Industry 4.0 – Only designed to fit the German automotive industry?

A multiple case study on the feasibility of Industry 4.0 to Swedish SMEs
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Title: Industry 4.0 – Only designed to fit the German automotive industry? A multiple case study on the feasibility of Industry 4.0 to Swedish SMEs

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Abstract

Problem: Industry 4.0 is still in an early development phase and it promises to bring remarkable benefits to the manufacturing industry around the world when employing the Smart Factory application in large organizations and their supply chains. Initiatives incorporating this concept can already be found in Sweden. However, there is a risk of a miss-match when trying to introduce Industry 4.0 to SME’s as the concept, with its pursuit of becoming flexible and achieving the desired “batch size one”, is mainly being developed around large German manufacturing firms. In Sweden SMEs account for more than 99,8% of all enterprises, and in 2015 they accounted for 52% of all employments within the manufacturing sector in Sweden. Therefore, it is of great importance to see if this predicted change within the manufacturing industry will be feasible for the Swedish manufacturing SMEs as well to ensure that they are being considered and approach in an accurate way for a successful implementation of Industry 4.0 in Sweden.

Purpose: The purpose of this research is to explore the feasibility of implementing Industry 4.0 in manufacturing SMEs in Sweden by identifying the potential barriers to implementation, as well as the benefits and trade-offs that these companies would expect from an implementation of these integrated technologies.

Method: The qualitative study presented in this thesis is applying a multiple case study strategy that incorporates seven interviewees from three Swedish manufacturing SMEs within different industries. The data is collected through semi-structured interviews and observations made at the production sites. Statements were derived based on the findings and these were then categorized and used as a foundation for the analysis.

Conclusions: Not only the level of automation or the technological features of the SMEs will determine if the concept of Industry 4.0 is feasible for them. Their business strategy and culture, as well as the product features and the leaders’ mind-set will also play a crucial role when it comes to adapting to an external change. Swedish manufacturing SMEs are not likely to implement i4.0 as it is defined today though, but rather to create different applications for the usage of these technologies, customized for their own conditions and needs.

Key words: Industry 4.0, Internet of Things, Internet of Services, Cyber-Physical Systems, Smart Factory, Interoperability, Small and Medium sized Enterprises
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1 INTRODUCTION

This thesis will treat the topic of Industry 4.0, a concept developed in Germany that describes how the next industrial revolution will be based on interconnected and self-optimizing technology, and if this is something that would be feasible for Swedish manufacturing SMEs to implement.

1.1 Background

In the late 1700s the world experienced the first industrial revolution. Primarily in Europe, societies changed from having an agricultural based economy to an industrialized economy. The development of the steam machine allowed the mechanization of manufactured goods. Prior to the invention of these machines, manufacturing was performed by a few specialized people in small workshops. Even though most of the manufacturing industries existing at that time were affected by this revolution, the textile and iron industry experienced a growth that had never being seen before. Since then, the manufacturing industry has changed enormously, from the mechanization of manufacturing processes to mass-production of standardized products to service integrated products and customization. New technologies emerge almost every day and how to benefit from applying these technologies to the manufacturing industry is always an ongoing research.

Several research institutes have in the last few years predicted that the joint use of various kinds of advanced technology will create the next revolution within the manufacturing process and thereby facilitate for customized mass-production. Germany is one among several countries that are using financial and human resources to research how this could be realized, focusing on global manufacturing firms, such as the automotive industry. It could therefore be questioned whether these new systems and processes will only be designed to fit these large entities, or if it would also be of interest and applicable to smaller manufacturing firms.

1.1.1 Three Industrial Revolutions that changed the world

Since the end of the 18th century, the world has gone through different industrial revolutions that have changed and reshaped industrial production, societies and businesses.

The first revolution introduced the steam power engines enabling mechanical production in the 1780’s, it began in Britain and spread to Europe and the rest of the world with the mechanization of the textile industry. The laborious hand work of the manufacturing of textiles used to be done by individuals or families in their own homes in different locations, but with the innovation offered by this revolution these individuals were grouped together in one place and the beginning of a new era started. Factories began to arise in big cities and a shift in the economy of countries could be seen from being mainly agricultural to industrialized, from rural to urban (Albert, 2015; Engineers Journal, 2014; Kagermann, 2015; The Economist, 2012).

The second revolution introduced the conveyor belts driven by electricity in the 1870’s, giving way to the mass-production enabled through the ‘division of labour’ and it was taken to the next level when Henry Ford mastered the use of the assembly lines by sourcing the parts that were interchangeable from different suppliers and so began the mass-production of the automotive industry using workers to assemble one piece at the time and passing it to the next station. For the first time a regular working person was able to afford a car in any colour so long as it was black. (Albert, 2015; Engineers Journal, 2014; H. Ford, 2004; Kagermann, 2015; The Economist, 2012)
In the late 1960’s the third revolution, also known as Industry 3.0, was introduced enabled by Information Technologies (IT): the automated production. This revolution presented organizations with an incredible increase on productivity, enhance product quality, decrease labour cost, improve safety and had a tremendous impact on skills, wages, employment and business (Engineers Journal, 2014). Some of the advantages presented by this revolution is that automated machines are capable of perform systematic and repetitive tasks, and are able to store large amounts of information. Therefore, new skills and businesses models were developed in order to cope with the increasing pace of technological innovation and although some adjusted fine to the new environment or found the right balance between traditional manufacturing and IT, others were left behind. (Brynjolfsson & McAfee, 2012; Kagermann, 2015; Nof, 2009; The Economist, 2012).

1.1.2 From product oriented to service oriented

One of the main outcomes of the second industrial revolution was the use of machines to mass-produce standard goods, reducing costs and production uncertainty. For more than a century, organizations worked towards gaining the benefits of the economies of scale, focusing on the development of products that could be standardized in order to increase production quantities, reduce production cost and increase profits. These product-oriented organizations push their final products to the consumers, expecting them to buy the products just as they are designed and produced by the manufacturing company. Nonetheless since the end of the 1980’s, organizations have been changing from pushing their standard products to integrate services to regular and everyday articles in order to offer goods with greater value for customers, for instance after sales service, customized colour or other traits, personal trackers and so forth (Kang et al., 2016; Lightfoot, Baines, & Smart, 2012).

The shift from product-oriented to service-oriented organizations is mainly due to two reasons. First off, established manufacturing companies have recognized that customers are not willing to pay higher prices for additional quality improvements (Brettel, Friederichsen, Keller, & Rosenberg, 2014), thereby the previous business trend to relocate production sites in low-wage nations, have driven high-tech, high-wage countries to find different alternatives to gain competitive advantage through the servitization of manufacturing. These integrated product-service offerings are distinctive, long-lived, and easier to defend from competition based in lower cost economies (M. Ford, 2015; Kang et al., 2016). Secondly, this shift has also been affected by the increased utilization and evolution of Information and Communication Technologies (ICT), enabling organizations to increase their productivity, quality, delivery, and flexibility based on technology convergence (Kang et al., 2016).

The servitization of manufacturing and the evolution of ICT are jointly leading the manufacturing industry towards an umbrella concept called Industry 4.0. New ICT are used to foster the individualized mass-production through the interoperability of the supply chain and a production process enabled by the modularization, virtualization, decentralization and real-time capability of information sharing.

1.1.3 The conception of Industry 4.0 – The Fourth Industrial Revolution

The concept of Industry 4.0 (i4.0) has its origin in Germany and refers to it being a 4th industrial revolution. While the first three revolutions had a major impact on the internal production processes on a ‘shop-floor’-level, the fourth revolution is anticipated to have an impact that stretches, not only across departments internally, but also externally across actors within the supply chain to form an integrated value chain across companies (Figure 1-1.) (Engineers Journal, 2014; Forstner & Dümmler, 2014). In spite of the great changes that i4.0 is expected to bring to the manufacturing industry, different opinions arise
as to whether it actually will be a revolution or not, and many experts prefer to speak of it as an evolution rather than a revolution due to the timescale involved (Albert, 2015; Kagermann, 2015). Albert (2015) argues that companies are probably more likely to implement the technology step by step and phase by phase, along with it being developed and available to the market.

Although the term “Industry 4.0” (or more correct “Industrie 4.0”) is German, the different components included in the concept are not all developed in Germany, and some of them have already been in use for quite some time in other countries as well, such as the U.S. for instance (Kang et al., 2016). Highly industrialized nations around the world are working towards the same goal: to gather the latest and most advanced technologies in order to support effective and accurate engineering decision-making, based on real-time information, through the introduction of various new ICT that are being merged with the already existing manufacturing technologies (Kang et al., 2016).

The manufacturing industry will be subject to radical changes in the next decade. Future manufacturing processes will include more flexible production lines and faster machines that are more accurate, efficient, smarter, and offer a greater IT-connectivity to ERP-systems and manufacturing execution systems (Hoske, 2015). I4.0 implies contextual and design changes in the Supply Chain (Delfmann & Klaas, 2005). The contextual changes will be outlined by the new high technological characteristics that will provide managers with real-time information across the entire supply chain, resulting in for instance a decreased uncertainty of demand and the possibility of an increased customization of products, while the design variables on the other hand, among other things, include the creation of new business models, decentralization of organizations’ structure, integration and coordination mechanism (Delfmann & Klaas, 2005; Sommer, 2015). Barriers, benefits and trade-offs are expected when implementing I4.0 to the manufacturing industry, especially if tested in Small and Medium Enterprises since these differ from the larger firms that have been the focus of the initial research (Sommer, 2015) and furthermore, the availability to implement new technologies is linked to the industry type and company size (Brettel et al., 2014).

![Figure 1-1. “From Industry 1.0 to Industry 4.0” by Carroll, D. (2014). Source: http://www.engineersjournal.ie/wp-content/uploads/2014/05/Domhnall_Carroll-006.jpg](image-url)
1.1.4 Small and Medium sized Enterprises

Small and Medium sized Enterprises (SMEs) are complex entities. Compared to large enterprises SMEs are less likely to influence their external environment and their activities are dictated by the market (Blackburn & Curran, 2001). SMEs are of high importance to the economies in the European Union as 99% of all businesses in the EU are SMEs (European Commission, 2015b).

1.1.4.1 SMEs in Germany

In Germany SMEs constitute 99,5% of all organizations, including the manufacturing industry, trade and services, and construction (European Commission, 2015a). Moreover the SMEs contribute to business turnover and employment (Blackburn & Curran, 2001; Sommer, 2015) and provide the biggest share of value added in the German business economy, contributing with more than 50%, and one out of five SMEs add value within the manufacturing sector (European Commission, 2015a). SMEs in Germany generate approximately 63% of all job opportunities, where small-sized companies account for the largest share of jobs while medium-sized firms produce the highest amount of value added (European Commission, 2015a). Furthermore, German SMEs accounted for 42% of production innovation in 2012, and the use of IT-systems in the SMEs is higher than in other European Countries, but this gap is getting reduced every year (European Commission, 2015a).

1.1.4.2 SMEs in Sweden

In Sweden SMEs constitute 99,8% of all organizations, among which the manufacturing industry, trade and services, and the construction industry are included, and the number of SMEs is yet expected to increase by 5.4% between 2014 and 2016 according to the European Commission (2015). In addition, SMEs contribute to business turnover and employment (Blackburn & Curran, 2001; Sommer, 2015). In 2015 over 2 million people were employed by SMEs in Sweden, or in other words, 65.7% of all employments in Sweden were generated by SMEs last year, and within the manufacturing sector SMEs accounted for 52% of all employees (European Commission, 2015).

1.2 Specification of the problem

I4.0 is still in an early development phase, and how to transform modern production processes towards an i4.0 design is currently an intensively researched topic in Germany. The main focus of the German research is centred around transforming the processes of large organizations, for instance the automotive industry, and due to this there is a risk that the processes within the concept are only being shaped around this type of business, rather than being more generally designed, and therefore the concept might not be valuable or feasible for other types of manufacturing firms within other industries or outside of Germany (Hermann, Pentek, & Boris, 2015; Jennings, 2015; Sommer, 2015). Sommer (2015) explains how the future of the German SMEs might be endangered if they are not being taken into account when the concept of i4.0 is developed, and considering the importance of these companies, excluding them could have a huge negative impact on the German economy. Therefore, a successful implementation of i4.0 is also highly linked to the capability of SMEs facing and adapting to this change (Sommer, 2015). At the same time though, the transition to Industry 4.0 might be very challenging or even impossible for some SMEs to go through with, as many of them are still trying to cope with the implementations related to the third revolution (Hermann et al., 2015; Jennings, 2015; Sommer, 2015).

Sweden and Germany are known to be rather similar in many aspects and to study each other in the areas where the other one is performing better. The role of SMEs in Germany and in Sweden are also very similar, as SMEs account for over 99% of all businesses in both respective countries, as well as more than
60% of all job opportunities (European Commission, 2015a, 2015b). i4.0 is receiving a lot of attention and resources in Germany and the government and the German industry have a close cooperation when it comes to conducting research projects within the field. In this aspect the Swedish industry is lacking the same level of governmental support as is does not have an own platform dedicated for this particular purpose, but even though the cooperation between politicians and the corporate sector is not as developed in Sweden as in Germany yet, the interest when it comes to advancing the industrial sector is still very high and actions are being made towards increasing the research activity. The Swedish industry have started several initiatives over the past few years to conduct their own research projects in an attempt to be a part of this ongoing and accelerating change (Produktion 2030, 2016). In an information release from the Swedish Ministry of Enterprise and Innovation (2016) it is described how Sweden’s strategy for new industrialization is aiming beyond the connected industry to also include the demands on renewal that the increasing sustainability requirements are placing on the industrial sector and its products. Nevertheless, one out of four focus areas for strengthening Swedish companies’ capacity for change and competitiveness mentioned by Swedish Ministry of Enterprise and Innovation (2016) is i4.0, and for the Swedish industrial sector to become leaders within “digital transformation and in exploiting the potential of digitalization”.

As Sommer (2015) stressed the importance of including SMEs in the development of i4.0 in Germany, and due to the similarities of the SMEs’ importance in both countries, this importance is also likely to apply to the Swedish SMEs’ inclusion in the Swedish research projects. Based on this, in combination with the focus area expressed by the Swedish Ministry of Enterprise and Innovation (2016), and since i4.0 is likely to have different applications and results depending on the research subject, we decided to focus this research on manufacturing SMEs, considering that many of the benefits proposed by i4.0 have been designed to fit and fulfil the needs of large enterprises. We therefore find it of our interest to see if the concept of i4.0 would be feasible for Swedish SMEs, and what benefits, trade-offs and barriers that could be identified for a potential implementation.

1.3 Purpose

The purpose of this research is to explore the feasibility of implementing i4.0 in manufacturing Small and Medium sized Enterprises (SMEs) in Sweden by identifying the potential barriers to implementation, as well as the benefits and trade-offs that these companies would expect from an implementation of these integrated technologies.

1.4 Research questions

1. What are the potential barriers that manufacturing SMEs might encounter with an implementation of i4.0?

2. What kind of benefits and trade-offs do manufacturing SMEs foresee if implementing i4.0?

3. How do the potential barriers, benefits and trade-offs affect the feasibility of introducing i4.0 in Swedish manufacturing SMEs?
1.5 Disposition of the thesis

This thesis is structured in the following way. First a background is presented, providing a brief introduction to the topic and an overview of the historical facts of what have led up to what is claimed to be the 4th industrial revolution. This is followed by a specification of the problem, the purpose of the research and the selected research questions. After the background and introduction, we present the theoretical framework, which is our frame of reference where we provide existent information from current research about i4.0, its enablers and the core outcome of implementing i4.0: interoperability. In the different sections delivered in the theoretical framework, we provide highly topical literature to bring the reader to an understanding of what i4.0 is, its enablers and how these enablers work on their own as well as when combined together. This chapter also touches on the importance of i4.0 for the development of the manufacturing industry. After the theoretical framework we describe the methodology and method used so as to provide the scientific value of the given research. In this section we discuss and support our chosen research design, the reasons that motivated us to use an inductive approach with a qualitative research method and semi-structured interviews. Subsequently we depict the empirical findings, where we show the main results of this research, followed by the analysis where we apply the theory of i4.0, presented in the framework, to the findings of our research in order to identify the barriers, benefits and trade-offs with i4.0 to Swedish manufacturing SMEs, as asked for in research question 1 and 2. Finally, we state our conclusions with the theoretical contribution of the performed research, which also answers our 3rd research question of the feasibility of introducing i4.0 in Swedish manufacturing SMEs, based on the benefits, trade-offs and barriers presented in the analysis, followed by managerial implications, and we then finish off with suggestions for future research.
2 THEORETICAL FRAMEWORK

In this chapter we present and discuss the key technologies and concepts of i4.0 and how these technologies and their applications contribute to the interoperability that is defining i4.0. We start by describing and defining i4.0 as the overarching concept, to go through the different technologies it is based on, the applications where they can be used, and the outcomes that are expected for the implementation and use of i4.0.

2.1 Industry 4.0

Industry 4.0 is a developing concept originated in Germany that has gained attention from the manufacturing industry, academia and government, building high expectations around its outcomes as i4.0 is committed to increase the performance levels of the manufacturing industry by synchronizing industrial automation equipment (Chung, 2015). “The German federal government may perceive Industry 4.0 as a way to reduce the overhead of low-skill labour and to address the competition of low-cost labour resources in other countries” (M. Ford, 2015). This term involves the use of three technologies called Internet of Things (IoT), Internet of Services (IoS) and Cyber-Physical systems (CPS) that when convened together in production sites engenders the application of Smart Factories.

Economic, environmental and social impacts on the manufacturing industry are expected when implementing i4.0. From the economic perspective, i4.0 aims at cost and risk reductions, performance improvements and flexibility (Leonard, 2015; Sommer, 2015), increased productivity (Chung, 2015; Schuh, Potente, Wesch-Potenten, Weber, & Prote, 2014), virtualization of the process and supply-chain, mass customization (Brettel et al., 2014), individualization of demand or batch size one (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014), creating resilient industries (Kagermann, 2015; Lee, Bagheri, & Kao, 2015), etc. From the environmental perspective, i4.0 use fewer resources more efficiently, and configure logistics routes and capacity utilization more efficiently (Kagermann, 2015; Wang, Wan, Li, & Zhang, 2016). Finally, from the social perspective individual workers will benefit from i4.0 as they will manage their own work time and will be the centre of the working environment, therefore is essential for workers to develop skills that fit the new needs of i4.0 (Brynjolfsson & McAfee, 2012; Kagermann, 2015).

I4.0 enables organizational and supply chain interoperability, incorporating smart infrastructure and production processes (Brettel et al., 2014; Hermann et al., 2015). To gain access to the benefits that i4.0 offers, organizations need to redesign processes and make investments in technology. For some manufacturers, the forthcoming i4.0 era is the logical next step, while for others i4.0 represents new and more difficult challenges as their organizations are still struggling with the innovative technologies that the previous revolution conveyed (Brynjolfsson & McAfee, 2012; Jennings, 2015).

As i4.0 is a rather new concept that is still under development, many different ideas exist of what i4.0 is and what is included in the concept due to the lack of a clear and generally accepted definition. Therefore we are basing our research on the definition proposed by Hermann et al. (2015), who after a systematic literature review presented a definition including four concepts or enablers of i4.0, which are Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS) and Smart Factory, and one principle that is the main outcome of this so called fourth revolution, Interoperability.
Hermann et al. (2015), defined Industry 4.0 as:

“A collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, Cyber-Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things (IoT), CPS communicate and cooperate with each other and humans in real time. Via the Internet of Service (IoS), both internal and cross-organizational services are offered and utilized by participants of the value chain.”

2.1.1 Internet of Things

The term Internet of things (IoT) can be track down to its roots in Massachusetts Institute of Technology (MIT) more than 15 years ago when research in Radio-Frequency Identification (RFID) was conducted (Wortmann & Flüchter, 2015). Since then, IoT has changed enormously, from tracking gears with RFID technologies to build a network of interconnected systems combining hardware, software, microprocessors, sensors and data storage capable to identify, sense and process information that communicate with each other over the Internet to reach a valuable result (Garrehy, 2015; Hermann et al., 2015; Whitmore, Agarwal, & Xu, 2014).

The innovation proposed by IoT is the ability to combine physical (eg. a window) and digital components (eg. a software) in order to create new ones (eg. a window that automatically closes the blinds when the sun hits that specific place during the day) the result of blending these two worlds are smart products (Wortmann & Flüchter, 2015). IoT is the foundation of smart infrastructures, for instance smart home, smart transport, smart cities, smart factories and so forth (Wang et al., 2016; Whitmore et al., 2014; Wortmann & Flüchter, 2015). It has been argued though that many of the “smart” things of today, especially when talking about products related to smart homes, are actually not as smart as one might expect. Thomas Eichstädt-Engelen, CEO and founder of open HUB UG, a company providing a software for integrating different home automation systems and technologies, held a keynote speech at the Accelerate conference “IoT – The smart thing about smart things!” at HHL in Leipzig (22-23 of April, 2016) where he highlighted how a lot of the smart home products that are currently on the market, are rather just a machine, or a lamp, connected to an app so that it can be remote controlled via your smartphone, and how there is nothing smart about that. According to Eichstädt-Engelen, the smart factor only appears when the software of several different products can communicate with each other to create added value, for instance if the lights in the house gets turned on as you park your car on the drive-way.

Smart factories are most of the time addressed through the umbrella concept of i4.0. IoT used within smart factories and Industry 4.0 is often referred to as Industrial Internet of Things (IIoT) to make a distinction between the IoT used by consumers and the IoT used in smart factories (Albert, 2015). Within i4.0 IoT technology provides each product with a unique identifier and makes its data available in real time through the web, and the IoT offers product traceability throughout the entire product lifecycle (Whitmore et al., 2014) and enables flexibility and operational efficiencies, reshaping the supply chain and manufacturing process (Chung, 2015).

Bryce Barnes, senior manager of the machine and robot segment at Cisco Systems, provided a definition of IoT that was rather comprehensible when speaking at the MC² conference in April 2015. He described it as:

*The intelligent connectivity of smart devices by which objects can sense one another and communicate, thus changing how, where and by whom decisions about our physical world are made* (Cited in Albert, 2015).
2.1.2 Internet of Services

As mentioned in previous chapters of this thesis, there has been a shift from product-oriented manufacturing to service-oriented manufacturing (Brettel et al., 2014; M. Ford, 2015; Huang, Li, Yin, & Zhao, 2013; Kang et al., 2016; Lightfoot et al., 2012) and this change is slowly becoming the new configuration of the manufacturing industry (Huang et al., 2013), especially for innovative manufacturing firms (Lightfoot et al., 2012). The companies that are able to be innovative are the ones that will come up with new business ideas so as to benefit from this new technology.

From the customers’ perspective, this swing to the servitization of the manufacturing industry is creating more value for them as the product can be monitored increasing the customer satisfaction offered by a better customer service (Lightfoot et al., 2012). Manufacturers also benefit from this shift as the entire life cycle of the product can be trace and therefore the probabilities of product malfunctioning are decreased and the source of the problem can be tracked down accurately to the starting point (Kang et al., 2016; Lightfoot et al., 2012). The servitization increases visibility of product performance and new trends (Lightfoot et al., 2012), and in the production sites, down time can be extremely reduced as the machine itself will be able to communicate when it needs maintenance in order to avoid a breakdown (Hermann et al., 2015).

Manufacturing firms are facing different challenges when trying to embrace this technology especially for managers that work in a traditional product-oriented approach (Lightfoot et al., 2012). Huang et al. (2013), identified six problems that SMEs face when trying to implement a service-oriented manufacturing site: First of all, SMEs are usually at the bottom of the value chain and are more likely to be influenced by the external environment investing more in general labour, design and privately owned machines than their bigger counterparts in order to cope with changes. Second, lack of innovative thinking that allows companies to adopt new technologies. Third, they are unable to provide a follow-up service and therefore in some cases, the relationship with customers can be damaged due to the inability of companies to deal with product inefficiencies. Fourth, inability to collaborate with other manufacturers in order to benefit from each other’s knowledge, this is mainly due to the difficulties to build a close relationship with others regarding the trust and information sharing. Fifth, most of the SMEs rely on their network and websites to offer their resources, causing a lack of source credibility and difficulties to build the SME reputation. Sixth, for some SMEs their success is their downfall as they cannot handle the demand that has been created by the product and therefore the company credibility is affected.

For this research we are defining Internet of Services as the technology that monitors the product life cycle in order to be able to make decisions based on the information previously gathered and analysed with the help of other technologies, and to offer breakdown prevention as a service that assists companies to avoid sudden breakdowns to achieve a seamless production flow and ensure the reliability of machines and products.

2.1.3 Cyber-Physical Systems

Electronic integration is an old concept and manufacturing firms are already using collaborative planning to embrace electronic integration at all levels. I4.0 will take the integration to an upper level through the interoperability of the systems (Chung, 2015; Schuh et al., 2014; Whitmore et al., 2014).

Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the seamless integration of software and physical components; CPS is characterized by a network of interacting elements with physical input and output, resembling the structure of a sensor network (Chang et al., 2015). Stanovich, Leonard, Sanjeev, Steurer, Roth, Jacson, Bruce (2013), addressed that a CPS often relies
on sensors and actuators (or called actors, in some cases even called controllers as they control mechanisms or systems) to implement tight interactions between cyber and physical objects (Cited in Hu et al., 2016). The sensors (cyber objects) can be used to monitor the physical environments, and the actuators/controllers can be used to change the physical parameters (Hu et al., 2016).

In i4.0 companies, CPS and humans are connected over the IoT and the IoS. (Hermann et al., 2015). Cyber-Physical Production Systems comprise smart machines, warehousing systems and production facilities that have been developed digitally and benefit from end-to-end ICT-based integration, incorporating everything from inbound logistics to production, marketing, outbound logistics and service. (Kagermann, 2015)

CPS are not designed from scratch, instead they evolve by networking existing infrastructures with embedded information technology – with the help of the internet, mobile communication services and the cloud (Geisberg et al., 2011). Traditionally, the way to exchange data has been by means of electronic data interchange (EDI), different developers of EDIs created systems that are generally incompatible with each other, leading to an internal integration of data exchange and storage but excluding the external integration due to the incompatibility of systems (Harrison & Van Hoek, 2008). Integration is a very tough task because each member in the supply chain may have different hardware and software (Motiwalla & Thompson, 2012). Two major critical success factors emerge when using electronic communications to deal with business process between buyers and sellers: first, a legal framework that ensures a trustworthy environment and second, technical issues that obstruct the proper coordination of processes in a heterogeneous environment, where integration and interoperability are the key-enabler for the deployment and management of the workflow (Alvarez-Rodríguez, Labra-Gayo, & de Pablos, 2014; Whitmore et al., 2014)

CPS is defined as “transformational technologies for managing interconnected systems between its physical assets and computational capabilities”. (Lee et al., 2015)
2.1.3.1 Cyber-Physical Systems architecture levels

Lee et al. (2015) developed a 5 level structure for implementing CPS in factories which they called the 5C (Figure 2-1.) by using this structure, organizations can create a progressive flow work to execute CPS in the production sites and furthermore it can help to assess the CPS’s level of appliance.

![Figure 2-1. The 5C structure for implementing CPS](image)


According to (Lee et al., 2015) in level I or Smart connection, precise and consistent data is generated by the different machines, components and controllers, and the different software used by the organization. Level II or Data-to-information conversion refers to the adaptation of data from one format to another keeping the integrity of the information during the process in order to foster the interoperability of the systems, this level brings up the self-awareness of the machines. Level III or cyber is the focal point of the information operations, here the whole information is gathered from the diverse machines, components, software and so forth, and analysed and the self-comparison ability is constructed allowing machines to compare itself with other machines or with historical figures. Level IV or cognition discusses the management of the information and knowledge generated in previous levels, now that the machine is self-aware and can compare itself with others, therefore decisions regarding performance and maintenance can be constructed. Level V debates the response from cyber space to physical space and provides machines with the ability of self-configure and adapt according to the needs of the production, here corrective and precautionary decisions can be made.
2.1.3.2 Automation

The definition of automation according to Frohm, Lindström, Stahre, & Winroth (2008), is usually related with the scale of machines’ usage in manufacturing sites, but nowadays automation is grasping the use of different IT technologies in order to not only automate the physical work but also to automate cognitive labour, the latter is the ability of systems and machines to generate, analyse, interpret data and decide the next step.

According to Frohm et al (2008) there are several ways to assess the Levels of Automation (LoA), however, most of these models assess automation in relation with human factors, for instance the degree of human intervention when operating a machine or the number of humans operating a production site. Furthermore, automation is not black or white, rather automation is continuous and varies in different points of time. The basic level of automation is a human performing a manual job using only his or her hands and personal force, later a tool is provided to facilitate the work and therefore the technological level increase, subsequent the human and the tool are substituted by an automated machine to perform the same repetitive task. Every machine is automated with the use of subsystems that can be later fused together with other autonomous machine to create networks of automated machines. Hence they developed a 7-step reference scale model to describe and assess the level of automation in manufacturing sites (Figure 2-2.). Frohm et al (2008) created a two-dimension model where they assess not only the type of equipment used by the production site but also the degree of information sharing and analysis, these two dimensions are: Mechanical and Equipment and, Information and Control.

<table>
<thead>
<tr>
<th>LoA</th>
<th>Mechanical and Equipment</th>
<th>Information and Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Totally manual - Totally manual work, no tools are used, only the users own muscle power. E.g. The users own muscle power</td>
<td>Totally manual - The user creates his/her own understanding for the situation, and develops his/her course of action based on his/her earlier experience and knowledge. E.g. The users earlier experience and knowledge</td>
</tr>
<tr>
<td>2</td>
<td>Static hand tool - Manual work with support of static tool. E.g. Screwdriver</td>
<td>Decision giving - The user gets information on what to do, or proposal on how the task can be achieved. E.g. Work order</td>
</tr>
<tr>
<td>3</td>
<td>Flexible hand tool - Manual work with support of flexible tool. E.g. Adjustable spanner</td>
<td>Teaching - The user gets instruction on how the task can be achieved. E.g. Checklists, manuals</td>
</tr>
<tr>
<td>4</td>
<td>Automated hand tool - Manual work with support of automated tool. E.g. Hydraulic bolt driver</td>
<td>Questioning - The technology question the execution, if the execution deviate from what the technology consider being suitable. E.g. Verification before action</td>
</tr>
<tr>
<td>5</td>
<td>Static machine/workstation - Automatic work by machine that is designed for a specific task. E.g. Lathe</td>
<td>Supervision - The technology calls for the users’ attention, and direct it to the present task. E.g. Alarms</td>
</tr>
<tr>
<td>6</td>
<td>Flexible machine/workstation - Automatic work by machine that can be reconfigured for different tasks. E.g. CNC-machine</td>
<td>Intervene - The technology takes over and corrects the action, if the executions deviate from what the technology consider being suitable. E.g. Thermostat</td>
</tr>
<tr>
<td>7</td>
<td>Totally automatic - Totally automatic work, the machine solve all deviations or problems that occur by itself. E.g. Autonomous systems</td>
<td>Totally automatic - All information and control is handled by the technology. The user is never involved. E.g. Autonomous systems</td>
</tr>
</tbody>
</table>

Figure 2-3. Levels of Automation for computerized and mechanized tasks within manufacturing

Mechanical and Equipment is the replacement of the human strength (level 1) for an entirely operation of mechanized or automated machines (Level 7). On the other hand, Information and Control is the degree of interaction between humans and machines in a system in order to improve the understanding and awareness of the up-to-date and future situations, where level 1 is totally manual and the users employ their previous experiences to perform the task, and level 7 is totally automatic and information is managed by the IT system. (Frohm et al., 2008).

2.1.4 Smart Factory

With the development of new emerging technologies such as the Internet of Services, the Internet of Things and Cyber Physical Systems, the materialization of the Smart Factory (SF) is becoming a reality (Wang et al., 2016; Whitmore et al., 2014; Wortmann & Flüchter, 2015). Forstner & Dümmler (2014), argued that the Smart Factory is the keystone of i4.0 as it provides a common ground for humans, machines and resources to communicate with each other, increasing the interoperability of processes enabling to change or adapt processes dynamics (Loos, Werth, Balzert, Burkhart, & Kämper, 2011).

Smart factories are vertically, horizontally and end-to-end engineered integrated to support the customization of products (Forstner & Dümmler, 2014; Wang et al., 2016). A Smart Factory is vertically integrated in the internal hierarchical subsystems of the operational processes creating an adaptable manufacturing system, it is horizontally integrated through inter-corporation value networks enabling collaboration from suppliers to customers and, it is end-to-end digital integrated of engineering crosswise the value chain to assistance product customization (Forstner & Dümmler, 2014; Wang et al., 2016).

The technical features demanded by the Smart Factory differs from the traditional factory (Figure 2-3.). In traditional production lines the main objective is to produce high volumes of the same item, while in the Smart Factory the objective is to produce small-lots (also known as batch size one) of diverse types of a product, meaning that the sort of resources needed will increase. In Smart Factories the routing is dynamic and it is automatically reconfigured by the system with an ongoing production this is possible due to people, machines, resources and information systems are able to communicate with each other, in contrast the traditional production line is fixed and though reconfiguration is seldom required, it is done manually by people with the system down as the machines subsystems store information individually and it is not shared or interact with others. In traditional production lines subsequent tasks depend entirely on previous workstations completed task, therefore the breakdown of a machine or workstation interrupts the production flow, whereas in Smart Factories the machines are aware of their condition and are able to decide to restructure the dynamic of the system. With Smart Factories, the information generated by one machine is storage and analysed in the Cyber-Physical System where it can be used by others, instead of being produced for the use of one user only.
<table>
<thead>
<tr>
<th>Traditional production line</th>
<th>Smart Factory production system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited and predetermined resources – Mass production of one item</td>
<td><em>Diverse resources</em> – Different sorts of a product that increases the number of resources</td>
</tr>
<tr>
<td><em>Fixed routing</em> – the route is configured to follow same path and reconfigured manually with the system down</td>
<td><em>Dynamic routing</em> – the route changes according to the different features of the product and it is done automatically</td>
</tr>
<tr>
<td><em>Shop floor control network</em> – every machine performs a specific task and communication among them is not needed</td>
<td><em>Comprehensive connections</em> – humans, machines, resources and information systems communicate with each other by means of a high speed network</td>
</tr>
<tr>
<td><em>Separated layer</em> – machines are lonely subsystems and are separated from other information systems</td>
<td><em>Deep convergance</em> – the industrial network is integrated by the Cyber-Physical System and IoT and IoS are created</td>
</tr>
<tr>
<td><em>Independent control</em> – Every machine is configured to execute a task and malfunctioning of one affects the whole production line</td>
<td><em>Self-organization</em> – the task is distributed to different entities and machines discuss and decide the dynamic of the system</td>
</tr>
<tr>
<td><em>Isolated information</em> – the information generated by machines is normally used by the machine and rarely shared and used by others</td>
<td><em>Big data</em> – Huge quantities of information are generated by systems and subsystems and it is stored and analyzed in the Cyber-Physical System</td>
</tr>
</tbody>
</table>

Figure 2-4. Smart factory production systems compared with traditional production lines


According to Lucke, Constantinescu, & Westkämper (2008), smart factory is:

“a context-aware factory that assists people and machines in execution of their task, this is achieved by systems working in the background with information coming from the physical and virtual world, these systems are working on different levels of the factory and are able to communicate and interact with its environment”

2.1.5 Interoperability

Interoperability is one of the main traits of Industry 4.0 (Hermann et al., 2015; Schuh et al., 2014), it is a key success factor to foster collaboration productivity thru the different areas of companies and business partners (Daclin, 2012; Loos et al., 2011; Schuh et al., 2014). In contrast to Smart Factories that upholds the communication between machines, humans, systems and resources as a result of creating a Cyber-Physical System to gather and analyse information in order to decide the dynamic of the system (Wang et al., 2016), Interoperability under i4.0 is a fundamental factor at the supply chain level as it allows the collaboration between different organizations (Daclin, 2012; Loos et al., 2011). Daclin (2012), identified four required abilities of business partners for interoperability to function: partners must be compatible
to ensure the right functioning of the system, interoperational ability to achieve high performance levels in relation to the quality of the exchange, the integrity of information and so forth, it ought to be autonomous and reversible as partners need to receive or provide services, resources, etc., keeping their own functions and objectives even if adjustments occurred.

The term of interoperability has two different approaches, the technological approach where interoperability is defined as “The ability of systems to exchange and make use of information in a straightforward and useful way; this is enhanced by the use of standards in communication and data format” (Daintith & Wright, 2008). This approach exposes the problematic that companies are facing when they try to connect with business partners as IT systems are written in different languages and therefore coupling them together is a difficult task (Daclin, 2012; Loos et al., 2011; Motiwalla & Thompson, 2012). During the Accelerate conference of “IoT – The smart thing about smart things!” at HHL in Leipzig (22-23 of April, 2016), Thomas Eichstädt-Engelen stressed that one of the major barriers to interoperability between systems today is that there is still no standard when it comes to the languages that are used in the different software. For them to be able to communicate, share information and work together they either need to use the same language, or the market will need a software that is able to decode and convey the information in-between systems. Eichstädt-Engelen also pointed out that several attempts to create a new standard language had already been done, but that it so far only had resulted in yet another language out on the market, making the gap between the existing systems even larger. He showed how the trend over the last few years had been that the number of languages had been increasing at an even higher pace, instead of a decrease and an effort to gather around one or at least a few languages.

On the other hand, enterprise interoperability is “the ability of multiple firms to perform a generation of added value in division of labour, self-coordinated, within an overlapping business process, based on the exchange of coherent information, with a common goal and without fundamental changes to the initial organizational, procedural, and technical landscapes of the enterprises” (Loos et al., 2011). According to Loos et al. (2011), enterprise interoperability is built on three concepts: business, process and information interoperability. Business interoperability can be considered to be Industry 4.0 and according to Loos et al. (2011) this interoperability is determined by the market itself as this is going to define the drivers of the business and it is framed by the environment, for instance the culture, the regulations and the economy of the different markets. The process interoperability can be compared to the Smart Factory, where the interoperability fosters the ability of adapt to changes and synchronize tasks within the company and with business partners without interrupting the process flow (Loos et al., 2011), and the information technology refers to the architecture of the system that reasons and adjusts to the behaviour of actors (Loos et al., 2011).
3 METHODOLOGY AND METHOD

In this chapter we present our methodological choices and methods used when conducting this research. Starting off with describing our inductive research approach and exploratory design, we then motivate our choice of the qualitative research method and performing a multiple case study using semi-structured interviews complemented by observations to collect data. We then state our sampling techniques and describe the sampling process, followed by generalizability of the study as well as the ethical aspects of the research procedure.

3.1 Research approach

The research presented in this thesis has been conducted with the social approach of induction, as our empirical findings and theoretical statements are derived from data gathered through interviews and observations, as opposed to deduction where hypothesis are created from already existent theory and then are confirmed or rejected against data (Blaikie, 2004; Miller & Brewer, 2003). Our contribution to academia is to increase general understanding (Easterby-Smith, Thorpe, & Jackson, 2015; Fox, 2008) and, create new theory (Blaikie, 2004; Eisenhardt, 1989) about the future implementation of i4.0 in relation with Small and Medium Enterprises in Sweden.

We intend to comprehend the circumstances that SMEs might face when or if i4.0 becomes a reality by learning from selected SMEs experiences and points of view. Instead of presenting hypothesis to be rejected or accepted as deductive approach indicates, we start our research presenting three research questions, where the first two are general questions and the third question is focused on Swedish SMEs in order to fulfil our purpose. These questions were developed after observing that i4.0 importance is growing in places beyond Germany and realizing that the different actors will experience this fourth industrial revolution in diverse ways.

Inductive research face one problem as it involves interpretations, meaning that in some cases the generalization may be contradicted by new observations (Fox, 2008). For instance, it is of general understanding that all dogs have fur, but this affirmation has a contradiction due to there are dog breeds that are bald. Though researchers suggest that in order to avoid this problem a deductive and inductive research could be done, we rather accept that an inductive approach generate prepositions generalizable enough to allow people to trust in certain irregularities in real life (Fox, 2008). Thereby this study is generating prepositions that can be generalized with some anomalies due to the width of the topic.

3.2 Research design

3.2.1 Classification of research purpose

The research purpose of this study is to understand the concept of i4.0 and explore the feasibility of implementing it in Swedish SMEs by looking for patterns and ideas rather than testing or confirming hypotheses, therefore we assert that this work is completed as an exploratory research (Vogt, 2005). According to Stebbins (2001), the importance of explorative and inductive research to science lies on that deduction alone does not have the ability to revel new ideas and observations.

Following the advices on exploratory research suggested by Stebbins (2001), a literature review was performed at the beginning of our research in order to demonstrate the scarcity of research done about i4.0 outside Germany, as this country is the heart of the term and furthermore, this gap in the literature
becomes broader when trying to find literature involving Small and Medium Enterprises, as this concept focuses mainly on large enterprises.

According to Stebbins (2001), when writing a report, exploratory researches must resist the temptation of presenting a wandering, heavy and distracting literature review due to the pressure exerted by other researchers and thereby this section of the report is usually short in contrast with confirmatory research literature review. This supports our decision of focusing more on the findings and analysis of the data than on the theoretical framework, as we can offer more inputs during the analysis of the empirical than trying to have an extensive frame of reference that is difficult to understand.

An exploratory research is challenging and special attention needs to be paid when writing a research of this kind as researchers often lose track, roam away from the purpose and end up in a totally different place (Stebbins, 2001), thereby we constantly review and remind ourselves of the purpose of this research in order to stay on the path of our study.

Exploratory research provide researchers with freedom and elasticity when preparing the research design and data collection, but still validity and reliability is an important issue with this type of research (Stebbins, 2001; Streb, 2010). According to McCall & Simmons (1969) (Cited in Stebbins, 2001), the major problems of validity and reliability on exploratory research are related to the perception of the phenomenon since the presence of the researcher might affect the typical actions of the researched object and furthermore the results might be biased by perception and interpretation of the investigator. Hence in order to tackle the validity problem, we perform unobstructed observations and interviews to gather data that complements each other, additionally two researchers conduct this study to reduce the perception and interpretation biases that can arise when only one researcher perform a study of this nature. To confront the reliability problem, we execute an extensive documentation of the research process in order to be replicable by other researchers but on the other hand, the researcher’s skills, training and understanding of the topic is different from one person to another, therefore the results may differ due to the researchers’ background.

3.2.2 Research method

The research method chosen for this research is qualitative as this method is the best to understand a phenomenon (Rosaline, 2008) and according to Hurmerinta-Peltonäki & Nummela (2004), social-oriented researchers need to get as close as possible to the phenomenon with the purpose of getting a better understanding of the phenomenon itself, and to do so a qualitative research is required. Furthermore, Fox (2008), suggested that qualitative researches are highly relevant to the inductive approach because they develop an understanding and new theories in unexplored fields.

Qualitative research suits our research as it provides an indication of how the general traits affect individuals’ actions, while quantitative research explains the associations between variables by determining the influence of an individual variable on other variables that are subject of the study, or by finding the effect that one variable has on other variables (Fox, 2008; Rosaline, 2008).

Opposed to quantitative methods that relies on a research design that is more or less linear, qualitative methods are flexible and allows tools and even research questions to evolve during the research (Rosaline, 2008). This supports our decision to change the original focus of this research, as at the beginning of our work we were aiming at understanding the changes that i4.0 was going to bring when assessing suppliers, to a more basic focus where we try to understand the feasibility of SMEs implementing i4.0.
3.2.3 Research strategy

According to Eriksson & Kovalainen (2010), the use of case studies in business and management is mainly to examine matters connected to industrial and economic areas, where the major themes of interest are external or internal events affecting a business or industry and, processes or changes happening in organizational and business surroundings. The purpose of case studies is to create new knowledge and increase contextual understanding by using a single case to study multiple phenomena, or to study multiple cases comparing only one phenomenon (Eriksson & Kovalainen, 2010; Putney, 2010; Rosaline, 2008). In this research we are studying one phenomenon, how i4.0 is perceived in three different case companies in order to increase understanding on how SMEs view this expected change.

Due to the novelty and complexity of this topic, the use of exploratory, qualitative case studies as a research strategy is recommended, as using a quantitative approach would make the research difficult or impossible to complete (Putney, 2010). Case studies in general are based on detailed analysis of rich empirical data, therefore multiple case studies need to take into consideration the number of cases selected in order to have a high-quality analysis, rather than a complicated and low-quality analysis due to the high number of cases performed (Putney, 2010; Rosaline, 2008). In this research we decided to look into three different companies and interview several employees at each company in order to gather a rich amount of information on all of them.

Yin (2014), stated that multiple case studies have the same methodological design as single case studies, and according to Putney (2010) multiple case studies are just an alternative to single case studies, thereby they do not need to be considered as a different kind of study and furthermore the selection of similar or different cases is enough to generalize theory. In our research we use multiple cases as we try to comprehend the impact of the holistic phenomenon on SMEs within the manufacturing industry, instead of trying to understand the matter that it represents to one case only.

We are carrying out an exploratory multiple case study as a result of the lack of previous researches and theories due to the novelty of this topic, and therefore the shortage of scientific work reduces the options of methodologies that can be used in order to study a phenomenon (Streb, 2010). On the other hand, multiple case studies are useful when researchers want to target a specific area of the field especially when the research approach suggest that realities may differ from one subject to another (Bleijenbergh, 2010).

3.2.4 Data collection

3.2.4.1 Semi structured interviews

Daniels & Cannice (2004), suggested two situations where interview-based studies are appropriate. First, interview-based studies are well suited for exploratory researches and as the aim of this study is to explore the feasibility of implementing i4.0 in Swedish SMEs, this suggestion fits our purpose. Second, interview-based research is optimal when there is a small population of possible respondents as this is an opportunity to acquire a richness of information from each respondent thereby and due to the novelty of the topic i4.0, specific characteristics were required from our research subjects, reducing our sample drastically and therefore also the second suggestion is suitable for our study.

The data collection for this thesis is conducted through semi-structured interviews, supported by observations. The collection of data is in line with the qualitative method chosen for this research as suggested by Rosaline (2008). An interview guide (Appendix 3) has been created and used as a support throughout the interviews to ensure that all questions and parts needed to fulfil the research objectives is covered. As opposed to structured interviews where a manuscript of precise questions in a certain order
is strictly followed, the topic guide is more of an informal list of topics and questions that can be addressed without any particular order (Easterby-Smith et al., 2015; Rosaline, 2008).

When we at first approached our case companies to ask for the interviews, we also asked for their consent to hold them in English since one of us is not fully fluent in Swedish yet. But even though our preferred language was English, we were still able to be flexible on this matter if the language proficiency of the interviewee required it, in order to not let this restrict the extension of the information provided. Due to the fact that the research is conducted in a Swedish speaking country, some of the interviewees do not use English on a daily basis and do therefore not feel fully confident conducting an interview in this language. Therefore, we conducted interviews in Swedish when we noticed that this would get us a richer answer. Out of the seven interviews, three were held in Swedish and four in English. This is not to be seen as a problem that could affect the result though, but rather as an advantage since we could provide them with the possibility to express themselves in their own preferred language.

When it comes to data collection conducted through the use of questions, no matter if they are asked via a survey or during an interview, it is highly important to consider how the questions are formulated since this will be determining the type of answers that you get (Yin, 2014). The advantage of asking questions during a face-to-face interview though is that it is easier for the interviewer to see how the interviewee is reacting and responding to the questions, and it is hence also easier to discover if there seem to be any misunderstandings or misinterpretations, and these could thereby also rather easily be corrected or explained (Saunders, Lewis, & Thornhill, 2012). To avoid the risk of not getting the answers we were looking for due to poorly formulated questions, we have been contemplating advices found in the literature on how to formulate good questions. We then tested them on our supervisor and friends to see if they understood them correctly, and adjusted them when needed, before conducting the interviews. It has also been important to remember how to phrase improvised questions though, since the interview guide only is used as a support during the interview and if questions are asked differently than in the guide they still have to follow the different guide lines for how to affect the answers as little as possible and get the interviewee to tell as much as possible.

3.2.4.2 Observations

Observation as a data collection strategy serves as a basis for the collection of impressions of the phenomenon that is researched (McKechnie, 2008). Quantitative and qualitative researchers may work with observations, while the former is structured or systematic, the latter is non-structured, naturalistic and it is likely to be used to observe the participants and their environment (McKechnie, 2008). Observation is of high importance for exploratory and descriptive research (Bottorff, 2004), as through the use of the sight and hearing senses researchers can gain significant data (McKechnie, 2008), and validate and extend data (Bottorff, 2004) during the study, especially when combined with other data collection methods (Bottorff, 2004; McKechnie, 2008). Thereby we use personal observations in production sites so as to complement the data obtained through the interviews and secondary data collection.

The use of qualitative observations suits our research method as we are interested in studying the SMEs perception of i4.0 in Sweden, and how the SMEs see the expected industrial revolution by observing on one hand the interviewee’s verbal and non-verbal behaviours, attitude and believes (Bottorff, 2004; McKechnie, 2008) and, on the other hand we observe the setting of the production sites and organizations to assess their level of automation (Marvasti, 2014). We select unstructured observations as it assist exploratory researchers to be flexible when studying a new phenomenon in order to uncover new information (Bottorff, 2004). The observations are discreet and our presence does not affect or influence
the behaviour of the participants as it is not conducted as an explicit observation, but rather a walk around the company and its production site, and therefore the data collected is consider to be trustworthy (Bottorff, 2004).

3.3 Sampling

3.3.1 Sampling strategy

Based on our qualitative research method, we chose to use non-probability sampling techniques (Easterby-Smith et al., 2015; Saunders et al., 2012). We mainly used a purposive sampling strategy, a strategy that is described by Easterby-Smith et al. (2015) as when the researcher has a clear idea of what sample units are needed for the purpose of the study, approaches potential research objects to check if they fulfil the researcher’s requirements and if they do they are used, if they do not then they are rejected. We had a clear idea of what characteristics we wanted our case companies to have and created a list where we specified the criteria regarding the company size, industry and position in the supply chain, as well as the positions for the interviewees we wanted to talk at the case companies. The criteria we used were following:

- **Size:** Small (10-49 employees) and Medium (50-249 employees, preferably within the same part of the range, fine to differ around 50, and preferably at the higher end of the range, around 150-249 employees)
  
  **Motivation:** This since they may be more likely to have a more advanced production process if it’s a larger firm, and we want them to be at least somewhat familiar with more advanced technology so that they are not doing everything manually since the question about the feasibility then would be completely unnecessary and it would be hard to have long interviews when the answer is too obvious already at the beginning.

- **Industry:** Manufacturing. Has to be a product that could be customized, one way or another.
  
  **Motivation:** It does not have to be very customized today, but if it is a product that cannot be customized at all then the idea of self-optimizing, customized mass-production may not be that relevant either way.

- **Position in SC:** End manufacturer that is manufacturing or assembling the final product.
  
  **Motivation:** To be able to derive some kind of indication of the feasibility of implementing i4.0 in Swedish manufacturing SMEs based on the answers we get from the empirical findings, it would be good to have them all on the same level in the supply chain to avoid different answers due to different positions. The reason we want end manufacturers is once again that the probability of having products that could be customized may be higher.

- **Interviewee position:** Depending on the size and the structure of the company the name of the positions, apart from the CEO, may vary, so the following are the responsibility areas that we are aiming at reaching: 1. CEO, 2. Head of production, 3. Head of supply chain and logistics, 4. Head of production related purchasing, 5. Head of IT/ERP-system.

1 The ones in bold are our first hand priorities
Motivation: The CEO will have a more holistic and probably less detail oriented perspective of the company and its business, as well as being responsible for the strategic decisions which hence gives a very valuable insight and point of view. The head of production might be able to provide another angle as being the one who is more involved in the production process and having the detailed knowledge about the current operations, types of machines, efficiency within production, idle time at the different work stations etc. The head of supply chain and logistics as well as the head of purchasing, supported by the head of IT and ERP-systems, might be able to add yet another viewpoint as being the ones who are more in contact with the suppliers when supervising supplies and deliveries, and they might be able to provide a more detailed picture of how the interoperability between systems could work on a supply chain level.

In addition to the purposive sampling, we also wanted to ensure that we got to interview both small and medium sized companies and therefore we used a second sampling strategy, quota sampling. Quota sampling is when the chosen population is divided into different categories based on for instance gender or origin, with the purpose of being able to ensure that each category is represented according to a certain quota proportion chosen by the researcher (Easterby-Smith et al., 2015). In our case we wanted to have 1-2 small companies and 1-3 medium sized companies (sizes according to EU definitions), depending on how many we would need to approach and interview until we had reached the volume of data needed.

Finally, apart from wanting our case study objects to be producers manufacturing the end product and having a certain number of employees and turnover to classify as a SME, we also wanted them to be in the Jönköping area. Due to the fact that we added that final criteria one could argue that we also added a third sampling strategy, convenience sampling, since it was more convenient for us to visit local companies. Convenience sampling is described by Easterby-Smith et al. (2015) as a sampling method where the researcher selects sample units based on how easily accessed they are, and since we wanted to be able to visit our case study companies we found this last sampling strategy to be a suitable fit for our study.

3.3.2 Sampling process

The first search engine that we used to identify potential research objects was allabolag.se. It was not possible to filter on all our criteria that we had decided upon though, therefore, after using their filters for industry (manufacturing), turnover (50-500 million SEK for medium sized enterprises) and area (Jönköpings län) we still had hundreds of hits. Even though it was not possible to use a filter for whether the company had a parent company or not, this information could be found under the detailed descriptions of the companies. Since one of our criteria was that the case company could not have a parent company that could support them with capital or personnel (according to the EU definition of SMEs), we went through the results and excluded all those companies. It turned out to be rather difficult to find medium sized manufacturing companies that were independent. Most of the larger manufacturing SMEs that we identified were part of larger groups and did hence not fulfil our requirements or the SME-definition.

In an attempt to narrow down the number of results and try to find better filter functions with regards to our criteria we tried the databases “UpplysningsCentralen” (UC), InfoTorg and contacted Bolagsverket, but the databases required special access and none of them were able to help us. A contact at the Corporate Development department at Jönköping municipality helped us with access to the UC registers, something that could otherwise only be obtained through costly orders, and he also helped us identify companies that had production of own products. Unfortunately, the same problem occurred again with most companies being parts of larger groups. Due to these fruitless results despite our efforts, we had to
return to where we started, and what finally led us to our case companies was a close check-up of all hits at allabolag.se to identify all potential case companies based on the information available. The last step was then to call the candidates that we had identified, to in accordance with our purposive sampling strategy ensure that they fully matched our criteria, and then see if they were willing to take part in our study. Thanks to our thorough background check, all companies that we called did match our criteria. We contacted five companies in total out of which three were able and willing to take part in our research during the time frame we had for data collection. We did identify one additional potential candidate in Gislaved, but since we managed to retrieve enough data from the first three companies, contacting them was not needed.

3.4 Data analysis

After the collection of data, we follow the steps proposed by Roulston (2014) for analysing and presenting interview data. First a reduction of data is performed, the principal objective in this step is to interpret and to obtain the essence of the interview by eliminating the repetitive and irrelevant data. In the second step we reorganize the interview and observation data and present it in an organized way to provide the reader with a structured overview of the findings from each case company. In the third step we derive statements based on the findings that we then match with the different technologies and applications described in the theoretical framework to be able to identify benefits, trade-offs and barriers for each one of them. We then classify and categorize this data further through coding to find patterns. The codes are developed through reading, rereading, reflecting, writing and discussing. The statements are presented in three tables (Appendix 4), one for benefits, one for trade-offs and one for barriers, where they are sorted according to the corresponding technology or application as well as labelled with the given code.

3.5 Generalization

For the presented research and due to the novelty of the topic, we are looking to have diversity in our research subjects that can provide better insights and rich empirical data of the phenomenon as an alternative of having a representative sample that generalizes our research findings. When using a qualitative research method based on a case study strategy, researchers tend to have only a single case study or, as in our case a multiple case study, a relatively low number of cases. Yin (2014) argues that this means that it is not possible to do any statistical generalization based on the results from a case study, but that it on the other hand is possible to use it as a ground for an analytical generalization. Furthermore Rosaline (2008) mentions that statistical generalizability is not a problem for qualitative case study research as it is not the core objective of the method in the first place, and Putney (2010) added that multiple case study researchers need to be careful in the number of cases they chose to analyse due to the in-depth analysis of the empirical data obtained and the picture provided of every case. Instead, case study findings can be used to implicate new situations (Yin, 2014) and in the case of our case studies our findings can be used to give an implication as to whether Swedish manufacturing SMEs find i4.0 feasible for their type of business or not.
3.6 Ethics

Although ethics in research once was considered to be unnecessary and external to science, it has in more recent years gained attention and it is now part of the research design in order to protect the integrity of the participants and research community and to avoid misguidance and misleading of data (Easterby-Smith et al., 2015; Herrera, 2010).

The lists of the ethical disputes that may arise from performing a research could be endless, from issues as broad as religious and political, from legal to cultural concerns, intellectual matters and so forth, all depending on the perspective of the different actors involved in the research (Herrera, 2010). Therefore we follow the key principles in research ethics suggested by Easterby-Smith et al. (2015). Regarding the protection of research participants, all participants were treated equally and with dignity, as well as provided with a consent form (Appendix 1) in order to be informed about the aim of the research, asked for their permission to use their name, the organization’s name, and to ensure the confidentiality of the data. Although all the participants allowed us to record the interview for a better analysis of the data, not all agreed on the disclosure of their names and the recorded material, therefore we will only refer to all participants with the position they have within the organization. Regarding the protection of the integrity of research community, we were transparent on the purpose and the intended goal of the research by firstly contacting and informing the participants via phone about our intentions and objectives, secondly we confirmed the date agreed upon during our call via email to the respective participants, as well as providing them with a written introduction (Appendix 2) to our research topic. The purpose of the written information provided was to give them an overview and gain a basic understanding of the subject prior to the interview, and in an attempt to avoid any deception about the nature of the research.
4 EMPIRICAL FINDINGS

In this chapter we present our findings based on the material collected from our interviews and observations. It is presented company by company to provide the reader with a clear overview of each case company, covering their background, products, internal integration and current supply chain IT and interoperability.

Table 4-1. Interviewee information

<table>
<thead>
<tr>
<th>Company</th>
<th>Size #Employees</th>
<th>Interviewee</th>
<th>ID</th>
<th>Position/Title</th>
<th>Interview date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A*</td>
<td>ca 19</td>
<td>Worker A1**</td>
<td>WA1</td>
<td>Sales (and unofficial CEO)</td>
<td>2016-04-12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker A2**</td>
<td>WA2</td>
<td>Production/Logistics</td>
<td>2016-04-12</td>
</tr>
<tr>
<td>Company B*</td>
<td>ca 28</td>
<td>Worker B1**</td>
<td>WB1</td>
<td>CEO/Sales</td>
<td>2016-04-13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker B2**</td>
<td>WB2</td>
<td>Production Planning</td>
<td>2016-04-13</td>
</tr>
<tr>
<td>Company C*</td>
<td>ca 83</td>
<td>Worker C1**</td>
<td>WC1</td>
<td>CEO</td>
<td>2016-04-14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker C2**</td>
<td>WC2</td>
<td>Production manager</td>
<td>2016-04-14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker C2**</td>
<td>WC3</td>
<td>Purchasing/Logistics</td>
<td>2016-04-14</td>
</tr>
</tbody>
</table>

* The name of the company is fictional
**The respondent chose to be anonymous

Figure 4-1. Interviewee information

4.1 Company A

4.1.1 Company background

Everything started when the founder of the company—the great grandfather of the current sales manager—moved to the middle parts of Sweden to work in the long time established sawmill industry, where he learned and mastered the skill of tensioning the previously handled circular sawblades in the sawing sites. At the same time, Nässjö was becoming the major railway connection point in Sweden mainly due to its geographical location, allowing Nässjö to develop a strong forest industry. The traits of the growing city attracted many people to work and live there, among them the founder of Company A, whom in 1902 decided to open a sawblades repair shop, where the main chore was to repair and retention the circular sawblades that were used by the sawmills.

During the mid-30s, the two sons of the founder joined him in the task of picking up the circular sawblades at the railway station and soon they began looking for ways to grow the company, deciding to produce circular sawblades from scratch using the ones that were too damaged to be fixed by implementing a reheating process. After they grasped the production process they began to sell their new circular
sawblades to a company in Gothenburg that distributed the product to different customers. These two processes (producing and repairing circular sawblades) are still part of the activities that the company continue to do.

After a while and during the 70s, the company formed a joint-venture with a famous Swedish company that sold different sorts of blades, including the circular sawblade and Company A focused its attention only to the production of circular sawblades. The product was commercialized around the world under the brand of well-known company. In the course of this period Company A did only business with the reseller, the latter was in charge of the customers, export, distribution, and so forth, while company A was a simply producer.

Later on, heading to the end of the millennium, the reseller decided that they wanted to shut down the business and bring to an end the almost three decades of business partnership. Company A resolute that if they wanted to keep with the circular sawblades business, they needed to focus on the local market as they did not know how to export. Thereby they contacted the reseller’s Swedish customers in order to keep supplying them with the product. Most of the customers decided to keep working with company A and because of the century of experience that Company A has, they were able to stablish a close relationship with their customers by developing tailor made circular sawblades together with them to increase the performance of the blade.

4.1.2 Products

Company A produces big circular sawblades, which range from 600mm (the smallest one) to 2000mm (the biggest one) and furthermore, the equipment used to produce the big circular sawblades is different from the small circular sawblades, therefore they are not able to produce smaller circular sawblades. The most important material is a special type of metal alloy that is only available in one foundry in Europe and perhaps in the world, Company A usually buy it once or twice per year as the lead time is three months and a minimum quantity is needed so that the foundry produces it. And despite of the difficulties that company A faces to get the material, they rather continue to use it as its performance is high when use it under the tough conditions of the forestry industry. Depending on the needs of the customer, the circular sawblades may use other types of metal that are bought more easily.

According to Company A, tensioning is the process of stretching the circular sawblade by putting pressure and hammering it with the purpose of increasing the sawblade’s stability. Moreover, tensioning big sawblades is a process that only few people can do and it is difficult to double with a machine as the worker needs to “feel the tension”, thereby the tensioning process is still a highly manual work that depends on the skills of the worker.

The main customers are sawmills where big logs are sawn and cut into sheets and, private persons that have their own equipment to saw big logs every now and then. Currently Company A sells its products to different markets around the world and in Sweden under two different models. The first one is producing and selling standard circular sawblades using different distributors, usually this product is discarded by the customer itself, this type of production is not within the scope of this study. The second model involves the tailor made products that once are used by the customer, they are returned to the Company A’s production site to be renewed and retensioned. In order to keep track of the sawblades that will be returned for retensioning, Company A uses a number that is encrypted directly in the surface of the blade, this number provides the name of the customer, the number of times that has been renovated and retensioned and, the date it should be ready for shipping it back. Every sawblade can be renewed up to ten times before it needs to be melted to produce a new one.
4.1.2.1 Customization

The big circular saw blades are highly customizable and manufacturing custom-made products is one of the success factors of Company A. Different reasons exist for tailoring the product for instance, the size of the logs, extreme weather conditions that affects the traits of the logs -in winter logs are harder than in summer, rainy conditions also softer the woods-, the type of woods also determines the degree of hardness of the logs, and so on.

The customization can take place in different stages of the production, at the beginning of the process Company A cuts the circular sawblade with the desired size and, number and form of teeth. Afterward the original teeth are reinforced with a stronger metal teeth depending on the resistance of the woods. In the middle of the production process, the grinding is also customized according to the required thickness of the sawblade. Then the sawblades are retensioned manually one by one. Finally, the sawblades are covered with oil and packed to be shipped.

4.1.3 Internal integration

Company A uses a system called VISMA to manage their internal communication, the system helps them to track the status of an order from the moment they receive a requisition to the delivery, including the post-sale service offered to certain clients. The order is manually entered into the system with the special characteristics requested by the customer. The sawblades that are meant to get the after sales service, Company A engraves a unique number that can be traced during the entire life-cycle of the sawblade. The information becomes available for the different people working on the order, from the designers that sketch the drawing to the workers in the production site and the managers. Once one task is completed, the order need to be cleared from that step and send it to the next step. As this is a small company, if one person fails to conclude the task on the system, the next one requests personally to the previous worker to finish the chore so he or she can continue with the sequence. Besides the IT system, Company A uses meetings and communicate with each other during the lunch to keep track of the different activities that are taking part in the company.

In the production site the order can be accessed from four different screens allocated in strategic locations around the production area. The system then shows the tasks that need to be performed and the workstations that are plan to be used. Regardless of the automated level of the machines, workers are still in charge of moving the product from one workstation to another and supervise the right functioning of the machines.

4.1.4 Supply Chain IT & Interoperability

Though Company A has its own IT system for their internal integration, the system is not connected neither to its suppliers nor to its customers. Company A claims that they are “very traditional” and that they work in an “old-fashion way to do business”. Consequently, in the administrative area of the organization they use mainly telephone calls e-mails to share information with its customers and suppliers and believe that this is the only way that the company can do business as the key of their success is to understand the needs of the customer. Another way for them to communicate the performance of their product is by using a hand writing system where the customers write down the number of the sawblade, the functioning and other information that they consider is relevant for Company A.
Regarding the production site, Company A owns a machine that is connected to its supplier in Germany, however the supplier only inspects the status of the machine when requested by Company A and mainly to fix problems instead of monitor the functioning.

4.2 Company B

4.2.1 Company background

Company B was founded in 1983 by the current CEO and his brother, and started off as a small business designing and manufacturing rehab aid tools in wood and aluminium, down in their basement. In 1997 they were asked by another Swedish aid tool manufacturer if they wanted to buy that company since the owners were retiring. The other aid company had around 300-350 rehab aid tools that could be added to the current number of around 25 different aid tools, so the brothers decided to buy the other company and merge the two businesses into one. Around the same time the brothers were also asked to help a retail solution company to design and manufacture a display for bread, made out of wood, and this became the start of the main business of Company B as it is run today. The aids section still exists, but 28 out of the 32 employees are working within the food display and cash desk section of the company, and all together the company had a turnover of around 44 million SEK last year.

A strategic decision was made when the production of food displays and cash desks took off, to only focus on the manufacturing and being good at producing, using high quality materials, excellent machines and being able to deliver with short lead times. Thereby the decision was also made to let resellers take care of the sales and interaction with the end-customers, and today all sales are made through five different resellers.

4.2.2 Products

Apart from the over 350 aids within the aids section (that is not the focus of this study), the manufacturing section is mainly manufacturing cash desks and food displays. The cash desks are used in different stores such as books stores, hardware stores, design stores, gyms, pharmacies, in the small shops and gaming sections outside supermarkets, at post offices and petrol stations, sometimes also including the coffee and food section. The food displays are mainly used in supermarkets to display fruit or vegetables. Most of the products are made by different wooden materials, with the added possibility to have some parts made by glass or plastic.

The main material used in the production is wood and chipboard, which is bought with a certain finish to it already when delivered from the suppliers. These pieces are then cut to the right size, painted, holes are drilled using CNC-machines and edging is applied. Once all parts are ready they are also assembled to the finished product before they get delivered to the end customer so that they are ready to use as soon as they are put in place. This eliminates the risk of missing parts, a problem that could occur earlier when they used to send flat packages and had some parts delivered straight from the suppliers to the customer. The CEO argues that the added service of the assembly, and the elimination of the errors of missing parts, is compensating for the added transportation costs of sending the product fully assembled instead of as a flat package.
4.2.2.1  Environmental aspect

The environmental aspect is always considered throughout the production when it comes to choices of materials used and taking care of waste. Only water based paint is used, which is the most environmental friendly version, and all waste from wood, chipboards, plastic, paper and cardboard is being recycled. This is not something that Company B market a lot though, since they reason that most customers know that Swedish companies are good at this in general and it is understood and expected, even when not explicitly mentioned. Since the municipality is paying a small sum for each ton of waste that is recycled, this covers the costs for having a container on site and having it replaced when full, and therefore it goes without saying that recycling the waste is the only natural thing to do.

4.2.2.2  Customization

According to the CEO, around 90 percent of all orders are customized. The resellers help the customers design the layout for the whole store, as well as the design for the cash desks or displays as well. They then get feedback from Company B as to if there might be some ways that the design could be changed to display the products even better. Sometimes changes could also be suggested for the product to better fit the production process and thereby become cheaper, while still fulfilling its purpose in an equally good way. Apart from designing the shape of the cash desk or food display, the customization also includes the choice of different colours and materials, where the paint for instance might need to be approved for usage in contact with food, or the material might have to be made in a fire-proof or less flammable material to fulfil requirements from, for instance insurance companies.

4.2.3  Internal integration

Company B uses the business system VISMA and this is hence where the incoming orders are being registered after they have been received and where they are being processed all the way to the invoice. It is possible to follow the progress of the order via the system, but only to a certain extent. An order is only registered as processed when it is fully done at that station since there is no status available between 'work started' and 'work finished', which sometimes result in a whole order being stuck at a certain work station due to for example, lack of material. This also makes it hard for the production manager to estimate the delivery time since it is not possible to see how much of the order that is already done, without having to walk out into the manufacturing site and check manually.

Both the production manager and the CEO states that they have been wanting to get a Material Requirement Planning-system (MRP system) for some time, but that it is hard to find the right one. They agree on that the company has grown fast over the last years and that VISMA is not good enough as the only IT-system anymore. A new and better suited system could help them identify the actual production time for an order and better be able to schedule the production efficiently and reduce the idle time at several work stations. It would also allow personnel to follow the order via the system throughout the production process and its different stages, and through that also get more detailed real-time information on how much of the order that has already been processed at a certain work station, for instance, if it is one item out of a hundred or if it is fifty out of a hundred.

4.2.4  Supplier IT & Interoperability

Company B has one main supply chain for each one of the main materials wood, metal, plastic and glass. In general, the supply side has three supply tiers for each of these materials. Wood for instance, is bought
from a reseller in Sweden, who is buying from a manufacturer in Austria, who is buying its raw material from an Austrian forestry. The production manager is the one that has the most frequent correspondence with the current suppliers. Most communication is regarding material availability and delivery dates and is done via e-mails or over the phone. Since customers are normally given a delivery date based on estimations of material availability and average delivery times, these dates are quite often subjects to change. Often the exchange of information is rather basic though, and the production manager admits that a joint IT system where everyone could see that actual material availability and how far certain orders have gotten in the process would have saved a lot of time for everyone.

According to the CEO, all of the first tier suppliers are using rather simple business systems today, equal to the one used at Company B, any they do not currently have any interconnection between their systems on any level. If they were to use interconnected systems instead, where they could not only enter each other’s systems to check for material availability, but also have the orders being visible and synchronized the whole way through straight away, something the CEO believes could lead to massively reduced lead-times. Since the orders are entered manually at each company today this adds a few days of lead-time for each step since they are most times not being taken care of straight away.

4.2.5 Future

The CEO have been looking for robots suitable for this type of smaller production scale, but it is hard to find. The metal sector provides a better range of robots than the wood industry, where close to all, if not all robots are designed to fit larger industries. They are looking for something a little less advanced that could handle the small batch sizes and that is affordable also for a smaller company – “The ones that are currently on the market are nice, but too expensive for the small scale production we are running”.

The production manager on the other hand can see a value in reducing paper work done manually since papers tend to get lost, and piles of material are sometimes found in the production site without a production order attached to them stating what has already been done and what is left to do. Even though a system where every work piece is registered and tracked throughout the production could be interesting and valuable, it is questioned whether a small scale production like this one would be able to gain enough from it to compensate for the costs of buying and implementing the system. On the subject of automating the whole production site, the production manager cannot see how machines could replace all workers - “We will still need the manual handling the whole way”. Today there is one operator per machine. Human knowledge and experience is hard to replace, and for robots to possess enough knowledge they require programming, which takes time and requires different settings for all different tasks, something that might require more time to program than it saves with having the robot doing it, due to the small batch sizes.

4.3 Company C

4.3.1 Company background

Company C is a Swedish printing company based in Bankeryd, Sweden. It was founded in 1991 by the current CEO and was initially only operating as a reseller of envelops. After a few years they started to print envelopes themselves and in 1999 they opened up a web-to-print shop and expanded to other printed products as well due to the declining market for envelops. Today they have a turnover of around 170 million SEK and their main business is still printed envelops, but they have also developed other sections within the business such as expo printing and printed office supplies and business cards.
All business is done via resellers since printed products normally not are high priority items for the end customer and they prefer to have suppliers that can supply them with more products, either in terms of prints on all kinds of products, or in terms of a full range of office supplies. The decision to sell via resellers was not only strategic in the sense of not having to have a large sales team, but the CEO also describes how they, by strictly enforcing to only sell via resellers, have built up a trust among their customers. The fact that they will not try to steal the resellers’ customers makes them rather unique, since that is otherwise rather common within the industry and creates a lot of uncertainty and dissatisfaction among the resellers.

4.3.1.1 Current market situation

Envelopes, both printed and non-printed, does still compose around 50 percent of the current business, but it is a declining market. In year 2000, approximately 4 billion envelopes were used in Sweden. Last year, in 2015, this figure was only 1.4 billion envelopes. The market has been declining at a steady pace of around 5-7 percent per year over the last years, and one of the main reasons to this is the increasing number of invoices being sent electronically today instead of via mail. The CEO does not think that we will stop use envelopes entirely, but he is estimating a continued decrease of the envelope market over the next few years and that it later on might stabilize at around half of the current market volume, with a more sustainable level of around 0.7 billion envelopes used in Sweden per year.

The CEO of Company C is stressing that it is hard to grow business within a declining market, but that the aim is to stay competitive and gain market shares instead, at the same time as they expand their business into other printed products as well in an attempt to be able to offer as many different printed products as possible. The CEO is also arguing that the good thing about competing in a declining market is that the threat from new entries is very low since it is not very attractive to establish new business within that kind of market.

Today they have around 1 000 resellers in Sweden and Denmark as customers, out of which some buy all of their different products, while others only buy pens, business cards or envelopes, and approximately 95 percent of the resellers’ customers are large enterprises. The CEO estimates the potential market to be around 4 500 customers though. Most of them are print shops or advertising companies.

4.3.2 Products

As previously mentioned, 50 percent of the current business is based on printed and non-printed envelopes, and approximately half of all envelopes sold are without print and hence pure resales. The other half is printed before it is shipped to the end customers, and this is mainly done in two different ways, either digitally or in the more old-school way of printing which is called offset printing.

When it comes to the offset printing machines, the machine can only print one colour at the time, and the production is planned accordingly to minimize the amount of times that the operators have to change colour and clean the machine, since this is idle time when the machine cannot be used for printing. Company C has invested in new digital printers as well, but even though these ones do not require any change of colours in the same way as the older ones, and hence do not have any downtime for this, they are still only efficient to use on smaller batch sizes since the printing speed is not even close to the one of the older, offset printers. The digital printers they currently use in their production can print around 2000 envelopes per hour, compared to the offset printers that print up to 25 000 envelopes per hour. Due to the setup time for the offset printers they are only used for orders or batch sizes with over 500 prints though. Today the average order is on around 5 000 prints, and very few orders are under 500, but the
CEO predicts that digital printing still might take on a larger role in the production in the future, due to decreasing order sizes and efficiency improvement of new digital printers for envelopes. This development of printer efficiency when it comes to envelope printers is moving rather slowly though, but the breaking point between offset and digital printing efficiency is expected to be able to increase to a batch size of around 1000 prints.

In addition to the envelopes they are currently also printing business cards, letter heads, notepads, invoices, indexes, folders, paper bags, cardboard boxes, gift bags, expo prints and pens, and the latest addition to their printed product range is t-shirts, which still is in a start-up phase though. The business cards, expo prints and t-shirts are all printed digitally, and the t-shirt printer for instance is very high-tech and takes care of the colours itself so that the only thing that has to be planned with regards to production is the material that is printed on.

All of the items that are printed at Company C are bought from suppliers, and the only production they have in-house is hence the printing.

4.3.2.1   Environmental aspect

The whole shop is ISO-certified for quality and environment, and Company C believes that it is very important to consider the environmental aspect of their production. In addition to that they have a standard series that is licensed by the Nordic Ecolabel (also known as “Svanen” or “The Swan”), and all printed products can be printed on material that is approved by the Nordic Ecolabel. Not all customers choose to buy the Swan-licensed products, but the CEO still thinks it is important to offer them the possibility to buy environmental friendly products, especially since trends in society are moving towards an increased awareness on environmental impact, and it provides a good image. This also applies to the new t-shirt printing where the customer will able to choose between licensed and non-licensed t-shirts.

4.3.2.2   Customization

The customization at Company C is only applied on the printed products, since that is their production and the rest is pure reselling. Company logos are being printed on envelopes, pens and other office supplies, and business cards and expo prints are printed according to customer design. The orders range from just adding a small logo to an envelope, to having special shaped envelopes with full colour prints all over it, but most orders are standard products with customized prints.

4.3.3   Internal integration

The order process is based on two main structures, one for the printed products and one for the reselling of products without prints. Since all prints are customer specific these products are never made to stock. Instead, all of the printed products are always made to order, with a lead time of 3-5 days for digital prints and 4-8 days for offset prints depending on how the order fits with the production planning. The order can be tracked and traced throughout the whole production. The production uses its own production system called the “iProd” where virtual copies of the finished products are stored and can be accessed by the operators at each printing machine via iPads that are placed out at each station. The iPads are used to steer the production process, as well as to send information to the production management on the performance of both the operator and the machine. The iPads are also connected to the intranet and used as a mean to keep workers updated on internal information.
Company C has its own business system where they register incoming orders and process them all the way to the invoice. Most orders are received via email and then entered manually into the business system and the production system, but they also have a direct channel from the web-to-print shops where the end customers’ orders are transferred straight from the web shop to the production system. The web-to-print shop is currently used by around 400 end customers, but it is designed to give the user the impression that it is ordering from the reseller and Company C is then invoicing the reseller by the end of each month for all products sold. The end customer also receives updates via texts about the order progress, informing them when the package is shipped from the production.

4.3.4 Supplier IT & Interoperability

The average supply chain, from raw material to end customer, consists of six tiers. Taking the envelopes as an example, then the end customer places an order at the reseller, who buys from Company C, who prints on products bought from their supplier, who buys paper from a papermill, who buys their raw material from a forestry. Company C has 2-3 really large suppliers from which they buy almost all of their envelopes and paper products. One of them is a large German manufacturer, that also is a part-owner and owns 25 percent of Company C, and they have a very close relation where they exchange some numbers on the manufacturing efficiency and Company C receive some information that makes it possible for them to benchmark themselves against other printing companies.

The purchasing and logistics manager provides a picture of a rather difficult situation when it comes to finding good suppliers. Most of them do not want to sell to companies that are competitors to their current customers. The market is described to be divided between the big sellers, which makes it hard to pick and choose between suppliers or to change their current ones if they would want to, since it is very difficult to find other suppliers that are willing to sell to them. This is also mentioned as one of the reasons as to why most supplier relationships are close and long-term relations. According to the production manager, most of all products that are sold, printed and non-printed, are bought from 10-15 suppliers. Apart from the 2-3 ones supplying paper products, they have five major suppliers for the expo print products, and the rest are supplying them with smaller product categories and special products. Most suppliers are located in Sweden and Germany, and some in England, Poland and the Netherlands.

The non-printed products are ordered in bulk from suppliers based on a forecasted demand. In order to get the best prices, they buy large quantities of each type of envelope, and the orders are being placed to fit with the supplier’s production schedule since it is cheaper for them to buy it directly when the supplier is producing it than if the supplier has to store it first. Due to this Company C have several pallets each of around 300 different envelope models in stock. This might sound economically inefficient, but the CEO argues that it is absolutely necessary to always have everything in stock, especially when it comes to the products where they are acting as a reseller, since the competition is fierce and low price and ability to deliver straight away is crucial to not lose customers. In this case, having everything in stock is regarded as a service offer to the customer, and since they never know if a customer will order 1000 envelopes or two full pallets, they must have large quantities in stock.

Material for the printed products on the other hand, is ordered internally between the different business units. That way they can avoid long lead times, which in turn facilitates for the possibility to push orders through the system in case a customer has an urgent order with short notice, something that would not had been possible with just-in-time (JIT) deliveries. Since almost all products are ordered in bulk from the suppliers, none of the interviewed employees can see any benefits from being able to see the end customer’s order straight away as it is placed at the reseller, as they still only buy large quantities when prices are low and keep it in stock, and the delay of the information does hence not make any difference.
When it comes to connected systems and services the production manager mentions that the newest digital printers they have are connected to the suppliers so that they can see the current ink-level in real-time and automatically order and send more as soon as it starts to run low on any ink colour.

4.3.5 Future

The CEO expects the envelope business to still represent around 40 percent of the sales in five years from now. He explains that most improvements that could be done within this segment has already been done since it used to represent around 70 percent of sales only 3-4 years ago and hence has been the centre of attention when it comes to exploring potential development opportunities. Further development of that area is also rather restricted due to the declining trend within the market, which in extension leads to that the development of new machines for this type of production is starting to cease. The old school printers are hard to integrate in any kind of automated processes that are more advanced than the current ones, and the digital printers are unlikely to evolve into being as efficient as the old ones since no one wants to spend a lot of money on developing advanced high-tech machines for a shrinking market. The CEO is looking upon this in two different ways. The good thing is that there is no need to invest a lot of money in new technology within that section, but the bad part is that they cannot benefit from new technology that probably could be applied to the processes if anyone bothered to design new machines with the latest technology.

Within the other sections he can see a lot of potential for improvements though, especially when it comes to optimizing production, increasing the level of automation and working towards a material flow that is closer to JIT. The production manager can see potentials with a more automated production planning. Today the production planner manually assigns different jobs to different machines, depending on what colours are to be printed and what machine and which operator is most suitable and efficient for the individual jobs, by placing the printed order in a rack as well as electronically putting it in line for that machine. The worker then picks up the orders in the rack and collects the material needed for the printing manually, while colours for the offset printing are mixed by a machine after the colour code has been typed in. He believes that parts of this process could be automated since there are some patterns and rules to how the assigning process is done.

The purchasing and logistics manager is the one that appears to be most sceptic when it comes to imagining a future that might be more interconnected. She explains how a lot of information would be sensitive to share with suppliers, such as if they were to be able to see what prices they charged their customers for different products or even just the names of their customers since some suppliers are direct competitors in some fields.

The company is expected to keep growing and there is room for another production facility in connection to the current ones, but since the envelope market is irreversibly declining it is important to increase focus on developing the other parts of the company to stay competitive.
5 ANALYSIS

In this chapter we first present an analysis of each company covering an evaluation of the company’s current level against the provided theoretical framework, followed by the identified benefits, trade-offs and barriers with these technologies and applications for the respective company. We then provide a compiled analysis for each component of i4.0 based on the findings from all companies, and finally we discuss some of the differences found between the different companies in the analysis.

5.1 Company A

5.1.1 Evaluation of current level against framework

The level of automation in Company A’s production site differs in some of the stations depending on the task that needs to be executed. Based on the Level of Automation assessment from Frohm et al. (2008), we assert that except for the tensioning station where the level of automation is level 4 and work is still done manually with assistance of some automated tools, most of the equipment is ranked in level 5 meaning that the gears are automatic and designed to carry out one specific task, additionally the connection between stations is still done by workers that move the product from one place to another. On the other hand, the information and control level ranks in 3 as the worker uses a checklist system to achieve the task successfully.

Regarding the technologies used in the organization and compared to the concepts of i4.0, Company A implemented an IT system in the past two years that is mainly used for administrative work, and when it comes to the production site, the IT system is used to display the production status of an order resembling what it could be a first step of the CPS. Though company A is not using any kind controllers, they are engraving the product with numbers and letters that can be tracked in the production site using the IT system, this resembles the IoT. Company A also has a machine that can be connected to the supplier that provides the maintenance service in order to provide examinations when Company A request it, this is similar to IoS functions. About the Smart Factory application, Company A is not as developed and is lacking of a system that can communicate with other subsystems.

5.1.2 Identified potential benefits, trade-offs and barriers

The identified benefits in Company A are mainly related to IoT, IoS and Smart Factory. From IoT and IoS company A expressed that they will be able to track down problems related to the different components of the product and the final product itself, and equally important they will be able to monitor the environmental impact of the item in order to reduce the manufactured goods’ footprint, which goes in line with one of the goals of Projekt 2030, which is the reduction of the environmental impact of manufactured goods. Regarding the Smart Factory, Company A would benefit from getting the raw material with the right features, reducing lead time and costs. Additionally, in Company A we identified a reduction of the labour cost due to the use of self-aware machines but at the same time they see this decrease on the use of workers as a trade-off because they have a strong relationship with the employees and care about them as a family. As company A has an old-fashion way of doing business, they also see as a trade-off the ease of maintenance and fixing the machines themselves as now with the high technology they will have to find an external supplier for this service.

We recognised several barriers that Company A might encounter in the probable implementation of i4.0, these are associated to the Smart Factory feature and the cost related with escalating the production site
and the organization to a level where i4.0 can be implemented. Apart from the high costs associated with this kind of upgrading, the static market does probably not have any demand for the increased output an optimized production site would result in which makes it even hard to see a value in making this kind of investments. By having an automated production site the quality of the final product might also be compromised as the machines are not going to be able to get the “feeling” during the tensioning and retensioning steps to produce a high quality circular saw blade. Interoperability faces two barriers, the cost of making the organization interoperable and the threats that sharing information with others convey as they believe that if the information is in a system then the competitors will be able to access it and benefit from it. Regarding CPS, they expect that loading the information to a new system demands much effort from employees. From the IoT perspective we identified that the characteristics of the product and the working environment that the manufactured product faces is challenging so as the application of a tracking device or chip would be impossible. From the IoS point of view, Company A would rather prefer to own their own machines and run them as they need than leasing the equipment and be under the threat that the provider of the machines and maintenance services suddenly shuts down affecting the Company A’s business.

5.2 Company B

5.2.1 Evaluation of current level against framework

Company B does currently have a quite high automation level when it comes to performing the different tasks at each station within the production, but the transportation of the products between the stations is still done manually and each machine has its own operator supervising the work. When assessed against the “Level of Automation” framework created by (Frohm et al., 2008) Company B could be considered to be on mechanical and equipment automation level 6, “Flexible machine/workstation”, as they are using CNC-machines in their production that can be reconfigured and programmed to perform several different tasks. Regarding the information and control level they are on the other hand rather on level 3, “Teaching”, as the customer order, once it has been entered to the system together with the blue prints, provides the system, and thereby also the machines and the workers, with a list of what needs to be done, at what stations and in what order.

When it comes to the different technologies and concepts of i4.0 they do not have anything that could classify as IoT or IoS as the only identification that follows components and material in the production is a printed order, and machines are not connected to their suppliers for breakdown prevention in line with how it is described by (Hermann et al., 2015), this is only handled through predefined service contracts. There is a virtual copy of the finished product in the production system though, that can be accessed from all workstations and machines, which implies that they are using something that reminds of a CPS the way that Hermann et al. (2015) describes how it monitors the physical process in relation to a virtual copy, but with the difference that the virtual copy does not mirror the progress in the physical world, this is only shown by confirmations from the different work stations when the batch is completed. There is currently nothing smart about the production at Company B though. The routing of a product through the production site is not fixed as mentioned by (Wang et al., 2016) as a feature of a traditional production line, but this can be explained by the fact that the products are not mass produced and hence needs a more dynamic routing depending on the different features of the product, but it still cannot be classified as smart since the decisions for the dynamic routing are all made by the workers and not the machines, just as the transportation between the different work stations.
5.2.2 Identified potential benefits, trade-offs and barriers

The identified benefits from a potential i4.0 implementation at Company B can be found within CPS, IoT, IoS and smart factory as well as interoperability. The ability to trace material and components with the help of RFID and IoT was mentioned as a valuable feature in order to both be able to monitor more precisely how far in the production process a certain product had gotten, instead of only being able to see when the whole batch is done at a station, and to be able to locate material that sometimes go missing within the own production site. The service provided through IoS was also mentioned as something that could help ensure a more stable production without unforeseen breakdowns or having to replace spare parts unnecessarily early, since the current system with contracted, prescheduled maintenance was not always working seamlessly smooth. The CNC-machines were specifically mentioned in this sense since the whole production line gets affected if one of them break down. Benefits identified related to CPS and interoperability were mainly the value of real-time information throughout the supply chain since this would facilitate for a better demand accuracy for Company B if they could see the actual demand of the end customer instead of only working based on the demand estimated by their customer. They could also see how this could shorten lead times if the suppliers down the line could see the orders straight away and could start preparing the material immediately instead of the order being delayed a few days at each supplier before being entered into their system and passed on to the next supplier in line. Shorter lead times was also seen as a way to become more competitive as all customers value to get the product as fast as possible once they have decided on what they want.

Finally, having a smart factory that could better optimize production through better machine utilization was also identified as a benefit for Company B, and if this could be reached without increasing operations costs too much then the increased output would result in a lower average cost, leading to a competitive advantage and a possibility to gain market shares on a normally rather saturated market.

Despite all the positive thoughts, a trade-off from using smart factories was also identified. If the whole production were to be fully automized with machines executing the tasks and making conscious decisions based on how they have been programmed, then it might take a lot longer to discover a programming mistake. If someone have made a mistake in the settings for the CNC-machines today, when they all have their own operator supervising the work, then the operator with his logic thinking and knowledge from experience would be able to discover if the robot is doing something wrong due to a programming fault, before too many pieces of wood have had for instance a hole drilled in the wrong place. If the machines are working all alone on the other hand, a whole batch might have to be discarded since the mistake was not discovered until the batch was inspected before sent off to the customer, or when it was not possible to assemble the parts.

There are also still a lot of barriers to a realization of the smart factory. New machines and systems would be needed within the whole production and this would be an enormous investment for a small company such as Company B. Another barrier is that most new, high-tech machines available on the market or the ones being developed for production within this industry are designed to fit companies with a much larger production volume. The small scale production is additionally the reason behind the doubt as to if it would be worth to go through with this type of change, if there is a market for the increased capacity and if it will cover the investments. We could also identify a scepticism towards the capability of the technology to run itself and being able to make the right decisions and discover mistakes, as seen with the mentioned trade-offs, and this could be seen as a barrier in the mindset towards the smart factory. This was partly admitted by WB2 as well when the lack of knowledge of how to setup a smart factory was mentioned as a possible barrier.
5.3 Company C

5.3.1 Evaluation of current level against framework

The technical level of the production at Company C varies between the different parts of the production since the offset printers are using an older technique but are controlled by the iProd-system via the iPads, while some of the digital printers are very high-tech. When assessed against the Level of Automation framework (Frohm et al., 2008) the mechanical and equipment automation level could be considered to reach the 5th level, “Static machine/workstation” on most machines within the envelope printing as all the offset printers are automatic but only designed to perform one task. The digital poster printers on the other hand could classify as automation level 6, “Flexible machine/workstation”, in the mechanical and equipment category as they are optimizing their own production, printing in the most efficient order, and they are flexible enough to print different prints on each sheet without manual reconfiguration in-between.

Regarding the automation level for information and control the offset printers only reach the 3rd level though as the iProd connected to them via the iPads provide the worker with a list of the jobs to be done as well as instructions to print the labels for the box of printed envelopes before the next order can be started. Then again the poster printers could be classified as level 6, “Intervene”, as they are self-optimizing, and can also assess the colour output themselves to ensure an even usage and distribution of the print colours.

In relation to the i4.0 technologies and concepts of value chain organization (Hermann et al., 2015) Company C is probably the one out of the three case companies that is working closest to the idea of i4.0, even though it is still mainly small, internal things within certain parts of the production, and they still have a lot left until they are closer to a more holistic implementation on all levels. They do not have anything like IoT where each component is marked with their own RFID, and this would probably also not be valuable in this kind of production as the finished product is not assembled from several different components, but it is rather just one product, for instance an envelope, that gets printed, so the only value in having id tags on the envelopes would be so that they could be sent to the right printer and get the right print printed on them. The self-service system for the poster printers could definitely classify as a level of IoS though, since the printer is constantly connected to the supplier who immediately receives a message if when the ink is starting to run low and automatically sends new ink without Company C having to do anything at all. This service is a form of breakdown prevention (Hermann et al., 2015) that is aimed at keeping the printer running and functioning nonstop. The iProd system have some similarities with a CPS as virtual copies of the finished product are to be found and accessed from all monitors in the production through the system, as well as real-time information on how far a certain order has gotten in the production process. But it still has not reached the level where the virtual copy is reflecting the physical world throughout all steps of the production and make decentralized decisions in the way it is described by Hermann et al. (2015)

The way production is done today there is nothing smart about the factory itself, and hence it is not a smart factory yet, but as shown above it already has some of the components needed at individual workstations. The interconnectivity between the machines and the ability for them to be self-organizing, in line with what is suggested by Wang et al. (2016), are two major things, out of several, still missing for it to be close to something defined as a smart factory.
5.3.2 Identified potential benefits, trade-offs and barriers

The benefits identified for Company C if they were to implement the concept of i4.0 were mainly related to the features of smart factories and how they can optimize production and the use of resources. The assignment of tasks to workers and machines depending on their capabilities and strengths could most likely both be done faster and better by a smart system. Production time could be reduced in most parts of the production through better optimization, and all parts but the envelope business could also improve efficiency and reduce costs through automation and with just-in-time deliveries. Using the CPS for interoperability within the supply chain was seen as having some positive aspects, especially if the main supplier could see their inventory levels and send more when needed, before they run out, without them having to order it manually themselves.

Even though several parts of the production could benefit from the self-optimization of smart factories, Company C also brought up many trade-offs on an i4.0 level that were all connected with the idea of having an integrated, flexible supply chain with on demand production instead of having large stocks at the own site. Since the lead-time for the printed envelopes is quite short already to begin with it would be hard to keep the same short lead-times if the wood pulp would not be made into an envelope until an order have been placed from the end customer, and if the lead-times cannot be kept short enough then there is a risk of losing the customer. This risk is even higher if the order would be for non-printed items, since these are easy to buy from other suppliers as well then short lead-times, low prices and the ability to deliver is essential to keep customers. Not only the lead-times are in danger when moving towards a just-in-time delivery model, but also the second key competition aspect, the prices, since only buying small quantities based on orders would not result in the same low prices as buying in bulk at the time when it is produced, and hence the price per item would be higher. Company C also mention the insecurity of being dependant on the supplier for the ability to deliver, instead of being in control yourself by having your own stock. This dependence is also related to losing the sense of control since not having your own stock makes it impossible to “push an order” through the system for faster delivery when the customer requires it.

Finally, we also identified some actual barriers to a potential implementation of i4.0 at Company C. The main barrier would definitely be that since envelope printing is a dying business there are no new machines developed for this purpose anymore, and this will hence be a massive barrier, at least for that part of the production, since new machines would be needed to handle the new technology for interconnectivity and communication for interoperability. There was also an expressed concern regarding the sharing of information throughout the supply chain since some of Company C’s suppliers also are their competitors, and they would due to that not want them to be able to see who their customers are or what they are charging them for the products.

5.4 The technologies and applications of i4.0

5.4.1 Internet of Things

The identified benefits of having IoT were categorized as technological, environmental, information and product related, where the technological benefits referred to IoT as an enabler for a higher machine utilization thanks to better production planning, while the ability to collect information on the usage of the product throughout the whole product life cycle to facilitate for better product development, and to be able to backtrack problems and identify the affected products was categorized as product and environmental related benefits. If the material and components had RFID tags this would also make it easier to find material that has gone missing within the own production site.
None of the case companies expressed anything that could be interpreted as a trade-off with using IoT. But Company A expressed a concern about the tough environment where the sawblades are used, since they get very warm from the friction and the surface is worn down, then a RFID-tag would most likely not stay on the blades and thereby not possible use in the intended way, a circumstance that hence could be identified as a barrier.

5.4.2 Internet of Services

Tracking down problems was mentioned by WA2 as a benefit with the usage of IoS, and WB1 could see a great value in that IoS is supposed to discover and prevent problems or breakdowns even before they occur, two features that both could be classified as technological benefits. But at the same time handing over the control over maintenance of the machines fully to the supplier could also be identified as a trade-off (WA1) by Company A as they had been used to be able to perform most maintenance themselves, and losing that control would make them feel a bit more vulnerable and dependant in a way WA1 did not like. This dependence could also be seen as a barrier since Company A is an old family owned firm that always have been used to being independent, and they therefore feel resistant to being too dependent on others and WA1 expressed a fear of the risk of having someone come to pick up machines from the production because they, due to the new business models, only would rent the function of the machine instead of owning it themselves, and if the supplier would go bankrupt they would need them back to cover their debt and Company A would not be able to produce or deliver according to plan anymore.

5.4.3 Cyber-Physical Systems

CPS is the place created for the physical and virtual world of production sites to meet and construct Smart Factories. Aligned with our observations, interviews, the LoA and the 5C structure for implementing CPS, we recognise that the researched subjects have a certain level of automation however it varies from one station to another making difficult to integrate a network of interconnected machines and furthermore none of them have the level of automation required to implement a CPS.

We identified that the researched companies agreed on that they will experience benefits in the long term mostly related to the accuracy and real-time information sharing fostered by the use IoT, additionally they also feel confident that the enabled IoS will support them to prevent break-downs, especially in key tasks machines.

On the other hand, we identified that the implementation represents an economical and technological barrier for them, particularly during the setup phase as they believe that a huge investment has to be done to update the facilities to allow the system to work and communicate with the different components of the Smart Factory, moreover loading the data into the system will consume many of the human resources of the company during a long time. From the legal perspective while for some companies this is not an issue, for others this represents that the information will be endangered and therefore a legal framework should be developed before embracing this technology.

In this research we did not identify any trade-offs associated with CPS.

5.4.4 Smart Factory

According to Lucke et al (2008), a Smart Factory is a factory that is aware of its environment and assists people and machines to execute their tasks by the means of systems that communicate and interact with
each other. Furthermore, there are several differences between the traditional production line and the smart factory production system (Wang et al., 2016).

According to Wang et al (2016), one of the characteristics of a Smart Production System is the need of a wide range of “diverse resources” due to the diverse range of products offered, but we also found that the researched SMEs have the ability to produce tailor made items, and even though they are not currently producing as smart factories they still have the same need for a wide range of resources to fulfill the customers’ needs. Based on this we assert that this characteristic does not apply to SMEs, since they generally do not have the same mass production lines as large companies, but rather already a more flexible production suitable for customized production. Furthermore, these SMEs do not follow a configured production route as the items are transported from one work station to another by the worker, either manually or using a trolley. The rest of the traits differs from one company to another, and furthermore these varies from one machine to another, for instance one of the machines in Company C has “comprehensive connections” as suggested by the Smart Factory production system and could be classified as being in-between the “separated layer” of a traditional production line and “deep convergence” of the Smart Factory production system. Additionally, the machines are configured to execute one repetitive task and the sequence of the production is affected if one brakes down as the “independent control” suggests, and the information generated is “isolated information” that rarely is shared and used by others, as the traditional production line proposed.

Lots of the benefits that SMEs encounter when enabling the Smart Factory application, are related to the optimization of the production line, this optimization leads to economic benefits such as reduction of costs due to a better planning, less storage, reduced lead times, reduce the consumption of resources for instance human labour and raw material. Another benefit identified is the accurate and real-time information flow.

We also identified technological and social trade-offs when it comes to the use of the Smart Factory, in the traditional production line if someone entered wrong data to the system, workers are still able to identified this mistakes as they can judge and take decisions from their own previous experiences, while if the data is wrong from the beginning, machines will not be able to judge if the task is right or wrong as they are doing what they were programmed to do. From the social perspective and with the introduction of fully automized factories, they foresee a reduction of the human labour force.

When it comes to barriers, we spotted technological, quality, economical and mindset. When talking about technological barriers, we identified that the companies doubt that the machine producers will work towards a smart machine due to the small market share of these specialized productions and furthermore, even if they produce smart machines, the companies questioned if they will be smart enough to make decisions and perform tasks that are inherent to the human reasoning. The latter can also be related to the quality issue as the different interviewees mentioned that machines are not capable of performing the tasks as good as a human worker. Regarding the economic barriers, we identified that is related to the setup stage as the cost of implementing this technology might exceed the benefits gained from the Smart Factories. The last barrier that we encounter is the mindset since the interviewees wondered if this technology is really effective for their companies, moreover some negative previous experiences with IT systems make them to hesitate about trying a new one.

5.4.5 Interoperability

As interoperability is about enabling the communication between different systems and subsystems, the benefits recognized are mainly in the supply chain. Companies will be more responsive due to the
information will allow them to adapt faster to changes and also, they will be more efficient as to they will shorten lead times and use resources more efficiently.

On the other hand, the identified barriers are economic as they are concerned about the cost of enabling this technology and also the confidentiality of the information as they are worried about who will access this information, the treatment and usage by other users.

During this study, no trade-offs were identified related to interoperability.

5.5 Analysis discussion

Looking at the results from our analysis we can see a lot of similarities, but also some differing results from the different companies, differences that cannot always be explained by their current technological level. A certain feature of i4.0 can for instance be perceived as a benefit by one company and a trade-off or barrier for another company. Having orders automatically processed the whole way throughout the supply chain is an example of a such feature, where Company B sees it as a benefit that the first supplier receives the order faster and thereby can start preparing the material for the order, while Company C sees it as a trade-off or even barrier to apply an order based just-in-time delivery system since it would make it hard for them to stay competitive with regards to prices and lead-times. These differences appear to be related to the individual business strategies and the characteristics of the products, rather than the actual ability to implement the suggested technology. Envelopes are small, easy to keep in stock and even though some are customized it does not take long to print an envelope. The end customers are often indifferent to who is doing the printing, and availability, low prices and short lead-time is of high importance to not lose customers since transaction costs are low and competition tough. Cash-desks on the other hand are large, and practically none of the material is kept in stock as it is too spacious. Delivery times are accepted to be longer since the whole product is designed and built from scratch. It is also something that you buy once and not a commodity, as opposed to the envelopes that you only use once and that are easily replaced with another brand. Since a lot of the cash-desk material is ordered on demand, sometimes several steps back in the supply chain, it then makes sense that the real-time information for demand, throughout the whole supply chain, would be more beneficial in this context since it could speed up the lead-time.

We could also see that the company culture seems play an important role when it comes to how open-minded the different individuals are to more radical changes of the production and how the company is run. Company A did for instance mention their traditional background being a family firm as a reason to be more conservative and value having their workers there instead of replacing them with more efficient machines, since they all are like family. Another thing we could see that is likely to have a large impact on if the SME’s will adopt to certain changes or not is the mind-set of the people in charge, this is based on that some of the trade-offs and barriers mentioned by the interviewees themselves would not actually have to be a problem if the technologies and applications were implemented as intended. Often this turned out to be a result of the lacking knowledge regarding the new technology and its applications, but sometimes we could also identify a closed mind-set and a lack of interest to see the possibility and potentials with doing things differently.
6 CONCLUSIONS

In this chapter we go over the theoretical implications that can be made based on this study, followed by social and ethical implications, and managerial implications for the future aspects of Industry 4.0 in Sweden, to then finish of with limitations of the study and suggested future research.

6.1 Theoretical implications

Many of the SMEs in Sweden are working towards i4.0 in a certain way without knowing it as they are all trying to increase the interoperability of their systems and subsystems. In this sense we agree with Albert (2015) and Kagermann (2015) that the future implementation of i4.0 not is likely to be a revolution, but rather an evolution.

The capability of organizations to fully exploit the benefits of i4.0 depends on several factors that are not always related with the level of automation or technological features of the SMEs, instead the business strategy and culture, as well as the product features and the leaders’ mind-set play a vital role when it comes to adapting to an external change.

Regarding the feasibility of an implementation of i4.0 in accordance with the definition used, the findings indicate that the concept of i4.0 as a comprehensive solution it is not very feasible for Swedish manufacturing SMEs due to both economic factors as well as the nature and the features of the firms. Additionally, we identified indications of that i4.0 in the sense of how it is defined today by Hermann et al (2015), is not that important for Swedish manufacturing SMEs as they already are flexible and producing the “batch size one” that is targeted by large companies. Instead Swedish manufacturing SMEs are more interested in product or business innovation. Therefore, they are more eager to implement only what they consider to be suitable and useful for them, for instance the interoperability enabled by different technologies, and leave aside the application of the Smart Factory or apply it only to a certain degree.

Highly innovative SMEs are likely to create their own systems using these technologies, but in different applications and not in the way that the application of the Smart Factory is defined. Moreover, if the innovative solutions of applying these technologies turn out to be successful and transferable, it is possible that they will be able to influence other actors in their supply chain to use them as well.

6.2 Social and ethical implications

The number of employees is likely to be substantially lower in the future factories of industry 4.0, but the ones still working there will have to be highly educated so that they can repair the systems if something goes wrong as well as reprogram and make other changes when needed. Due to the simplicity of the daily tasks in relation to the high educational background of the employees, they will risk being under stimulated at work as long as the production run as normal. This in combination with having fewer colleagues to talk to, both for discussing work and for socialising with during breaks might make it hard to attract employees.

6.3 Future aspects of Industry 4.0 in Sweden

To be able to create a change it is important to establish a consent for the need of change. If Sweden is serious about wanting to be up front when it comes to both research in the area of new and innovative technology, and transforming current industries into a more updated and high-tech industry, then they
will need to begin with the start of a movement towards spreading information about industry 4.0 and its expected benefits to get both companies and the society onboard this upcoming change. If companies do not see the need to change their current way of doing business, then they are not very likely to want to change either. It is also important to show how changes can be made step by step, and how they can differ depending on the type of business, that there is not only one solution that or one format that everyone have to adapt.

6.4 Limitations and future research

What we found in this study is only an indication of what might apply to Swedish manufacturing SMEs, based on the findings from our research of these companies, hence our conclusions cannot be generalized to all Swedish manufacturing SMEs. Further research can be done to validate the conclusion that Swedish manufacturing SMEs not are likely to implement i4.0 as it is defined today, but rather to create different applications for the usage of these technologies. We suggest that a quantitative study can be done to substantiate these conclusions.
7 REFERENCES


8 APPENDIXES

8.1 Appendix 1.

Interview Consent Form

INFORMED CONSENT FOR INTERVIEWS Case Study: How feasible is Industry 4.0 to be implemented in Swedish SMEs?

I, _________________________________, agree to be interviewed for the Master’s thesis entitled “Industry 4.0 – Only designed to fit the German automotive industry?” which is being produced by Fanny Stävmo and Maria del Mar Rodríguez Masdefiol under the supervision of Per Skoglund at Jönköping International Business School, Jönköping University, Sweden.

I certify that I have been told of the confidentiality of information collected for this project. I have been given satisfactory answers to my inquiries concerning project procedures and other matters; and that I have been advised that I am free to withdraw my consent and to discontinue participation in the project or activity at any time without prejudice.

I give my permission for: (Please mark the appropriate box)

☐ This interview to be audio recorded
☐ My name to be used
☐ The organization’s name to be used
☐ The information made public

I agree that any information obtained from this research may be used in any way thought best for this study.

__________________________________________  _________________________________
Date                                               Signature of Interviewee

Thank you very much for your participation in our case study.

Fanny Stävmo and María del Mar Rodríguez
8.2 Appendix 2

Presentation of Industry 4.0 to the interviewee

Industry 4.0 is an umbrella concept that includes CPS, IoT, IoS and Smart Factory to foster the interoperability within a company and between companies that are part of a supply chain network. Cyber-physical systems (CPS) are networks or interconnected systems with small computers equipped with sensors and actuator, that is connected over the internet with materials, objects, tools and machine parts through built-in embedded systems. The physical and the digital world is thereby connected through the Internet of Things (IoT). And it is constantly monitored by the Internet of Services (IoS) to check the wellbeing of the machines, products, etc., to ensure the seamlessly flow of goods and information.

In the future this will lead to that many processes could be controlled and co-ordinated in real-time via remotes over long distances. This requires a standardization and modularization of many, individual steps in the production process, and programming of virtual, editable models of these modules. Future industrial processes would be planned, navigated and controlled via these systems. The network facilitates for the continuous exchange of data, and based on this the process will be customized for each different situation. The use of CPS allows a decentralization of the process control, which, for instance, could be taken over by the work piece through the process of embedded Environmental System-data that will lead the command instead. This way production would be considerably more flexible. Complex, computerized calculations underlie the high production flexibility, where operation flows are connected to each other through different control levels. This vertical integration of all processes – from the processing of incoming orders and the resource management, to the manufacturing and the shipping – is revolutionizing the industrial production. The process levels of the operations are constantly connected with each other and can basically check current process data in between each other all the time.

The internet enables this constant coordination, also between globally spread industrial locations and across corporate boundaries. The horizontal integration, as in the interconnectivity in-between several companies, is the starting point of the flexible design of their joint value creation process. In the future companies will create dynamic networks from which their job and product specific capacities will be merged into collective, virtual productions. A central function in such value chains is the continuous optimization of all processes based on current data from the markets and the production itself. The optimization is taking several parameters into consideration simultaneously: Time, quality, costs, the use of resources and energy costs are only the most important ones. The goal is for the optimization process to cover the whole product life cycle. In the future, digital product memories will register data from the production, logistics, usage and disposal, that will be used in the product and process optimization.

For the worker, the use of this new technology will lead to a change in their working environment and their tasks. The automation will gain importance in many processes, and in other operations humans will be supported by light weight robots and intelligent assistance systems. This way the employees will always have access to information relevant to their tasks, anywhere and anytime. User specific training could be called in based on need to promote an optimal fulfilment of tasks for all employees.

The transition into a more flexible and cross-sectional production technology offers many advantages in the long run. The customization of the production facilitates for companies within several different sectors to produce a larger number of different products at a lower cost, and thereby cater for individual customer wishes. It will also be easier to follow developments on the market and react to quick changes in product demand, or fluctuating raw material and energy prices. The systems will adjust themselves, quickly and precise, in the case of unforeseen events such as power cuts or supply disruptions. Thanks to embedded
systems providing full transparency of the condition of all machines, the repair and maintenance of plants and systems will be a lot easier since they can order spare parts themselves as soon as there are any signs of something having to be replaced. The cost of inventory and production is lowered due to the existing potential for optimization. Errors are better avoided or can be repaired faster. And not to forget - new, innovative business models will be developed through the use of new applications.
8.3 Appendix 3

**Interview topic guide – Industry 4.0**

Setting the interview

The interviewees will be provided with a one-page document and a short video where we explain the concept of Industry 4.0 and its four components, Internet of Things, Internet of Services, Smart Factories and Cyber Physical Space.

CEO, Head of production, Head of logistics, Head of product relationship, Head of IT and ERP

Opening questions

- Introduce ourselves.
- Ask for consent to take part in the interview – provide the “Informed consent for interview” template.
- Inform interviewee that they have the right to withdraw from the research at any time.
- Introduce the interview structure – based on the four pillars: present Industry 4.0, ask about the company, then benefits, trade-offs and barriers related to that pillar.

Ice Breakers

- Name and position within the company
- Can you talk a little bit about the company? (Structure, if it is independent or has a parent company? Number of employees, when was it established?)
- What decision areas are you responsible for? (Try to relate this to areas affected by Industry 4.0, eg. when it comes to supply chain and production)

The following questions/topics should be discussed with a timeframe of 3-5 years in mind:

**Industry 4.0**

**Product (understand the product complexity)**

- What are you producing?
- Can you describe how the product is produced?
- How do you customize your products? (predesign or if it is designed to order)
- What do you do internally and what is done by suppliers?

The purpose of this research is to explore the feasibility of implementing Industry 4.0 in manufacturing Small and Medium sized Enterprises (SMEs) in Sweden by identifying the potential barriers to implementation, as well as the benefits and trade-offs that these companies would expect from an implementation of these integrated technologies.

**Internal integration (Smart Factory, Cyber Physical Space)**

When you get an order

- How is your internal integration? (communication between departments, meetings)
- How is your internal IT integration? What IT system do you work with? What modules are you using?
• How do you track the status of an order? (Where the physical manufactured product is? Can it be followed in the IT system in real-time, or only scanned/registered at specific stations?)
• Do you have any type of integration between parts, actuators and software? (RFID)
• Benefits, trade-offs and barriers

Supplier IT (IoT and IoS)
• How many suppliers do you have? Key suppliers/strategic suppliers vs non-strategic suppliers (main/strategic supply chains/supply chains for components/material to main products)?
• What level of IT and automation do they have?

External IT (interoperability)
• How is your internal and external IT integration? For internal IT integration
• For external IT integration, what does your supply network look like? How many tiers? Do you have any type of IT system integrating all or part of your supply chain?

In our study we use the term interoperability to describe when two or more systems and/or actuators, that were designed to work independently, can work together without changes whatsoever.

• What are your thoughts on interoperability?
• From your company’s perspective, what benefits can you foresee from interoperability? (eg. Flexibility, demand uncertainty decrease, monitoring of machines’ performance and so on)
• Can you name some trade-offs associated with interoperability?
• What barriers can you identify? (expensive, information security issues and so on)

• How feasible would you say it is for your company to implement the concept of Industry 4.0 within your production supply chain?

• third question: avoid asking q about IT before you have discussed the internal IT structure. After having discussed internal IT go then back to supplier IT and then external integration.

Closing questions
• Anything to add?
• Follow-up contacts

Objectives
1. Identify potential barriers & explore in what way they would be a barrier – how could they be overcome?
2. Identify benefits & trade-offs & their perceived importance to the company & impact on its business

Think about during the interview
• Body language, tone, expressions
• Laddering up: Anything else about…? Why is that so? Why is this important? – to find out the interviewees’ different value bases
• Laddering down: Could you give me an example of that? – to obtain illustrations and examples
• Summarize and seek confirmation that it has been correctly understood

Probes:
• Repeat the initial question when the interviewee is wandering off topic
• Ask ‘What did you mean by that?’ or ‘Could you explain that a little further?’ if the answer is vague or incomplete

Examples

**IoS** – Preventing unexpected breakdowns by measuring for instance the condition of the liquids in a machine, or temperature. The system will react to changes that might indicate an upcoming break-down and send information ordering the parts needed for preventive maintenance so that maintenance can be scheduled when it will have the least negative impact on the production and the repair can be carried out before the machine breaks down.

**IoT** – Via eg RFID tags, the products can communicate with the production line and tell it how it should be transported through the line and what should be done to it at each station.

**CPS** – the system used for parts and machines to communicate with each other in the factory and in the supply chain (depending on the integration level)

**SmartFactory** – A factory using the above to have a smart and optimized production (internal level)

**New Business Models** – The servitization – Eg cranes in the harbour, instead of selling a crane to the harbour the crane manufacturer can stay owner of the crane and only charge for the time it’s actually used by charging a couple of cents per lift. This way they are also responsible for its function, and who’s better equipped to serve the crane than the manufacturers themselves?! Another example is the aircraft engine manufacturer that lease out the engines and their function, instead of selling them. Via IoT they measure their performance and use real-time information they keep track of when they need maintenance, and schedule this before they break down
### Categorized benefits

<table>
<thead>
<tr>
<th>I4.0 and enablers</th>
<th>Statements</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry 4.0</strong></td>
<td>Not Identified (NI)</td>
<td></td>
</tr>
<tr>
<td><strong>IoT</strong></td>
<td>...easier to find material within the own production, and identify where in the production process an order is at more precisely (WB2)</td>
<td>Information</td>
</tr>
<tr>
<td></td>
<td>...track down problems (WA2)</td>
<td></td>
</tr>
<tr>
<td><strong>IoS</strong></td>
<td>...would be good with a system supervising the CNC-machines to prevent break-downs (WB1)</td>
<td>Sense of control</td>
</tr>
<tr>
<td></td>
<td>...would be good with a system supervising the CNC-machines to prevent break-downs (WB1)</td>
<td>Sense of control</td>
</tr>
<tr>
<td></td>
<td>...track down problems (WA2)</td>
<td>Technological</td>
</tr>
<tr>
<td><strong>CPS</strong></td>
<td>...better demand accuracy with real-time information instead of the customer overestimating the end customers need (WB1)</td>
<td>Information</td>
</tr>
<tr>
<td></td>
<td>...with orders automatically processed the whole way to the first supplier it would ensure faster material deliveries and shorten lead times (WB1)</td>
<td>Information</td>
</tr>
<tr>
<td></td>
<td>...sharing real-time information on inventory levels with main suppliers so that they could send more products automatically when the inventory is running low (WC2)</td>
<td>Information</td>
</tr>
<tr>
<td><strong>Smart Factory</strong></td>
<td>...higher machine utilization thanks to better production planning (WB1 &amp; WB2)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...time saved by having systems assigning tasks to machines and workers to optimize the use of resources, instead of it being done manually (WC2)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...all areas, but the envelope section, could probably benefit from both automation, JIT deliveries and better optimization of production (WC1)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...it would be nice to call the German guys saying “I need this amount of sheets in that thickness” (WA1)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...less cost for labour (WA1)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...a lot of time could probably be saved if more processes were optimized (WC2)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...if the automation manages to create a higher output at the same cost, then this could lead to a competitive advantage and the possibility to gain market shares on a normally rather saturated market (WB1)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...everybody wants their products as fast as possible. “Now that I’ve ordered this cash desk, I want it tomorrow” (WB1)</td>
<td>Information</td>
</tr>
</tbody>
</table>
...higher machine utilization thanks to better production planning (WB1 & WB2)

**Interoperability**  
...with orders automatically processed the whole way to the first supplier it would ensure faster material deliveries and shorten lead times (WB1)
...everybody wants their products as fast as possible. “Now that I’ve ordered this cash desk, I want it tomorrow” (WB1)

**Categorized trade-offs**

<table>
<thead>
<tr>
<th>I4.0 and enablers</th>
<th>Statements</th>
<th>Category</th>
</tr>
</thead>
</table>
| Industry 4.0      | ...will not be able to keep lead-times as short if products are not kept in stock in-house and thereby risk losing customers (WC1)  
|                   | ...if everything were to be delivered JIT based on real-time demand instead then it would probably be a lot more expensive since the reason prices can be kept low today is that products are bought in bulk when they are cheap and then kept in stock. Unlikely to get as good prices with smaller order quantities (WC1)  
|                   | ...if everything is JIT and nothing is kept in stock, then it would not be possible to “push an order” faster through the system when a shorter delivery time is requested by the customer (WC1 & WC3)  
|                   | ...being dependent on the suppliers’ ability to deliver. If you do not have it in stock yourself then you cannot assure the ability to deliver what the customer want, and risk losing customers if you can’t (WC1) | Economicl |
| IoT               | NI | |
| IoS               | ...when I started we had machines that you could repair yourself... if something brakes now we call the German guys and they hook up with the computers, go into the system and say, “now its fine” (WA1) | Sense of control |
| CPS               | NI | |
| SF                | ...these three guys are maybe nice guys, they have a family and we have to look at that as well and it’s tricky though... (WA1)  
<p>|                   | ...machines might not be able to realize they are doing something wrong until it is too late and too many pieces have already been... (WA1) | Social |
|                   | | Technological |
| Interoperability  | NI | |</p>
<table>
<thead>
<tr>
<th>Industry 4.0 and enablers</th>
<th>Statements</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry 4.0</td>
<td>...costs of buying small quantities from suppliers, based on orders, would make it hard to stay competitive on the market (WC1)</td>
<td>Economical</td>
</tr>
<tr>
<td></td>
<td>...somebody else has the control over your company... (WA1)</td>
<td>Sense of control</td>
</tr>
<tr>
<td></td>
<td>...this is old fashion, old school no bank loans, so every machine now here is bought and payed for, and it’s our machine, nobody can come here and say “I went bankrupt last month, I am out of here so this machine is mine so good bye” (WA1)</td>
<td>Sense of control</td>
</tr>
<tr>
<td>IoT</td>
<td>...we have numbers on the blades... engraved!... The environment is so tough there! (WA1)</td>
<td>Product features</td>
</tr>
<tr>
<td>IoT</td>
<td>...this is old fashion, old school no bank loans, so every machine now here is bought and payed for, and it’s our machine, nobody can come here and say “I went bankrupt last month, I am out of here so this machine is mine so good bye” (WA1)</td>
<td>Sense of control</td>
</tr>
<tr>
<td>IoT</td>
<td>...I don’t know how much this will cost to get the machines do this communication stuff (WA1)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>...how much information? Which information? (WA2)</td>
<td>Information</td>
</tr>
<tr>
<td>IoT</td>
<td>...It’s a hell of a work to put everything down into that system. (WA2)</td>
<td>Technological</td>
</tr>
<tr>
<td>IoT</td>
<td>...depending on what the systems cost! (WA2)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>I think our business is too small to adopt that. (WA2)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>...if it’s still a growing market then, then it would be very interesting. (WA2)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>...within the production, cost would be the biggest barrier (WB2)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>...“is it really worth investing this much in computers, or is it worth investing in a robot? Considering the small scale...” (WB1)</td>
<td>Economical</td>
</tr>
<tr>
<td>IoT</td>
<td>...the people... they really like the current system actually, everyone is really curious so we have had for, what could it be now, a year or something? And it works really good... (WA1)</td>
<td>Mindset</td>
</tr>
<tr>
<td>IoT</td>
<td>...machines might not be able to realize they are doing something wrong until it is too late and too many pieces have already been put through the process. If they are programmed wrong, they will think they are doing it right (WB2)</td>
<td>Mindset</td>
</tr>
<tr>
<td>IoT</td>
<td>...we will also have a problem with the quality I think, because you have to have the feeling(!) in our process, but it’s a fact, it will be hard to get that feeling into machines! (WA2)</td>
<td>Quality</td>
</tr>
<tr>
<td>IoT</td>
<td>...(talking about machines available on the market) not enough options on the market for our industry and size of production (WB1)</td>
<td>Technological</td>
</tr>
</tbody>
</table>
...due to the declining usage of envelopes it is seen as a dying business and therefore no-one is developing new machines for envelope printing, which in turn is restricting the possibilities to have a fully automated and connected production (WC1 & WC2)

...lack of own knowledge to judge and determine what could be replaced by what and how to reconstruct the production (WB2)

<table>
<thead>
<tr>
<th>Interoperability</th>
<th>...but I can also use that information to, to do something better for someone, for their competitors. (WA2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...the sensitivity of the information shared. Would not want suppliers to find out who they are selling to or what prices they are charging since some suppliers are also competitors (WC3)</td>
</tr>
<tr>
<td></td>
<td>...I don’t know how much this will cost to get the machines do this communication stuff (WA1)</td>
</tr>
</tbody>
</table>

| Technological     |                                                                                     |
|                  |                                                                                     |
| Confidentiality  |                                                                                     |
| Economical       |                                                                                     |