has to be taught somehow and who would be a better source of information than the operator who knows the machine inside out and has been taking care of the maintenance and day-to-day operations. The machine operators might also have ideas on the development of the solutions. The concept of utilizing the knowledge of floor-level workers is however, conflicting because it is a fact that some of the jobs will disappear due to the emerging Industry 4.0 technologies. This problem as an entirety shows the complexity of the managerial challenges presented in Figure 2. The knowledge of the machine operators should already be utilized in the analysis phase, and the workers have to be re-educated parallel with the implementation of new technologies.

"The existence of a strategic plan varies greatly amongst our customers. In most cases, the strategic picture is unclear and it is blurred with factors such as security issues."
-Matti Meikäläinen

The managerial challenges also include the organizational challenges of the customer. When asked about whether X's customers usually have a strategic plan for new technologies, they say that it varies greatly, and the strategic picture is, in most cases, unclear. The lacking strategy can usually be linked with Gartner Inc.'s Maturity Model for Data and Analytics (Figure 3) that will be discussed in Chapter 5. According to Matti, industrial companies are in most cases on level 2 or level 3 on the maturity model. This means that their customers are, in most cases systematic users of data, but the reformative thinking needed for Industry 4.0 solutions isn't there. The persons driving the digitalization projects have to take internal organizational risk, which often leads to cautious investments in fear of failure.

"A cultural change in the customer organizations is needed to ease the process of implementing new technologies"
-Seppo Teollisuus

According to Seppo, industrial companies sometimes have large IT-departments, which might be especially change-resistant. They aren't usually comfortable in implementing third party solutions and potentially losing authority within their organization. The internal IT-departments are also, in many cases, incapable of handling these new technologies. The incapability usually originates from the simple fact that these technologies are extremely complex and it is impossible for an internal organization to be able to answer all of the questions regarding the technologies and solutions. X sees that this makes it especially hard for smaller solution providers to convince the hierarchical organization within the manufacturing industry. Matti concludes that "IT can create friction in corporations and internal wrestling slows the implementation process."

Business challenges

From the beginning of the sales process, X tries to focus on the business case and the desired economics of the implemented solutions. As Seppo says, crystalizing the added value to the executives might be hard, especially if the executives lack the technical competence to evaluate the offered solutions or even digitalization. As a service provider working with the newest technologies, X seeks to find innovative service-driven revenue models that are based on the added value of the service for the customer. According to Seppo, the selling and contractual formulating of these revenue models is hard with big corporations, which are not that eager to try such pilot projects with smaller third party suppliers, who lack the industry-specific domain data. On the other hand, recurring payments require smaller initial investments, which tackle one problem. The newer business models such as Paas (Platform as a Service), are also more profitable for X.

X’s revenue model consists of three different models: (1) Paas (Platform as a Service), (2) White Label licensing and (3) Solution product model. The ultimate goal is PaaS, but all of the revenue models complement each other. PaaS would mean customers would pay a recurring service fee for using X’s platform to operate their smart solutions on. In white Label licensing, for example larger companies, can rebrand X’s solution as their own for a licensing fee. Lastly, X can offer its solution as a product and one-time investment. The product model is not desirable since it is the least profitable and it is not upscalable.

“Formulating and selling the revenue model is a challenge especially in the beginning. After a successful PoC, the closer we get to measurable added value, the easier it gets to negotiate with the customer.”
-Matti Meikäläinen

The business challenges are accumulated at the beginning of the process. The closer X is to a measurable effect, the easier it gets to develop and implement the solution. The effects of an implemented smart solution can be very versatile, so even if it is known that they have significant value, the exact amount might be hard to assess. For example, a predictive maintenance solution can reduce downtime, reduce loss of revenue, maximize the lifespan of machinery and enhance product quality. Such promises from the service provider are hard to prove without carrying out a successful pilot project after a PoC. For a small solutions provider

“Our biggest business challenges as a solutions provider are credibility, upscaling, slow decision making by customers and resourcing.”
-Matti Meikäläinen

X’s offered end-to-end solution is for all of the three levels of enterprise applications recognized by Lee & Lee (2015) in Chapter 2. The solution is composed of open-source software components and there is no lock-in with the cloud. A small company like X can’t make the rules and force vendor lock-ins in their systems. In X’s case, they aren’t even interested in vendor lock-ins in their systems. I adapted the Value creation Layers in an Internet of Things Application by (Fleisch et al., 2014) to fit X’s end-to-end solution to highlight the customer value. All of the layers of the model are needed for the highest layer of Digital service.

"The ultimate goal for us is to offer our solution as PaaS (Platform as a Service). In the beginning, our offering was mainly project-based and included consulting as well"
-Seppo Teollisuus

Table 2. Value creation Layers in X's IoT application. (Bosch... Fig. 4 page 7)

Layers	**Layer name**	**X's provided product/service**
Layer 5	Digital service	End-to-end smart solution suitable for the customers' needs
Layer 4	Analytics	Data storage, analytics, artificial intelligence and integrations
Layer 3	Connectivity	On-site edge computing and secure industrial data gateway
Layer 2	Sensor	Customers' existing sensors or new local sensors (chosen by X)
Layer 1	Physical thing	*(E.g. a part of a paper machine or hydropower plant)*

X's solution is a hybrid in the sense of mixing the physical and digital worlds. X usually owns the hardware and the algorithms and the customer owns the gathered data. According to Seppo, the customers are more eager to pay for operational expenditure rather than capital expenses. The main challenge remains to be finding and understanding the business case. From the sales perspective, it is also important to find the suitable business owner for the digitalization project. Seppo explains, that the closer they get to the measurable added value of the offered solution, the easier it becomes to communicate with the customer. The deployment of the solution itself isn't hard after overcoming the challenges in the sales process and the development phase.

"The optimal business owner in a digitalization project is a senior business line executive, not an executive with particular technical authority within the organization."
-Matti Meikäläinen

4.2 Technical challenges and industry-wide problems

Since the solutions of X are customized, and the sales process starts with a focus on the business side, it might be that the customer is demanding things that X isn't able to deliver in their PoC. Seppo says that the security threats related to the Industry 4.0 technologies show in the digital strategies of industrial companies. Cloud computing makes it possible to analyze the gathered information on the web on scalable cloud platforms, but customers' IT-department might be keen to keep all of the information on their own servers. Frank et. al., 2019, found out that cloud computing is the most adopted Industry 4.0 technology because it might be used solely as an information storage for the company and not for any "smart" solutions.

"Safety issues etc. are the most common "tools" used for putting projects under question. If the customers' IT-department does not understand the concept, they are more likely to say no."
-Seppo Teollisuus

X provides end-to-end solutions, which is sometimes a challenge regarding the concept of interoperability in Industry 4.0. Their software can be integrated with other systems, but sometimes the customers' legacy software and hardware might hinder the seamless integration. Old operating systems might be running offline due to security issues. Even if the older operating systems or software solutions were connected, they usually do not have the computational requirements to work with more modern real-time systems. To tackle security challenges, X's autonomous solutions can be operated offline and isolated from other systems.

Security is a problem with ICT, and when companies are implementing Industry 4.0 solutions, this exposes them to even more unique security threats. Due to the increasing connectedness of things and machines across the supply chain, companies face unique security and privacy issues (Thames and Schaefer, 2017). Already in the final report of the Industrie 4.0 Working group by Kagermann et al., 2013, they recognized security as the biggest obstacle to overcome in implementing Industry 4.0 solutions. The industry lacks standardized platforms for such high-level solutions and too little is known about the possible security threats.

Successful implementation of Industry 4.0 solutions requires committed expert-level leadership and fundamental resource allocation (Ghobakhloo, 2018). An Industry 4.0 transition team is vital in executing the planned strategy and integrating the existing systems and infrastructure (Müller *et al.*, 2018). Not all companies have the resources to make the necessary changes, e.g. horizontal integrations, and to implement complete Industry 4.0 solutions. This will lead to more mergers and acquisitions in the manufacturing industry in the near future. (Frank *et al.*, 2019) research confirms, that the bigger the level of implementation of the Industry 4.0 concept is dependent on the size of the company.

In addition to presenting the technological challenges only shortly, this research ignores some other sources of challenges, which include political- and society related issues. These unaddressed challenges might be mixed with technological challenges for example, regarding privacy, data management and the legislation regarding the foregoing topics. Case company X doesn't feel that they have yet faced any insurmountable problems regarding legislation or society. Industry 4.0 can also be used to tackle global challenges regarding sustainability and labor supply, but these are not yet key areas of focus for case company X (Heng, 2014).

5 Discussion and conclusions

The purpose of this study was to find answers to the main research question: "What are the biggest challenges in implementing Industry 4.0 technologies in industrial companies?" Interviews with case company X provided this research with a solution provider's point of view of the sales process and common problems that they face with their customers. Based on the existing literature around the subject, the challenges into three categories; managerial-, business- and technical challenges. I was able to recognize and analyze challenges in literature and the interviews with case company X in all of the categories with a focus on business-related and managerial challenges.

From the interviews with case company X's representatives Matti Meikäläinen and Seppo Teollisuus, I was also able to draw new conclusions to the research questions mentioned in Chapter 1.1. Researchers are not unanimous on many of the concepts related to Industry 4.0 and its technologies, and therefore I have had to decide on a framework and definitions to work with. The theoretical background was explained in chapter 2. The problems faced by case company X are in many cases similar to the ones found in previous research about Industry 4.0. Security is one of the key issues within the technologies, but this isn't the sole reason why implementing Industry 4.0 technologies is so hard and companies of all sizes struggle with it.

5.1 Implications to research and practice

The six interrelated clusters of managerial challenges of Industry 4.0 by Schneider, 2018 are valid in case company X's experiences as well. The clusters were: (1) Strategy and analysis, (2) Planning and implementation, (3) Cooperation and networks, (4) Business models, (5) Human resources and (6) Change and leadership. These challenges were especially suitable for the analysis of the case company's answers since all of the challenges can be influenced directly by the company's' management. On the contrary to Gartner's Maturity Model for Data and Analytics in Figure 3., X finds that the optimal business owner for a digitalization project is a senior business line executive instead of a technical executive such as CDO, CTO or CIO. The role of a mature IT-department is important later on in the process, but during the PoC-stage of the process, they might create friction and slow the process down.

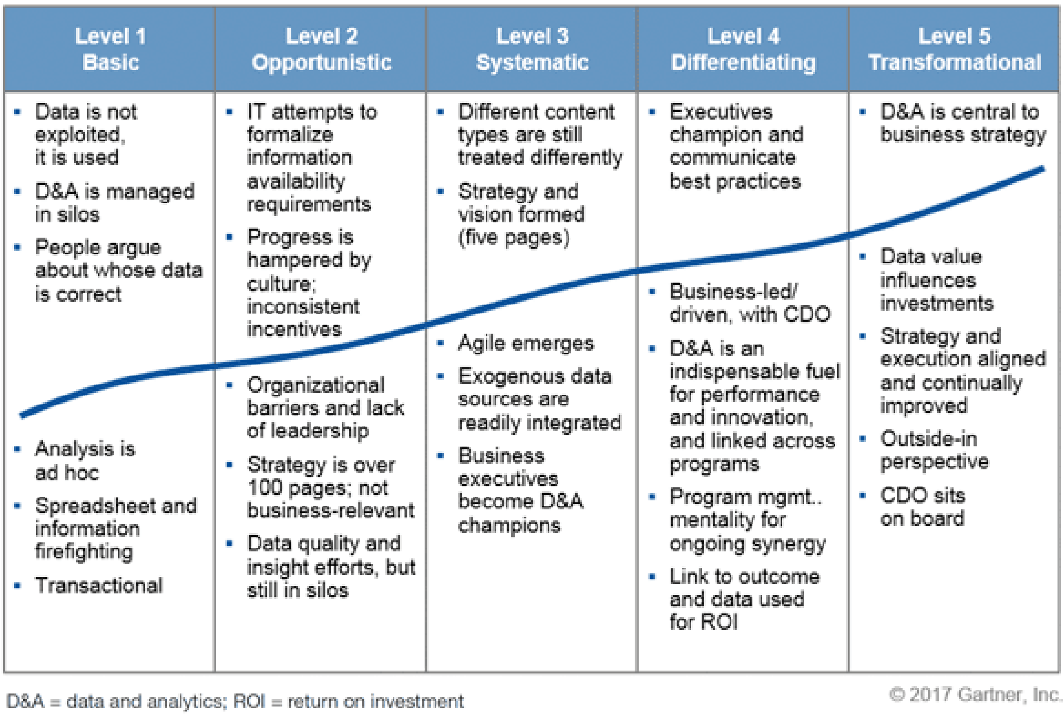

Figure 3. Overview of the Maturity Model for Data and Analytics (Gartner Inc. 2017)

The Maturity model in Figure 3. isn't especially designed to analyze the maturity of manufacturing companies regarding the use of data and analytics in their business. As noted in Chapter 4, manufacturing companies often find themselves from levels 2 or 3 (Seppo Teollisuus). The implementation of Industry 4.0 necessitates a higher level of maturity. Developing and implementing new agile solutions, with a company that is just starting to get familiar with agile, isn't desirable. Gartner's Maturity models level 4 and 5, which suggest that for those companies, data & analytics is essential for the companys' business strategy and investments. The name "Transformational" of level 5 captures the mentality of Industry 4.0 and the need for an outside-in perspective.

Müller, et al., 2018, researched that industrial companies should designate a separate Industry 4.0 transition team. X has experienced that sometimes the nominated technology-focused management is isolated from the business-line management and therefore, are often focusing on the solutions and technologies instead of the added business value and the value propositions. Big corporations are generally prepared for new technologies, but since the investment decisions regarding Industry 4.0 projects are hard to measure and the success rate is uncertain, the managers often work under fear of failure (Seppo Teollisuus). X's challenge of selling the new revenue models can, in fact, become beneficial. Industrial companies are more eager to invest through smaller service-based recurring payments, that in financial words are referred to as operational expenditures rather than capital investments.

To highlight the practical implications of this research, it is advantageous to conclude some of my findings on the secondary research question, "How can the process of implementing new technologies be streamlined?". Based on case company X's experiences and the existing literature around the topic, the following suggestions can be concluded by problem and category in the following Table 3. The problems are named in the first row and proposals are found below the heading in the same column. The categories of the challenges are in brackets.

Table 3. Analysis of streamlining the implementation process

Slow sales cycle	**Justifying Industry 4.0 investments**	**Productization of technological solutions**
Find the right business owner (Managerial)	Successful PoC justifies the investment (Business)	Form strategical partnerships (Managerial/Business)
Utilize the knowledge of floor-level workers (Managerial)	New service-based revenue models lower the investment barriers (Business)	Parallel productization development with the customer (Business/ Technological)
Faster utilization of PoCs (Business)	Cultural change is needed (Managerial)	More standardized process of implementation (Managerial/ Business/ technological)
Trustful relationship between the parties (Managerial)		

The challenges in Table 3 are considered significant from case company X's point of view and the theoretical background explained in Chapter 2. supports the foregoing challenges. The challenges in Table 3. can be utilized in practice in the implementation process of Industry 4.0 technologies. Many of the proposals are connected to each other or have a causality. Forming a strategical partnership may lead to a more trustful relationship. With good communication, a PoC can be developed in an agile way and both the customer and the service provider can benefit from a more standardized implementation and a better final solution. After the implementation process, the customer can start benefiting from the actual added value in the business case, which they wanted to solve in the first place.

The slow sales cycle hinders both the service provider and the customer. X highlighted the fact that finding the right business owner is a challenge and they suggest that the correct business owner is a senior business line executive. The existing research supports both having technical executives and a separate transformation team for the implementation of Industry 4.0. This suggests that the service provider should be trusted in the sales process to provide a PoC and a pilot project. After the executives have approved of the project and the investments, the importance of a transformation team stands out. The transformation team should make sure that the communication with the service provider is adequate and that all of the vital resources, such as the knowledge of the floor-level workers, have been put to use.

If the benefits of Industry 4.0 solutions would be certain and easy to visualize, we would surely have more real-life applications of Industry 4.0. It is clear that according to X, a successful PoC and a pilot project is the most common way of successfully implementing Industry 4.0 technologies. Still, a pilot project also requires some amount of investment. Without a transformational attitude for data-driven business, a pilot project might be neglected without any specific reasons. When the technologies become more standardized, piloting these technologies also becomes easier and the transformation from a pilot project to a complete solution is easier due to the service-based business models. As mentioned by Bischoff; *et al.*, 2015, company-specific solutions are likely to lack the full potential of the technologies, so companies should take more risk in partnering with smaller service providers.

Both parties also benefit from the better and faster productization and standardization of technological solutions. Standardization of the solutions drives the whole industry forward and makes Industry 4.0 solutions more accessible. Kagermann *et al.,* 2013 mentioned that the innovation cycles of machine manufacturers need to get closer to the innovation cycle of the ICT and technological industries. The standardizing tehcnologies also help companies like X in productization of their solution. The productization seems hard currently since many of the solutions are highly customized for individual customers. According to existing research, this seems to be a trend across the whole industry. There are already development platforms for IoT solutions from companies such as Siemens and IBM, but those are only the first steps in standardizing the technologies.

5.2 Limitations and future research

The research only had one case company, which is a small service provider. Many competitors of case company X are big industrial companies or consulting firms. This can make my research a bit biased and more suitable for manufacturing companies working with smaller third-party service providers such as case company X. The theoretical background of Industry 4.0 technologies and change management is general and applicable for further research about the subject. Since Industry 4.0 as a phenomenon is quite new, the effective implementation of Industry 4.0 technologies is still a subject of research (Lee *et al.*, 2015; Babiceanu and Seker, 2016; Dalenogare *et al.*, 2018) The case company's experience from managerial challenges is from Finland and Germany, and therefore the experiences are subject to cultural differences.

In more extensive research it would have been beneficial to interview several companies from both sides, the service providers and the customers. Some Industry 4.0 solutions are produced in-house by large industrial companies, but as noted in Chapter 2, strategical partnerships and networking are becoming increasingly important. The process of implementing Industry 4.0 solutions is agile, non-linear and hard plan beforehand. Comparing the proposals of streamlining the implementation process of Industry 4.0, it might be possible to find new patterns in the implementation process and refine the strategic roadmap. In the future, companies focusing solely on integrating different systems within factories and organizations might become more common.

Schneider assesses the possible research opportunities in Figure 4. and he uses the same framework for managerial challenges of Industry 4.0, as in Figure 3. Possibilities with a high-impact are in bold, practice-enhancing in italic, knowledge-enhancing are underlined and incremental possibilities have no formatting (Schneider, 2018).

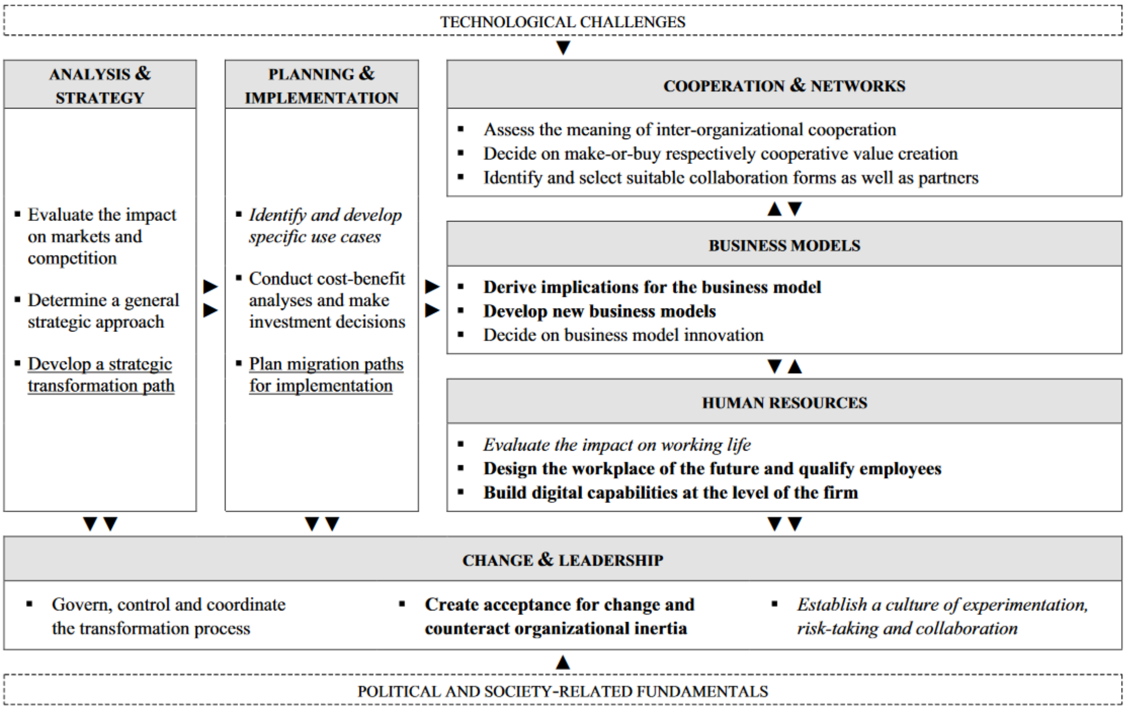

Figure 4. A framework for management research on Industry 4.0 (Schneider, 2018, Fig. 4., p.841)

The technological challenges and political and society-related fundamentals were mostly left out of this research even though they also have a major impact in the implementation process and the future of Industry 4.0. In addition to the future possibilities in management research named in Figure 4. by Schneider (2018). It will be interesting to see how the findings of this research occur in practice when more Industry 4.0 solutions arise globally and the implementation process is researched more comprehensively. Companies such as Siemens and IBM already have their own “easy to deploy” platforms and such trends are going to lower the barriers of developing new Industry 4.0 solutions. Also, sensor technology is developing fast and industry-wide standards will certainly be created in the future.

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Appendices

Appendix 1. Interview questions

1.	Which Industry 4.0 related technologies and concepts do you as a company focus on?
2.	What are the usual stages of a successful implementation of your solutions?
3.	What are the usual challenges in the implementation of your solutions?
4.	What is expected from the customer in the process?
5.	How are industrial companies prepared for new technologies?
6.	What are the biggest challenges for you as a service/hardware provider and why?
7.	What are the biggest challenges from customers point of view?
8.	How would you streamline the whole process from negotiations to a successful project?