JÖNKÖPING UNIVERSITY
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Impacts of Industry 4.0 on Swedish Manufacturing SMEs Context

PAPER WITHIN *Industrial Engineering and Management*
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This exam work has been carried out at the School of Engineering in Jönköping in the subject area of Industry 4.0 and value chains in manufacturing SME's. The work is a part of the Bachelor of Science in Engineering program at the Jönköping university. The authors take full responsibility for opinions, conclusions and findings presented.

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Abstract

Purpose- Industry 4.0 as a concept has created a wave of innovation in the manufacturing sector. In Sweden, the goal for the Swedish manufacturing SMEs is to be leaders in digitalization and stay competitive. Therefore, the purpose of this research is to understand the impacts of Industry 4.0 on Swedish manufacturing SMEs.

Method- The method used in this research is a multiple case study consisting of three manufacturing SMEs in Sweden. A literature review was conducted in a systematic way to give a background of Industry 4.0 and its technologies. The literature review provided the theoretical base and knowledge about the phenomena which led to preparation of interview guide used for data collection. Data collection was done through semi-structured interviews. Thereafter, the findings were analyzed within case, cross-case and compared with literature.

Findings- To analyze the impacts of Industry 4.0 on the manufacturing SMEs, the author developed a framework which included the ten main Industry 4.0 technologies, Porter´s generic value chain model and industrial performance indicators. During the analysis, it was found that all the companies were users of Industry 4.0; however, they were using mostly robots as the main technologies besides one company using cloud-platform technology. All the companies had impacts on their value chains operation activity. All five performance indicators flexibility, costs, productivity, quality and lead times were found to impact on Swedish manufacturing SMEs. The findings support the same indicators as found in literature. Furthermore, all three case companies confirmed that they have higher profits which shows that the implementation of Industry 4.0 not only improves industrial performance indicators but also can lead to increase in financial performance.

Implications- This thesis contributed to both theory and provides suggestions to managers with primary contribution being the framework which itself is a contribution to the theory. The framework can be used both by researchers and managers. Furthermore, the theory provided in the literature review of impacts of different technologies on the value chain can guide the managers to understand which of the technologies are useful in corresponding activities of value chain. The suggestions provided by industry peers are also a major advantage for the managers to prepare their companies for Industry 4.0.

Limitations- The research focused only on manufacturing SMEs in Sweden and from industry perspective, only SMEs manufacturing goods were included and not services. Within the case companies, all ten identified Industry 4.0 technologies were not found to be implemented in SMEs, therefore; the analysis and answers to research questions were based on the technologies found. Moreover, there was a constraint of time and resources which led to a small sample of three manufacturing industries.

Keywords: Industry 4.0, The fourth Industrial Revolution, Industrie 4.0, Digitization, Value chain, Supply Chain, Manufacturing, SME, Impacts, Barriers

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1 Introduction

This chapter gives a background information on the phenomenon of Industry 4.0 and problem formulation. The chapter also provides information on research purpose, research questions, scope, delimitations and outline of thesis.

1.1 Background and Problem formulation

In modern economies and organizations, innovations and technological developments play an important role. Industry 4.0 as a concept has created a wave of innovation in the manufacturing sector for a while now. The latest trend does not seem to die down but on the contrary, it is developing further and further. The implementation of Industry 4.0 technologies changes the way products are designed, the processes, production systems, operations and services (Ślusarczyk, 2018). Changing market conditions due to globalization has led to an ongoing paradigm shift in manufacturing, where manufacturing companies are trying to find cost-effective ways to stay competitive (Adamson, Wang, Holm & Moore, 2015). There been an ever-growing interest in the manufacturing industry concerning this new wave of manufacturing concepts. Countries around the world are looking in the concept of Industry 4.0, however; the developed countries have so far managed the practical implementation and progress in it. High-cost countries like USA, Germany, UK and Japan have seen the effectiveness of implementation of Industry 4.0 (Lobova, Bykoskaya, Vlasova & Sisorenko, 2018). Moreover, other high-cost countries like Sweden have yet to explore the implementation of Industry 4.0.

Sweden is a high wage, innovative and export-oriented country, that has prospered on its ability to innovate continuously in manufacturing. In 2015, the Swedish government launched a new strategy called *"Smart industry- a strategy for new industrialisation for Sweden"* with the purpose to enhance the abilities of Swedish companies to change and stay competitive. They choose four focus areas with one of them being Industry 4.0, which will contribute in Swedish industrial sector to be leaders in digitalization (Swedish Ministry of Enterprise and Innovation, 2016). Another initiative called "Produktion2030", has a similar vision with the aim to enhance manufacturing capabilities in the country so that it becomes a global destination for the development and production of advanced products and services (Swedish Energy Agency and Formas, n.d).

Industry 4.0 technologies are primarily understood to influence and contribute to the betterment of primarily the manufacturing function of the industry sector, but they can also influence and change the dynamics of the entire value chain. Small and medium-sized companies (SMEs) play a major role in the economies around the world contributing to entrepreneurship, innovation and a source of employment. Furthermore, they are driving force of many manufacturing-based economies. The impact of SMEs on the manufacturing industry is significant; however, they often face challenges when it comes to smart manufacturing and Industry 4.0 compared to multi-national enterprises (MNEs). As Mittal, Khan, Romero, & Wuest (2018) concluded that academic and consulting studies mainly consider challenges and requirements of MNEs rather than SMEs in the Industry 4.0 context. SMEs are not "early adopters" because they do not want to invest in wrong technologies, however; these SMEs have to acquire knowledge quickly on new and emerging technologies and digitalization to compete with MNEs.

In their research, Müller & Voigt (2018a) argued that the value chains of industries are largely dependent upon SMEs as their suppliers (Müller & Voigt, 2018a). Similarly, in Sweden, 99.9% percent of all the companies are SMEs (SCB- Företagregistret, 2018) and of these manufacturing SMEs make up to 6 % (Statista, 2018). According to Small Business Act for Europe (SBA) (2017), "*In 2012-2016, Swedish SMEs experienced strong growth and performed substantially better than large firms. SME value added increased by 13% compared with 3.8% for large firms"*. Research in the field is limited in the Swedish context as well, therefore, it is important to understand how Swedish SMEs are positioned to take advantage from the use of Industry 4.0 and its technologies and how their future looks like. it will be of huge importance to understand which one of these technologies are impacting which functions so that the SMEs can make proactive decision on their implementation.

1.2 Purpose and Research Questions

As stated previously and in alignment with Production2030, the goal for Swedish manufacturing SMEs is to be leaders in digitalization and stay competitive. It is important to understand how far the SMEs have come in adopting these technologies. Furthermore, the research of Industry 4.0 technologies within the Swedish manufacturing SMEs is limited. Therefore, the timing of this research is highly appropriate to address the extent and impacts of the use of Industry 4.0 and its technologies in manufacturing Swedish SMEs. The purpose of this thesis is:

"to understand impacts of Industry 4.0 on Swedish manufacturing SMEs"

The first step is to understand what the current state is or how much of the Industry 4.0 is being used in manufacturing SMEs. This will provide a mapping of the existing Industry 4.0 technologies out of the Industry 4.0 umbrella. Therefore, the first research question is:

Research question 1: To what extent are Swedish manufacturing SMEs currently using Industry 4.0?

The next step is to understand the impacts of Industry 4.0 and its technologies found in these companies on their value chains. This will provide the link between the impacts and the different parts of value chain. Therefore, the second research question is:

Research question 2: What are the impacts of Industry 4.0 on the value chains of Swedish manufacturing SMEs?

The final step is to prepare the managers of Swedish manufacturing SMEs to deal with this change. This issue is of greatest importance since SMEs form the largest part of the Swedish manufacturing industry and managers require support in dealing with Industry 4.0 in the future. Therefore, the third question is:

Research question 3: How can the Swedish manufacturing SMEs be prepared to manage the impacts of the Industry 4.0?

1.3 Delimitations

From a geographical perspective, the thesis will focus on SMEs only in Sweden, and not around the world in general. From industry perspective, the companies that will be considered will be the ones that are specifically manufacturing goods and not services. From a manufacturing footprint perspective, the companies that have manufacturing units outside Sweden will not be included, even if they serve a customer base in Sweden. Furthermore, from a business model perspective, other businesses that are dealing with logistical services, sell or import goods produced in other countries will not be included either. The focus of the thesis work will only be on Swedish manufacturing SMEs.

1.4 Outline

Remaining report is structured as follows. *Chapter 2* consists of the research methods, which explains the method and data collection. *Chapter 3* consists of the theoretical framework, which gives a background of the relevant theory. *Chapter 4* consists presents the empirical data collected from the multiple case study. *Chapter 5* presents the analysis and discussion with the theory theoretical background. Report concludes with *Chapter 6,* that summarizes the previous chapters in terms of the purpose and findings of this thesis. This chapter also includes the implication of the research, limitations and recommendations for future research.

2 Research Method and Implementation

This chapter provides insight on the research philosophy and approach, research process, sources of data collection and analysis of qualitative nature are explained.

2.1 Research philosophy and approach

Generally, there are two main types of research philosophies: positivistic and interpretive traditions. The positivistic philosophy is related to measuring numerical data while doing quantitative type of research, whereas, the interpretive philosophy relates to studying of phenomena and meanings behind text through qualitative research (Williamson, 2002). The research philosophy followed in this thesis is interpretative research since it will address the meanings behind the texts found in the literature and the case studies.

The research approach applied to this thesis work is inductive, since the author collects data in the real-world, studies patterns of the collected data, and later arrives at new theories or builds on previous theories (Williamson, 2002). The research uses qualitative data as the primary source of data. The author interprets the texts and empirical data for the literature review and the multiple case study, to explore the impacts of Industry 4.0 technologies and to understand how manufacturing SMEs in Sweden are prepared to manage these impacts. Therefore, this research is following an inductive approach to fulfill the purpose and research questions.

2.2 Research design

The research is conducted with the help of a multiple case study. In order to fulfil the purpose of the research two distinct strategies were used. A literature review was done to gather the theoretical knowledge and to gain a deeper understanding of the topic which further led to the preparation of an interview guide. Thereafter, semi-structured interviews were conducted to gather the empirical data. The analysis of this data with the help of existing techniques and the findings will be used to answer the three research questions. The research design is presented below in Figure 1.

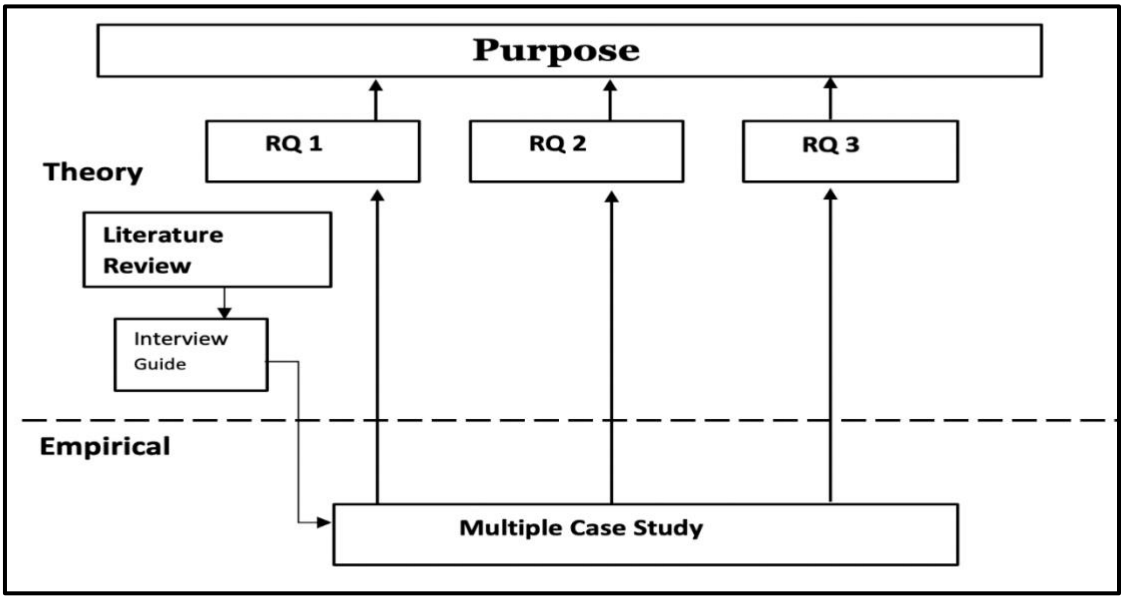


Figure 1 Research design for bachelor thesis [Source: Own elaboration]

2.3 Research strategy

As addressed above, there are two distinct research strategies used in this thesis. The first one is a literature review and the second one is a multiple case study. The literature review will provide the theoretical base to build an understanding of the previous research done and most recent trends in the field whereas; the multiple case study will provide the empirical data that will be collected through semi-structured interviews. Furthermore, this part will provide information on the processes used for both research strategies used and how the collected data was analyzed.

2.3.1 Literature review

A literature review in a systematic manner can be defined as "an explicit, and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents" (Fink, 2005, p.3). The literature review for the theoretical framework of reference was done in a structured manner to ensure the quality of the literature. Fink (2005) states that a literature review serves as theoretical foundation for research. By conducting a literature review the author can accumulate the information on the relevant topic. This provides the reader understand background behind the phenomena or concepts in the research. A literature review in a systematic manner is used to establish a search protocol which helps in identifying, selecting and reviewing the literature that focuses on the particular research questions (Fink, 2005).

The collection of the articles for literature review was done in a systematic way to identify the relevant literature, current trends and most recent updates in the field of Industry 4.0 concept and its technologies. In the beginning, two main search terms Industry 4.0 and value chain were taken. The search terms which are similar or have a different representation were also included, for example, Industry 4.0 and the Fourth Industrial Revolution or even 4IR. Thereafter, other important search terms were added like Internet of things (IOT) and Cyber Physical Systems (CPS) to get a broader range of literature on Industry 4.0 and its technologies. In the next step, the word impact was added to search with its synonyms followed by the SME´s and Manufacturing. This search was done in a very systematic way where the search results were continuously evaluated and reconsidered time and again to get the best search strings that fit the research questions and the aim of the thesis. Furthermore, the search words were used with the help of Boolean search technique to conduct the searches. In order to find the latest and most up to date literature, the search was limited from January 2015 till February 2019 (the time when this thesis was being written) due to the newness of this topic. Furthermore, the language criteria used for selecting articles was delimited to English to have international relevance. The access to the data bases was gained through the JU library website.

The databases used for the search were Scopus, Science Direct, ProQuest Central and Web of Science. A snowballing was also performed to find more articles. This was done through searches conducted using random searches on the databases mentioned above with the addition of Google Scholar, for retrieving articles and books. To choose most relevant articles that were considered as most appropriate from the authors perspective some delimitations were used along with the article evaluation criteria. All the articles were then screened in steps to find the most relevant ones, the steps and information on this can be found in appendices (appendix 2). All the articles were read with the same mindset which focused on mapping the use of different Industry 4.0 technologies to the different functions of the value chains and their impacts on it. These articles were chosen due to the relevance to the thesis purpose and questions. In some cases, other parts of the articles like findings and conclusions were also read to make sure that the articles fit the purpose of the thesis. This led to a total sample of 18 articles.

Industry 4.0 technologies they are addressing to understand the what kind of impacts they have on different function of value chains. Furthermore, the description of Industry 4.0 and the technologies that come under its umbrella were also analyzed to understand the most prominent technologies in the value chain context.

2.3.2 Multiple Case Study

A case study is an in-depth empirical inquiry of real-life phenomena that helps you investigate and achieve a deeper understanding of the phenomena studied (Yin, 2018). In simple words, a case study that has more than single-case is a multiple-case study. However, both single-case and multiple-case study are variants of the same methodology. Multiple-case study, however, has a distinct advantage over the single-case study as the empirical evidence gathered through the multiple-case study is regarded as stronger and more compelling than that of the single-case study (Yin, 2018). That is why in this thesis, a multiple case study strategy will be used. The choice of more than one case companies was purely based on the idea to achieve more reliable and compelling findings. Further on, a consistent set of semi-structured interview guide was developed by the author based on the theoretical framework. These interview questions were used in all the interviews.

2.4 Data collection

The selection of methodological instruments used for data collection was based on the multiple case study and the case companies. In order to find the most suited companies, in this case, Swedish manufacturing SMEs companies, this study used a purposive sampling. This was done due to the very fact that Industry 4.0 concept is recent phenomena and it is difficult to locate manufacturing SMEs that are using this concept. According to Bryman and Bell (2003) purposive sampling is used when it is difficult to select a sample from random sample and the selection of these groups has direct references to the research questions and their possible contribution in answering them. Furthermore, the specific group in this case is manufacturing SMEs that are using Industry 4.0 and its technologies. The main criteria were that SMEs had to be manufacturing goods/products in Sweden and using at least one of the Industry 4.0 technologies. Furthermore, the companies have to be following the Porter´s generic value chain structure where raw material is taken in through inbound logistics and then produced goods are sold through their own marketing and sales.

Based on criteria mentioned above, an extensive search was conducted online and with the help of science parks in Jönköping and Gothenburg (Lindholmen). Furthermore, a number of companies were also contacted through the industry representatives from School of Engineering (Jönköping University) in Jönköping, Gnosjö, Sävsjö, and Värnamo region. This resulted in more than 25 manufacturing SMEs. All these companies were contacted through emails. Out of these 4 companies answered. However, during the course of the study, one company had to be excluded since they did not meet the criteria of having at least one Industry 4.0 technology, even though this company created an explicit strategy only for Industry 4.0 purposes and will soon start making investments for these technologies. Therefore, on excluding Delta, this study will focus on the findings of companies Alpha, Beta and Gamma.

For the purpose of this multiple case study, semi-structured interviews were deemed as the most appropriate method of data collection, as a primary form of data collection. A structured interview has a fixed approach where pre-planned questions that are asked by the researcher; whereas, semi-structured interviews offer a flexibility so that the researcher can ask follow-up questions based on the reply of the respondent and the respondent has the room to explain and express themselves better. Furthermore, the answers provided in the semi-structured interviews are rich in content and more detailed compared to the structured ones (Bryman & Bell, 2003).

An interview guide was created based on the literature review. The interview guide was created according to funnel approach (Williamson, 2002). The questions in the interview guide started with general questions in order to create a positive atmosphere between the interviewer and the respondent, then moving to the questions that were more specific and that allowed deeper insights into the topic. The interview questions were compiled both in English and Swedish and they can be found in appendices section (appendix 1). It was ensured that the translation in Swedish language did not change the context of the questions. Thereafter, a pilot interview was conducted to ensure that the questions were understandable.

All the people chosen for the interview were in managerial positions in order to collect comprehensive data from knowledgeable sources within the respective companies. The interviews were conducted in person. All the interviews were taken at the respective company's manufacturing site. The details of the data collection are shown in Table 1.

Table 1, The details of data collection process [Source: Own elaboration]

Case	Respondents position in company	Type of Interview	Date of the interview	Site tour	Reference	Language
Alpha	CEO	Face to face	24th April 2019	Yes	1	English
Beta	CEO	Face to face	25th April 2019	Yes	2	Swedish
Gamma	CEO	Face to face	10th May 2019	Yes	3	Swedish

Before beginning the interviews, the author visited the manufacturing sites in order to get an overview of the type of products they manufacture, the processes they use and how and where they have implemented the Industry 4.0 technologies. All the interviews were recorded, on permission. Even though the interviews were recorded, writing notes were avoided during the interviews, as it was important to actively listen in order to ask follow-up questions to achieve deeper insights. All the interviews were approximately 30 mins long.

2.5 Data Analysis

All the recorded interviews were transcribed. Two out of three interviews were in Swedish and therefore they were first transcribed in Swedish and then later translated into English. The translation of interviews was done very carefully with focus on maintaining the context and content so that the actual context of the answers was not changed. One of the interviews conducted in English was transcribed word to word in English.

The data was analyzed using the *general inductive approach* as it is a convenient and efficient (Thomas, 2006). This method is done using three steps. In the first step, the extensive and varied raw transcribed data was condensed into a summary format. All the three interviews transcripts were formatted in the same way and the condensed data was placed based on the questions.

In the second step, clear links were established between the research questions and the summary of the findings that was obtained from step 1. This was done through the most relevant categorization of themes or categories based on the objectives of the research. These categories were created after reading the raw data multiple times and were described by the author while finalizing them. These categories were further analyzed to see if they fitted in a broader category.

In the last step, the overlapping data that fitted in one or more categories was marked in order to avoid repetitions in the analysis, and the data that was not relevant to the research questions was removed after careful consideration. Further on, text under each category was revised and refined in order to see if any sub-categories arise. Finally, the findings of the inductive analysis were reported.

2.6 Research Quality

The evaluation of the quality of research is very important for the readers to decide if the research is trustworthy. According to Lincoln and Guba (1985), four main criteria should be considered by a researcher while planning to conduct a research and the same should be considered while executing it in order to maintain the trustworthiness of the research. These criteria are creditability, transferability, dependability and confirmability.

2.6.1 Credibility

Six activities were conducted that increase the probability to produce more credible findings in this thesis based on Lincoln and Guba (1985). These are: prolonged engagement, persistent observation, triangulation, peer debriefing, referential adequacy and member checks.

First, prolonged engagement provides the researcher an opportunity to build trust and refers to the researcher putting in enough time in the research´s empirical context to understand the environment in which the research is being conducted so that researcher is able to decide that he or she has gone pass the own preconceptions and misinformation (deliberate or unintended). Second, persistent observation helps to identify the characteristics and elements of the concept studied so that the problem or relevant part of the research to be studied in depth is identified. Third, triangulation is ensuring validity of the research by cross-checking data by different means of data collection like interviews, questionnaires, observation, literature review and so forth. Fourth, peer debriefing, is the exposing yourself, a lone researcher or a group of researchers to your peers who are unbiased to ensure the collection of information and data is valid and transparent. Fifth, referential adequacy refers to researcher saving the data in its raw form or the way it is collected to deduce the findings so that it could be revisited when required, for example; audio or video recordings of the interview. Sixth, member checks refer to making the data collected, interpretations and conclusions available to the people from who the data was originally collected.

2.6.2 Transferability, Dependability and Confirmability

Transferability provides an understanding to the extent to which the findings of a research are transferable to some other context or settings or the same context at another time. Dependability and credibility are two sides of the same coin, hence there is no credibility without dependability. Dependability refers to giving the reader the possibility of examining the process used in the research, hence accepting its dependability. Whereas, the process that verifies the data, findings, interpretations, recommendation provided by the researcher and that they are the outcomes of the same process used in the research establishes its confirmability. A single audit if conducted properly can be used to determine both dependability and confirmability side by side (Lincoln & Guba, 1985).

Table 2, Trustworthiness of the research based on the criteria by Lincoln and Guba (1985) [Source: Own elaboration]

Trustworthiness criteria	Information related to thesis based on criteria	Author´s remarks
Credibility a) Prolonged engagement	The research on the thesis started in middle of January 2019 until the middle of May 2019.	The concept of Industry 4.0 and its technologies in the value chain was studied for four months by the author.
b) Persistent observation	Industry 4.0 is already a growing trend in the manufacturing sector and the empirical data was collected from three manufacturing SMEs. Site tours were conducted at the companies. Furthermore, these companies can be contacted for further enquiries.	As a researcher, the author had the possibility of visiting the manufacturing SMEs and conducting face-to-face interviews. Hence, the author was observant both during site tour and interviewing.
c)Triangulation	Data triangulation was achieved only regarding the extent of technologies used in the company, since the information from the interviews was cross checked with that observed during the site tour. Both sources converged on which of the	The time and resource constraint did not allow the collection of data from other sources. Hence triangulation was not possible.

	technologies were used. Regarding the impacts of technologies, other interviews no other sources of data was used. So, it was not possible to triangulate. Similarly, for the management of impacts, other than interviews no other sources of data was used.	
d)Peer debriefing	During the thesis, four seminars were conducted at different stages which included feedback from two different groups.	These seminars helped the author to improve the research quality based on the feedback by the peers.
e) Referential adequacy	The supporting quotes are provided in the empirical chapter to satisfy this part.	All the raw data in form of audio files, word to word transcription of text both in Swedish and its translation to English is saved so it can be revisited.
e) Member checks	The data is available for the respondents in case they want to check or provide feedback.	The author is lone researcher, however; one of the respondents asked to have the recorded audio file.
Transferability	The scope of the thesis, research methodology, empirical findings chapter suggest that the findings can be transferred to other manufacturing SMEs in Sweden.	The transferability of findings is possible given the same context is applied. The literature review was done in a systematic way and the availability of transcriptions allows the author to double-check the data in case the need arises.
Dependability	The chapter with empirical analysis is transparent and hence provides the reader possibility of examining the process used in the research.	Same as transferability that and the whole research is conducted systematically, and the author again go back and double-check.
Confirmability	The confirmability of the research can be verified based on the process used by the author as the analysis of data both from the literature and interviews was based on the same framework induced by author.	The author made sure that the consistency in maintained during the analysis of data.

3 Theoretical Background

This chapter informs the reader with the knowledge attained from the structured literature review of relevant articles. The theoretical background consists of recent literature about Industry 4.0, its technologies and its significance in value chains.

3.1 Industry 4.0

Industry 4.0 also called "The fourth Industrial revolution" was first introduced at the Hannover Fair of Industrial Technologies, in Germany (Barreto, Amaral & Pereira et, 2017). Introduction of steam engine and heavy manufacturing equipment, that could be propelled by the mechanical power led to First Industrial Revolution. Second Industrial Revolution was sparked by the discovery of electricity and power that could be generated by it. Third Industrial Revolution was fueled by the use of Information Technology (IT), electronics and the combination of these allowed the automation of production process (Szozda, 2017; Preuveneers & Ilie-Zudor, 2017; Barreto et al., 2017).

Fourth Industrial Revolution came about swiftly due to cyber technologies and the integration of these technologies with the help of digitalization, which helped the industries to communicate and find new ways of collaborating with each other (Barreto et al., 2017). All the four industrial revolutions can be seen figure 2 below. Industry 4.0 will develop the cognitive ability of the machines used in the manufacturing, leading them to becoming self-learning and intelligent machines (Vaidya, Ambad & Bhosle, 2018). This is achieved with the help of sensors that send the data over the network. These sensors not only help make proactive decisions but also improve the value-creating processes of an organization (Oláh, Nagy, Erdei, Máté, & Popp, 2018). Furthermore, it has also changed the dynamics of the traditional ways of doing business. New business models have appeared in the market fueled by the digital integration with the help of Industry 4.0 technologies (Bär, Lee Nadja, & Khalid, 2018). Digital integration can be achieved with the help of internet to connect a network of automated machines, devices and robots to assist the humans. The digitalization achieved through internet and supporting technologies helps the organizations to create a network of humans, intelligent machines, production lines and processes within and across organizations boundaries to create a seamlessly connected, intelligent and agile value chain (Bär et al., 2018;; Oláh et al., 2018; Ganzarain & Errasti, 2016).

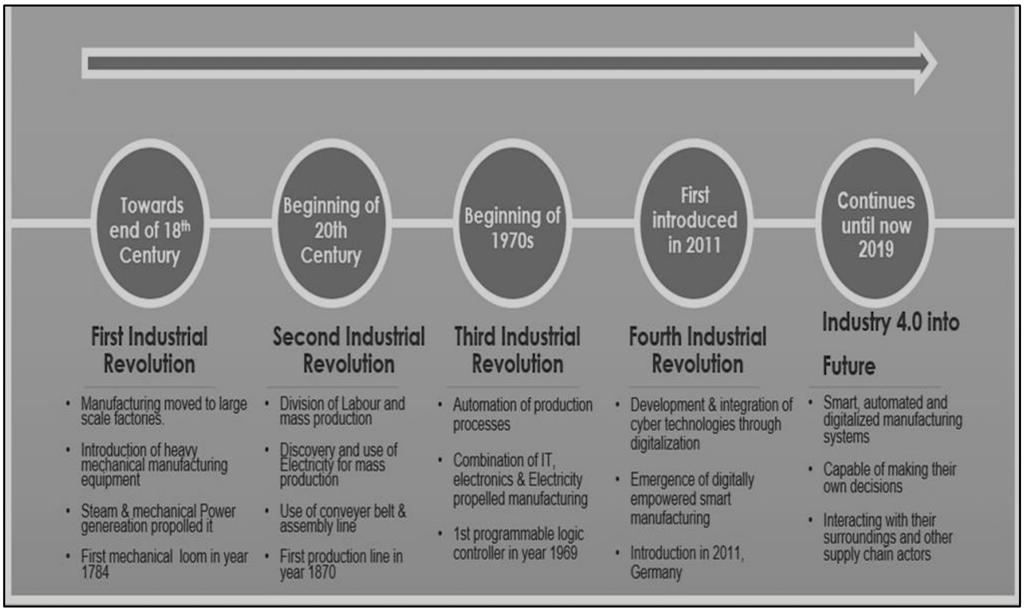


Figure 2, Industrial Revolution Timeline [Source: Adapted from Preuveneers & Ilie-Zudor, 2017; Vaidya et al., 2018; Szozda, 2017)

3.1.1 Technologies for realization of Industry 4.0

Main Industry 4.0 technologies that can impact the manufacturing industries have been identified from the literature. The articles were classified based on context where the technologies were addressed, and the specific Industry 4.0 technologies that were addressed (Table 3).

Table 3, Technologies in industry 4.0 addressed in the articles reviewed [Source: Own elaboration]

Articles addressing Industry 4.0	**Context**					**Industry 4.0 technologies**									
	Industry 4.0 in general	Industry 4.0 in SMEs	Value chain/creation	Manufacturing/Industrial	Supply Chain/Logistics	Cyber Physical Systems (CPS)	Internet of Things (IoT)	The Cloud	Big Data Analytics (BDA)	Robots	Additive Manufacturing	Augmented/Virtual Reality	Simulation	Cyber Security	System Integration
Ganzarain & Errasti, 2016	x	x	x												
Bahrin et al., 2016	x			x			x	x	x	x	x	x	x	x	x
Tjahjono, Esplugues, Ares, Pelaez, 2017	x				x	x	x	x	x	x	x	x	x	x	x
Szozda, 2017	x			x	x	x	x	x	x	x	x	x			
Preuveneers & Ilie-Zudor, 2017	x					x	x	x	x					x	
Barreto et al. 2017	x				x	x	x								
Zhong, Xu, Klotz & Newman, 2017	x						x	x	x						
Strange & Zucchella, 2017	x		x				x		x	x	x				
Moeuf, Pellerin, Lamouri, Tamayo-Giraldo & Barbaray, 2017	x	x		x		x	x	x	x	x		x	x	x	
Hofmann & Rüsch, 2017	x				x	x	x								x
Bär et al., 2018	x	x			x	x	x					x			
Oláh et al., 2018	x	x	x			x	x	x	x	x					x
Pereira, & Romero, 2018	x		x	x		x	x								
Müller, Buliga, Voigt, 2018b	x	x	x			x	x								
Rejeb, Sule & Keogh, 2018	x				x		x		x	x					
Silva, Kovaleski & Pagani, 2018	x				x	x	x	x	x	x	x	x	x	x	x
Farkas, 2018	x			x			x	x	x	x	x	x	x	x	x
Vaidya et al., 2018	x			x		x	x	x	x	x	x	x	x	x	x

3.1.2 Description of Industry 4.0 Technologies

From the literature it is evident that different terminologies were used to describe the same technology, since the concept is relatively new. Ten main technologies (and synonymous terms) were identified along with their description in the articles reviewed on Industry 4.0 and their description is presented below in Table 4.

Table 4, Description of Industry 4.0 technologies [Source: Own elaboration]

#	Terminology of Industry 4.0 technologies	Description	References
1	Internet of Things (IoT) Internet of Everything (IoE) Industrial Internet of Things (IIoT) (includes sensors and RFID)	IoT refers to interconnection of devices which are embedded with electronic sensors and other digital devices. Information can be collected and exchanged and shared via standard protocols continuously.	Bär et al., 2018; Zhong et al., 2017; Vaidya et al., 2018
2	Cyber-physical Systems (CPS)	CPS is system through which natural and human made systems like physical spaces, physical objects are firmly integrated and interwind with the help of computational software, cyber spaces and interaction between them.	Vaidya et al., 2018; Zhong et al., 2017; Bär et al., 2018
3	The Cloud Cloud Computing	An IT-based platform to store, share and exchange data generated by manufacturing processes, machines at one manufacturing site or across multiple systems over the internet. The data uploaded to cloud can be excessed in real time.	Moeuf et al., 2017; Vaidya et al., 2018
4	Big Data Big Data and Analytics Big Data Analytics (BDA)	The collection and analytical evaluation of data collected from range of sources like machines, sensors, devices and production processes and transform it into information and knowledge to help support decision making in real time.	Vaidya et al., 2018; Rejeb et al., 2018
5	Robots Autonomous Robots (includes Automated Guided Vehicles (AGV) and Collaborative Robots)	Robots are equipped with embedded sensors that helps them perform production tasks more precisely besides been able to work in areas hard to reach by their human counterparts.	Bahrin et al., 2016; Vaidya et al., 2018
6	Additive Manufacturing (AM) 3-D Manufacturing (3DM)	AM is primarily used to produce small batches of customized products that have design complexity to reproduce CAD drawing into solid 3D parts by putting several layers of material such as plastic or metal.	Dalmarco & Barros, 2018
7	Augmented Reality (AR) Virtual Reality (VR)	AR allows the display of information and work instructions on wearable devices to facilitate training and maintenance work. VR can create a real-time experience in a virtual world that facilitates visualization, design, planning, training and personalized shopping experiences.	Bär et al., 2018
8	Simulation	A virtual software that mirrors the physical world including products, machines and humans involved in the manufacturing system into a virtual one. This allows the virtual representation of an actual physical manufacturing system to test the machines and processes in a new manufacturing system before the actual set up.	Vaidya et al., 2018; Moeuf et al., 2017

9	System Integration Horizontal and Vertical Integration	Horizontal dimension helps in achieving integration between the networks internally within a company and its value chain. Whereas, the vertical integration contributes the integration of subsystems with a manufacturing system thereby facilitating the creation of a flexible and adaptable manufacturing systems.	Vaidya et al., 2018; Bareto et al. 2017
10	Cyber Security	Cyber Security ensures the safe exchange, distribution and storage of data that is been generated by all the sensors, processes, sales and so forth.	Silva et al., 2018; Dalmarco & Barros, 2018; Vaidya et al., 2018

3.1.3 Industry 4.0 in SMEs

The recent development and advancement in new and emerging technologies like Industry 4.0 technologies have led to their demand and potential use in SMEs (Moeuf et al. 2017). Müller et al., (2018b) found that many SMEs find Industry 4.0 concept intimidating and their approach towards the concept is cautious because of the challenges, lack of expertise in the field and high costs associated with it. They also found that SMEs have contrasting views, one hand they are optimistic about the implementation challenges while on the other hand, they are still contemplating how they can create value for their customers through it. Some of these issues can create new opportunities for cooperation and value creation between SMEs and other institutions, for example; the governmental and industrial initiatives can encourage and support SMEs with incentives.

Use of industry 4.0 in SMEs is mostly to monitor and improve the production processes present capabilities and flexibility. They also found most Industry 4.0 technologies are not exploited by SMEs and while the least advanced technologies like *The cloud* and *Simulation* are the most exploited ones because of their implementation is inexpensive. CPS to be complex and expensive technology involving the processing of algorithms. However, they did not find the significant use of CPS in SMEs besides its limited application in production and control citing the lack of in house competencies (Müller et al., 2018b; Moeuf et al. 2017). Bär et al. (2018) found the use of cloud-based platforms can help achieve the digitalization goals of SMEs. Thereafter, they could not find the implementation of technologies like Cyber Security and Collaborative Robots in the SMEs settings while they also found a lack of automation in production systems in SMEs.

Technological advancements due to Industry 4.0 is leading to the transformation of jobs and skill (Pereira, & Romero, 2018). Dynamic nature of changes due to Industry 4.0 will provide frequent trainings to their personnel and move them around in manufacturing department having that, it is also more likely for SMEs to be dependent on university graduates to provide technical support. However, the increasing implementation and integration of industry 4.0 technologies will have an impact on job profile and work management (Müller, et al., 2018b) (Pereira, & Romero, 2018).

Müller et al., (2018b) proposed four categories to analyze the alignment and extent to what SMEs are using Industry 4.0. *Craft Manufacturers*, these are companies using a lot of human labor with flexible production capabilities and very less automation. *Preliminary stage planners* are ones who understand the potential advantages of Industry 4.0 but are currently unprepared, these companies have a vision or a strategy for future with implementation in the next 5 to 10 years. *Users in Value Creation*, these SMEs have a vision they see the use of Industry 4.0 solely for value creation processes seeking benefits such as efficiency in data exchange with suppliers and customers and in production processes. Furthermore, these SMEs seek innovations in production system and equipment and efficient use of work force. *Full-scale adopters,* these SMEs seek competitive advantage and make profits. These SMEs already have a high degree of automation in their manufacturing processes and see Industry 4.0 as an opportunity rather than a threat.

3.2 Porter’s generic value chain

The value chain concept was first developed by Porter (1985). He proposed that the added value could be achieved and even increased by understanding and looking at a series of activities that the products passes through. These set of activities provides the products in more added value which leads to competitive advantage and higher profitability for the company. The business's activities are divided into two categories: Primary activities and the Support Activities. Margin is the difference between the total value created and the total cost incurred by the firm performing these value creating activities (Porter, 1985). These are summarized below (Table 5).

Table 5, Description of activities of Porter´s generic value chain in a [Source: Own elaboration]

Activities	**Description of activities**
Primary activities are performed by a company to compete in the market. There are five generic categories classified as primary activities.	**Inbound Logistics:** All the processes that involve receiving, storing and distributing of raw materials internally in the production.
	Operation: All the processes that convert the raw materials into the final product. Besides raw material this also includes use of labor and energy consumed to produce the products.
	Outbound Logistics: The processes that facilitate the delivering of the final product from the production line to the customer. These are storage, distribution and transportation of the final product to consumers.
	Marketing and Sales: This activity involves the processes that helps to market the product and creation of customer relationships. Marketing of products, advertising, promotions, distribution channels and pricing are some of the processes included in it.
	Service: Service involves all the activities needed to maintain value of the product's performance effectively for the buyer after the purchase such as installation of product and training to use it, maintenance, repair and after-sale services.
Support activities support the primary activities mentioned above. These are divided in four generic categories mentioned below.	**Procurement:** Procurement of raw materials for the manufacturing of a product, ordering and managing relationship with suppliers, agreements and even negotiations come under it.
	Technology Development: Activities in technology development relate to the development of products. Basically, relating to the research and development stage of new products and processes.
	Human Resource Management: Activities that involves the workforce required for an organization to function. Hiring, education, training of workforce.
	Firm Infrastructure: The set of activities that helps an organization to operate and run its routine operations and communication between different entities.

3.3 Impact of Industry 4.0

According to Porter (1985) the technological change or innovations does not automatically mean that they will result in competitive advantage for the industry but admits that innovations can have important strategic implications. In their research Bär et al. (2018) found out that the technological developments of Industry 4.0 significantly impact the entire organization. Oláh et al. (2018) also concluded that the technological developments, connection and integration achieved through Industry 4.0 impacts the entire value chain of an organization. The industries need to manage their whole value-chain in a proactive and agile manner so they can meet these challenges from product development phase to production to the delivery (Ganzarain & Errasti, 2016). Therefore, it is important for the companies to understand the impacts of new and evolving technologies like Industry 4.0 technologies to be able to either prepare themselves better or make proactive decisions in the best interests of their industries and employees (Bär et al., 2018).

Oláh et al. (2018) used Porter´s generic value chain to understand the impact of Industry 4.0 in the value creation process of organizations including SMEs. Thus, the author also proposes to use Porter´s generic value chain to understand the impact of Industry 4.0 on organization in general and SMEs as it helps to bifurcate the activities. By doing so, one can clearly see the impacts on different activities of manufacturing SMEs.

Each activity is separately addressed with the kind of impact it is having from respective Industry 4.0 technologies below and Table 6 shows the impact of Industry 4.0 technologies on the Porter´s value chain activities:

3.3.1 Impacts on primary activities

Inbound logistics: *IoT* plays a major role in the inbound logistics to track and monitor the movement, stage and condition of goods through the use of numerous sensors which send information. Within IoT technology, *RFID* helps to identify and track goods and other important parts which are inbound and lying around production areas. Furthermore, tracking the inventory in warehouses, receiving, storing and distributing of raw materials internally in the production (Zhong et al., 2017). Furthermore, the picking of orders with the help *AGVs* can assist inventory handling, increase efficiency, visibility and reduce costs as humans will not be needed for handpicking orders (Rejeb el., 2018). *Augmented Reality (AR)* and *Virtual Reality (VR)* facilitates in selecting of parts, stocks in the warehouse, provide workers real-time information on the statuses while also contributing in decision making.

Operation: *Robots* can enhance the production immensely through autonomous production methods doing repetitive tasks intelligently and safely, for example; robots in production like collaborative and welding robots (Bahrin et al., 2016; Farkas, 2018). Further on, Bahrin et al. (2016) also mentioned a 6-asis industrial robot inexpensive and adaptable robot called *Sawyer* from *Rethink Robotics* specifically developed for SMEs to increase their flexibility and efficiency in automation In many industries machining, remote monitoring of devices, robotic applications and the automation can be attained (Zhong et al., 2017) with the help of *The Cloud* as it allows control of production processes, evaluation of performance and planning (Moeuf et al., 2017). Use of *IoT* could also improve the collaboration between SMEs in distributed production networks. IoT coupled RFID technology can help obtain production feedback in real time and the retrieved data can be used to analyze the performance and variance of the machines used in the production (Moeuf et al., 2017). Similarly, *Sensors* inbuild in machines and incorporated with production processes can help in monitoring of production processes and variance. The analysis of data collected through *Big Data Analytics (BDA)* can enhance the quality of production and the production processes (Silva et al., 2018). However, it is still debatable whether the large amounts of production can be processed properly when needed for production planers and decision makers available (Zhong et al., 2017)(Moeuf et al., 2017). On the contrary, *BDA* can help manufacturer to find out critical parameters that have the most impact on quality variation (Moeuf et al., 2017).

The main characteristics of *CPS* is that it contributes in the atomization of the production process and decentralization (Vaidya et al., 2018). Technologies like *Additive Manufacturing (AM), Augmented Reality (AR)* present significant advantages to operations. *AM* will provide production advantages for the construction of customized and complex products while also contributing to reduction in lead times and inventory. This will further help the companies in being more responsive to the customer needs (Dalmarco & Barros, 2018). Whereas *AR* allows workers to perform work procedures, repairs based on instructions provided by the system itself reducing down time on machines and equipment with the help of innovative technologies like mobile devices and wearables. Google glass is one such device (Bär et al., 2018).

Moeuf et al. (2017) identified two main uses of *Simulation* in manufacturing companies. First approach Operation scheduling whereby the operation scheduling can be planned on-line and the second approach scenerio-based simulation where the simulation software is used to analyze and modify current production systems. This can be used by SMEs which are planning to increase their product range or capacity. Furthermore, there is also a possibility of setting up 2D and 3D simulations which can help test and simulate cycle time and the way different parts of the production system will work in the real scenario. Using this Industry 4.0 technology is highly beneficial to see issues in a production system in the start-up phase hence reducing the chances of failures (Vaidya et al., 2018).

Outbound logistics: *Big Data Analytics* helps in optimal decision making and flexibility resulting in cost-efficient supply chain (Preuveneers & Ilie-Zudor, 2017) (Zhong et al., 2017). This processed data can further be stored on *The Cloud* and can be accessed by other companies leading to better collaboration between companies sending, transporting and receiving goods (Silva et al., 2018).

Marketing and sales: Use of *Big Data* Analytics (BDA) technology can help a company to understand the sales patterns, forecasting, trends and the designs of the products, to understand customer requirements (Szozda, 2017) (Bär et al., 2018), provide personalized services to customers and even assist in decision making (Silva et al., 2018). In the sales section, the use of *IoT* platform used for communication can automatically update and complete the customer order after the customer has received it (Szozda, 2017).

Service: Customer experience is enhanced with use of Industry 4.0 technologies allowing customers to customize the products. Customer independency is another perceived benefit given that the company has designed its processes and communication platform in such a way that a customer can place an order, check the status and even track it (Bär et al., 2018). Additionally, companies can also benefit from using *IoT* technology specifically to make smart products that can be identified and tracked throughout their life cycle which can help them understand how the products perform (Pereira, & Romero, 2018) (Zhong et al., 2017). *Cloud computing* can facilitate servitisation of products manufactured by SMEs (Moeuf et al., 2017) and provide a platform for the storing and excess of data. In order to ensure the safe exchange, distribution and storage of data an IT based infrastructure that can ensure that the data is secure and available to right people brings *Cyber Security* in the picture (Silva et al., 2018) (Dalmarco & Barros, 2018) (Vaidya et al., 2018). Furthermore, putting data like customer feedback and order history from Customer Relationship Management (CRM) data into *Big Data Analytics* system can help many industries to improve customer engagement and satisfaction with the help of deeper analysis of their data (Zhong et al., 2017).

3.3.2 Impacts on support activities

Procurement: The use of *AGVs* inside the manufacturing plants can support the procurement function by providing better visibility of the follow of material both inbound and outbound and reducing stockouts. *IoT* also play a big role in procurement as the data collected through IoT sensors can be excessed by procurement managers to monitor the raw material being used. Additionally, information received through RFID can help tracking the movement of goods contributing to optimized inventory levels leading to reduction of costs. Having said that these technologies are still in the stage of development at the moment (Rejeb, et., 2018) (Szozda, 2017). Big Data provides the solution as its tools can help the managers to analyze large amounts of data on pricing, previous contracts and supplier performance attributes. This can be used to improve forecasting, operational planning and decision making within procurement. (Rejeb, et., 2018).

Technology development: The use of *Cloud Computing* technology can also facilitate the creation of new products or services via web-based interfaces and cloud computing platforms which can enhance customer loyalty and provide access to new markets for the SMEs (Moeuf et al., 2017).

Human resources management: *Virtual Reality* can produce real-time experience for customers in virtual representation which can be used for visualizing, designing, planning and even for educational and training purposes (Bär et al., 2018). *The Cloud* can help facilitate the adoption of Industry 4.0 as by using cloud-based services companies can help in hiring of new staff and even building new infrastructure for the smooth transformation of work tasks (Zhong et al., 2017).

Firm infrastructure: The business models that are created with the potential uses of *IoT* in mind can help companies to focus on the entire value chain rather than only themselves (Pereira, & Romero, 2018). Moeuf et al. (2017) identified five types of uses of *Cloud Computing* technology in the SMEs. These are servitisation, Resource optimization, Information sharing, Collaboration and Distribution production while also allowing the planning and utilization of resources, evaluation of performance and exercise control over processes. This technology aids the integration and interconnectivity both internally and externally between various stakeholders, for example supplier, internal departments and even the customers leading to better communication and information exchange resulting in overall operational improvements (Bär et al., 2018). Here the use of IoT platforms can enhance communication management as IoT based platforms allow control of infrastructure and maintenance costs while also allowing two-way communication between stakeholders or entities (Szozda, 2017). *The Cloud* allows organizations irrespective of their sizes to start using cloud-based services in early stages of the start of their businesses and invest in more resourceful cloud services when the need arises in the future (Zhong et al., 2017). In addition to that, Moeuf et al. (2017) noted the use of *Cloud Computing* can enhance the cooperation between organizations as it allows knowledge and information sharing which helps creating better partnerships between SMEs.

Table 6, Impact of Industry 4.0 technologies on the Porter´s value chain activities [Source: Own elaboration]

Industry 4.0 technologies	**Primary Activities**					**Support Activities**			
	Inbound Logistics	Operation	Outbound Logistics	Marketing & Sales	Service	Procurement	Technology Development	Human Resource Management	Firm Infrastructure
Cyber Physical Systems		x							
Internet of Things	x	x		x	x	x			x
The Cloud		x	x		x		x	x	x
Big Data Analytics		x	x	x		x			
Robots	x	x				x			
Additive Manufacturing		x							
Augumented Reality/Virtual Reality	x	x						x	
Simulation		x							
Cyber Security		x							
System integartion									
Impact of technologies on value chain activities	x	x	x	x	x	x	x	x	x

3.4 Industrial Performance Objectives

The technological development achieved through Industry 4. 0 will transform the manufacturing industry and parts of the supply chain by creating new and smarter products and processes leading to increase in efficiency and productivity (Preuveneers and Ilie-Zudor, 2017). The integration and connectivity between products, humans and machines will lead to more flexible, faster, efficient and high-quality production systems (Ganzarain & Errasti, 2016). Furthermore, the connection and integration achieved through these technologies will help the organizations to reduce costs by providing cost effective solutions, achieve better productivity and the possibility of observing the machines, processes, operations, workers and even the products produced through them. This might also lead to increased long-term profitability (Oláh et al., 2018).

The foundation of a company´s desire to implement Industry 4.0 technologies is to systematize and integrate their processes leading to organizational changes, improvement of quality, reduction of cost and lead time and better flexibility (Szozda 2017). Tjahjono et al., (2017) identified similar benefits like efficiency in production, improved productivity (Vaidya et al., 2018) and quality and even increased flexibility upon the implementation of Industry 4.0 technologies. Moeuf et al. (2017), also used a similar approach to understand which performance indicators SMEs can hope to improve upon implementation of Industry 4.0 technologies. Therefore, to assess the impact of Industry 4.0 on the SMEs, they used five performance indicators. First, *flexibility* as to the level of flexibility of the production system. Second, *costs* that refer to reduction in production costs and down time. Third, *productivity* such as employee's productivity and machine utilization. Fourth, *quality* referring to the increase of product quality. Fifth, *lead times* as to the time taken to deliver a product to customer after receiving the order.

3.5 Analytical Framework

After doing a rigorous literature review, the author developed an analytical framework, seen in Figure 3 for analyzing the information and the data collected both from multiple case study. The framework proposed has three main elements, each of these elements are derived through a literature review. First, the main Industry 4.0 technologies that are most appropriate to the value chain context are placed on top, since they impact Porter's generic value chain. Second, Porter´s generic value chain, where one can clearly see the activities that a firm performs to create value for its customers are positioned in the center. The arrows indicate that the Industry 4.0 technologies impact the Porter's generic value chain. Third, the operational performance indicators are positioned to assess the impact of Industry 4.0 on manufacturing SMEs. These consist of qualitative and quantitative indicators. The framework allows to identify the impacts of Industry 4.0 technologies on the value chains of manufacturing SMEs leading to the industrial performance indicators that the SMEs can improve and increase profits and competitive advantage with the implementation of Industry 4.0.

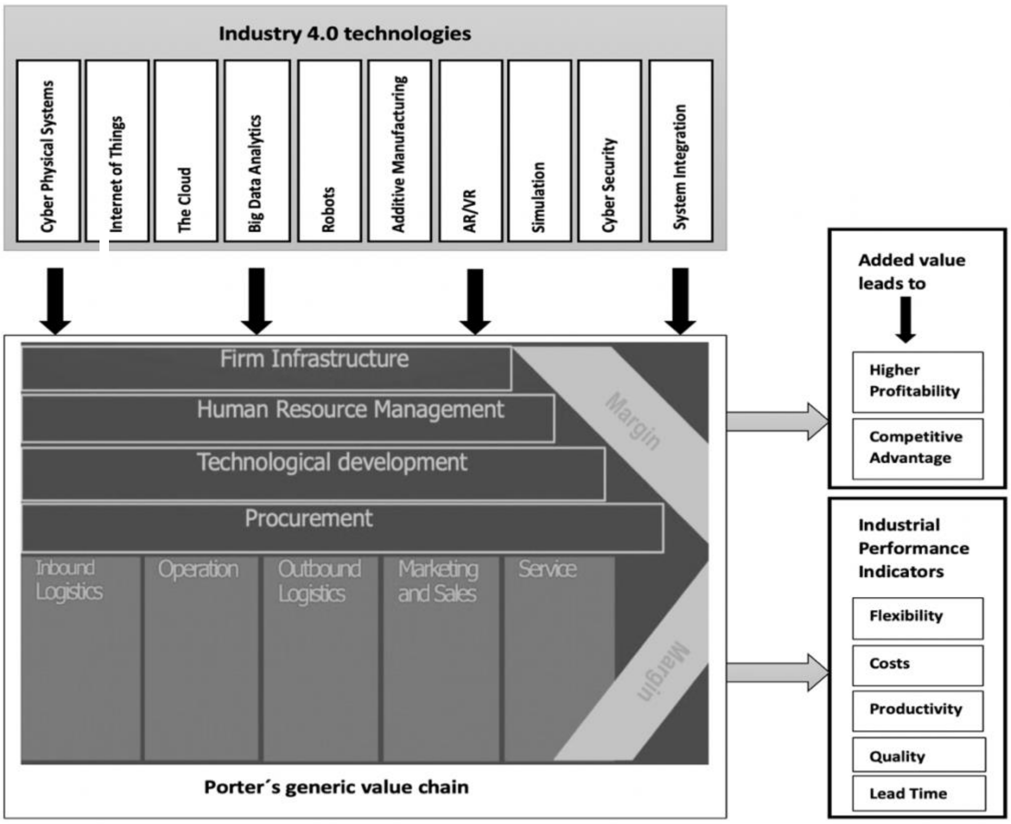


Figure 3, Analytical framework [Source: Own elaboration]

4 Empirical Findings

In this chapter the companies that were part of the multiple case studies will be presented. The description of each company is provided with respect to its size and turnover. Further on, the empirical data collected during the study is provided in with-in case and cross-case findings .

4.1 With-in case findings

According to European commission (2017), a small and medium sized enterprises (SME) is defined as company that employs less than 250 employees and has an annual turnover not exceeding 500 million SEK or balance sheet total that does not exceed 430 million SEK. In this study, all the companies chosen for the multiple case study are SMEs. The main criteria for choosing the case company were that first, the SMEs had to be manufacturing goods in Sweden, and second, they should be using at least one of the Industry 4.0 technologies mentioned in the section 3.2.3. All the companies in the sample have their operating structure according to Porter´s Generic Value chain model where the raw material is received at the inbound logistics, then the goods are manufactured and sold through their own marketing and sales functions, and the goods leave at the outbound logistics. Furthermore, all these SMEs are business to business companies.

The author will refrain from providing any specific details of the companies because of confidential reasons. Only basic company information like turnover, number of employees, the industry in which the company operations in, type of products it produces and sells and how their manufacturing looks like, will be provided for the reader to understand the profiles of the companies.

4.1.1 Case company Alpha

The case company Alpha has a turnover of 42 million SEK and employs 40 employees as of 2018. Alpha is a tier 1 and tier 2 sub-contractor which are manufacturing wooden furniture components and assembled furniture for example chairs. These products are mostly sold to manufacturers and retailers in Sweden. They are specializing in molding plywood and are market leaders with extensive experience in the field.

4.1.1.1 Extent of Industry 4.0 in company Alpha

Company Alpha was aware of concept Industry 4.0. According to Alpha Industry 4.0 is a complete integration of the company´s systems and processes. However, the company has no specific strategy for Industry 4.0, but they have a general understanding of how they want to shape their manufacturing and other processes around it. The company is working towards improving manufacturing. The manufacturing department consists of robots and multiple sensors

At present, the company has two types of manufacturing systems under one roof. The first type is the traditional one, where an operator works manually with the material, use CNC machines for form pressing and works on one product- one piece of product at a time. The second one is a combined manual and automated. Here you have two robots working with the workers and doing multiple processes at a time. Further on, company is using sensors to control the gluing in the form pressing and in varnishing sections. The data collected from the sensors can be viewed remotely to make sure the batches produced use the right amount of material. Company Alpha plans to implement more of Industry 4.0 technologies in the manufacturing department in the future more specifically in the painting and varnishing sections. This will help the company to integrate its processes effectively with other parts of the manufacturing.

4.1.1.2 Impacts of Industry 4.0

Company Alpha clearly experienced positive impacts of having the robots and sensors in the production. They definitely have improved productivity and effectivity, pushing the company to think big. Company Alpha has achieved productivity increase of 200 to 300% and cost reduction of at least 50%. He further states in his own words "*that the only way we can compete* *with low cost countries is to do an increased automatization or digitalization. We have these processes, the automated and the manual processes side by side today".* This company is mainly competing with Baltic and Eastern European companies on prices. This led the increase in profit margins for the company.

Most of the impacts are in the manufacturing operations. However, the marketing and sales department has also impacted positively because the company can market themselves to their customers as high-quality products which are manufactured in Sweden with a high degree of automation, instead of Eastern European countries. Furthermore, the company said that this also puts a pressure on the procurement, so the raw material should come on time and the robots should never stand still. Thereafter, the company also sees and expects a positive impact on the workers with the installation of robots. The workers will have to work with the same pace as that of the robots. In other words, the workers are moving at pace that is 2 to 3 times faster than before to keep up with the robots. Therefore, the company is using workforce rotation the every now and then which helps the workers to increase their skills and flexibility.

4.1.1.3 Preparing manufacturing SMEs for Industry 4.0

When asked how manufacturing SMEs can prepare themselves for Industry 4.0, the CEO of Alpha replied that the SMEs should do the current state analysis of their manufacturing (e.g., using value stream mapping) and analyze what kind of hindrances are experienced by the employees and target particular parts of their manufacturing. The management should take initiative in doing background research visits to other companies and learn what other SMEs are doing regarding Industry 4.0 and how they are tackling this problem. He further quoted that *"SMEs have a low degree knowledge of Industry 4.0 so take as much help from those who have knowledge"* before the implementing any such technologies. Therefore, managers should educate themselves and the employees regarding Industry 4.0. The Swedish governments can also help the SMEs by looking larger associations and different organizations could be also be beneficial, for example Träcentrum in Nässjö, ALMI and organization from EU.

4.1.2 Case company Beta

The case company Beta has a turnover of 76 million SEK and employs 35 employees as of 2018. Beta manufactures specialized and customized excavators, timber-handling products, wheel and telescope loaders that are used by large all-terrain machines in construction, forestry and excavation sectors. These products are produced on special orders based on the requirements from the customers and they are sold all over the world.

4.1.2.1 Extent of Industry 4.0 in company Beta

Company Beta is aware of concept Industry 4.0. The awareness extends to the fact that the new generation of manufacturing places a lot of importance on the high degree of automation and information technology. Strategically, the company invests in new technologies since their designers work with software such as Solid Works. Furthermore, all the administrative tasks are already digitalized. Company Beta plans to make major changes throughout the company with major investments in robotics and automation technologies, for example robots that can communicate, receive instructions, and send manufacturing data in real-time.

4.1.2.2 Impacts of Industry 4.0

Company Beta stated that the company has achieved better quality, shorter lead times, improved productivity and better efficiency. Furthermore, the ability to produce products of better quality has allowed the company to provide better warranty terms and improve their profit margins.

The impact is mostly on manufacturing operations. However, supporting activities like internal logistics and procurement processes are also impacted as they need to adapt to short lead times for each stage of manufacturing. Some impacts are also seen in human resources. Company Beta invests time and resources in training and educating its staff as the CEO quotes that "*All our staff get the training and the skills to be able to cope with the job. As we invest in new technology, we need to educate our staff*".

4.1.2.3 Preparing manufacturing SMEs for Industry 4.0

When asked how manufacturing SMEs can prepare themselves for Industry 4.0, the CEO of Beta replied that *"SMEs should not be afraid to hire young people with new ideas and that helps and drives the development"*, pointing out at manufacturing SMEs should invest into workforce that has the knowledge and skills for new and upcoming technologies within industry 4.0. Furthermore, a new blend of workforce skills is required, one that has a mixture of both technological skills and experience. The issue is that SMEs find it hard to hire skilled people since these companies are located away from the metropolitan areas. Therefore, according to Beta, educating the current workforce and attracting new skilled workforce is important in order to prepare manufacturing SMEs for Industry 4.0.

4.1.3 Case company Gamma

The case company has a turnover of 130 million SEK and 76 number of employees. Company Gamma is a manufacturer of sheet metal components that are delivered to leading automotive and industrial customers. They produce products like fan guards, front panel, oil tank, protection plate, drawer cabinet and heat shield. These products are delivered mainly to the automotive industries

4.1.3.1 Extent of Industry 4.0 in company Gamma

Company Gamma is aware of concept Industry 4.0. n and its use in manufacturing. However; the respondent was a little sceptic of such buzz terms like Industry 4.0, as he exerted " *I'm a bit allergic against these buzz words that come and trend, this is what I would probably say. Now, it was the Germans who came up with this industrialization 4.0, but we have been working with this much longer*".

The company is using an electronic platform such as Electronic Data Interchange (EDI) to send, receive and confirmation of their orders as well as invoices automatically from their customers since 2005. Further on, the company confirmed that it has a total of 5 robot cells and advanced CNC machines that they use to cut the metal. They also use sensors to monitor their processes. The company has a cloud platform where all the robot cells, the CNC machines, the progress and stoppages can be watched in real time by the managers. This cloud platform lets them monitor production from any device. Company Gamma has a clear strategy for future, and they will only invest and implement in Industry 4.0 if it pays off.

4.1.3.2 Impacts of Industry 4.0

Company Gamma had their machines and robots connected to the cloud for a while now, so they clearly see the impact in their manufacturing as they can monitor their manufacturing remotely. This not only led to better follow-up but also increased ability to visualize a problem in manufacturing leading to shorter response time to put measures to solve them.

The manufacturing flow has become more effective as company produces almost 2000 different articles every year. This effectivity in flows, compiled with better follow-up and governance has led the company to improve its routine operations. Furthermore, the company also benefitted from increased flexibility and shorter lead times. This has reflected on the profitability of the company. The communication with the suppliers and customers has also improved. The overall impact of the use of Internet 4.0 technologies has helped the company to become market leader in Scandinavia.

4.1.3.3 Preparing manufacturing SMEs for Industry 4.0

The respondent is sceptic about the trendy concepts and ideas, however; he was positive to technologies that help create value for the company. He continued further and stated "*Use consultants or university students or what. I would have done like that myself*" . In other words, take help and competence when it is needed.

4.2 Cross-Case findings

The cross-case findings are shown in two ways. A short description followed by the representation in form of the tables. Here the data collected from all the three companies can be seen in relation to each other.

4.2.1 Extent of Industry 4.0 in case companies

Table Y presents the comparison of the extent of Industries 4.0 and its technologies used in the case companies. The individual company's strategy for Industry 4.0 and their future plans are also presented.

Table 7, Cross-case comparison of Industry 4.0 in case companies [Source: Own elaboration]

Case Companies	**Alpha**	**Beta**	**Gamma**
Extent of Industry 4.0	Industry 4.0 user	Industry 4.0 user	Industry 4.0 user
Strategy for Industry 4.0	No specified Strategy	No specified Strategy	Have explicit strategy
Technologies in use	Robots	Robots	Robots & The Cloud
Plans for future implementation of Industry 4.0 technologies	More technologies in manufacturing to integrate the processes effectively	Plans for major investments in manufacturing in robots that can communicate in real time	Company will only invest and implement in Industry 4.0 if it pays off in manufacturing

4.2.2 Impact of Industry 4.0 on Porter´s Value Chain Activities

The impacts of Industry 4.0 technologies in general on Porter´s value chain activities are presented cross-case in Table 8 below.

Table 8, Impacts of Industry 4.0 on the Porter's value chain [Source: Own elaboration]

Companies	**Primary Activities**					**Support Activities**			
	Inbound Logistics	Operation	Outbound Logistics	Marketing & Sales	Service	Procurement	Technology Development	Human Resource Management	Firm Infrastructure
Alpha		x		x		x		x	
Beta	x	x				x		x	
Gamma		x			x				x

4.2.3 Industrial Performance Indicators

Performance indicators to assess the impact of Industry 4.0 on manufacturing SMEs is presented cross-case wise in table 9.

Table 9, Industrial performance indicators of all case companies [Source: Own elaboration]

Operational Performance Indicators	**Alpha**	**Beta**	**Gamma**
Flexibility			x
Costs	x	x	x
Productivity	x	x	
Quality	x	x	
Lead time		x	x

5 Analysis and Discussion

This chapter analyzes findings provides answers to research questions by the analyzing the data collected from the multiple case-study and its comparison with the theoretical framework.

5.1 To what extent are Swedish manufacturing SMEs currently using Industry 4.0 technologies?

Industry 4.0 is a new concept and all three interviewed are aware of it. Collectively, all agreed that Industry 4.0 will bring upon a new age of manufacturing in SMEs with high degree of automation, Information technology and integration of processes in manufacturing. Two companies Alpha and Beta had no specified strategies for Industry 4.0, while Gamma have an explicit strategy for their companies. All three companies have plans to invest and implement more industry 4.0 technologies mainly in their manufacturing in the future

Most used technologies were found out to be robots in Alpha, Beta and Gamma in all three companies. Gamma has also connected their robots and advanced CNC machines with the cloud through which they can monitor their production processes in real time. Furthermore, Alpha and Gamma are also using sensors in order to monitor their processes. According to Müller et al., (2018b) four categories were proposed to analyze how SMEs position towards Industry 4.0 and, in this case, all three SMEs are Industry 4.0 users and according to the findings they fall under category *Users of value creation*. These SMEs often visualize that they will be able to create value by innovating their production system with the help of Industry 4.0 technologies. The proposed four categories are used to analyze the alignment and extent to what SMEs are using Industry 4.0.

Table 10, Extend of Industry 4.0 among Swedish manufacturing SMEs and technologies used [Source: Own elaboration

Case Companies	**Extent of Industry 4.0**				**Industry 4.0 technologies**									
	Craft Manufacturers	Preliminary Stage Planners	Users in value creation	Full-scale adopters	Cyber Physical Systems	Internet of Things	The Cloud	Big Data Analytics	Robots	Additive Manufacturing	Augmented/Virtual Reality	Simulation	Cyber Security	System Integration
Alpha			x						x					
Beta			x						x					
Gamma			x				x		x					

Although, it is clear that all the case companies are users of Industry 4.0 they are in the initial stage of realizing the potentials of Industry 4.0 and its subsequent technologies. Moeuf et al. (2017), found similar results and concluded that even though the number of new tools and technologies such Industry 4.0 technologies are growing, their potential is still not fully exploited by the manufacturing SMEs and they are mainly using Industry 4.0 to monitor their processes and improve their current production capabilities. Implementation and integration of more Industry 4.0 technologies in future can possibly lead the SMEs to a high degree of automation and contribute to the integration of their processes leading to the so-called new age of manufacturing. However, to support this idea Moeuf et al. (2017) proposed that SMEs should consider having a strategy for Industry 4.0 as it enhances their processes, communications with partners, automation capabilities and customization of products.

5.2 What are the impacts of Industry 4.0 technologies on the value chains of manufacturing SMEs?

The impacts of Industry 4.0 technologies on different activities were compared with the literature and summarized in the table 8.

Table 11 , Comparison of impact of Industry 4.0 technologies on the Porter´s value chain with literature [Source: Own elaboration]

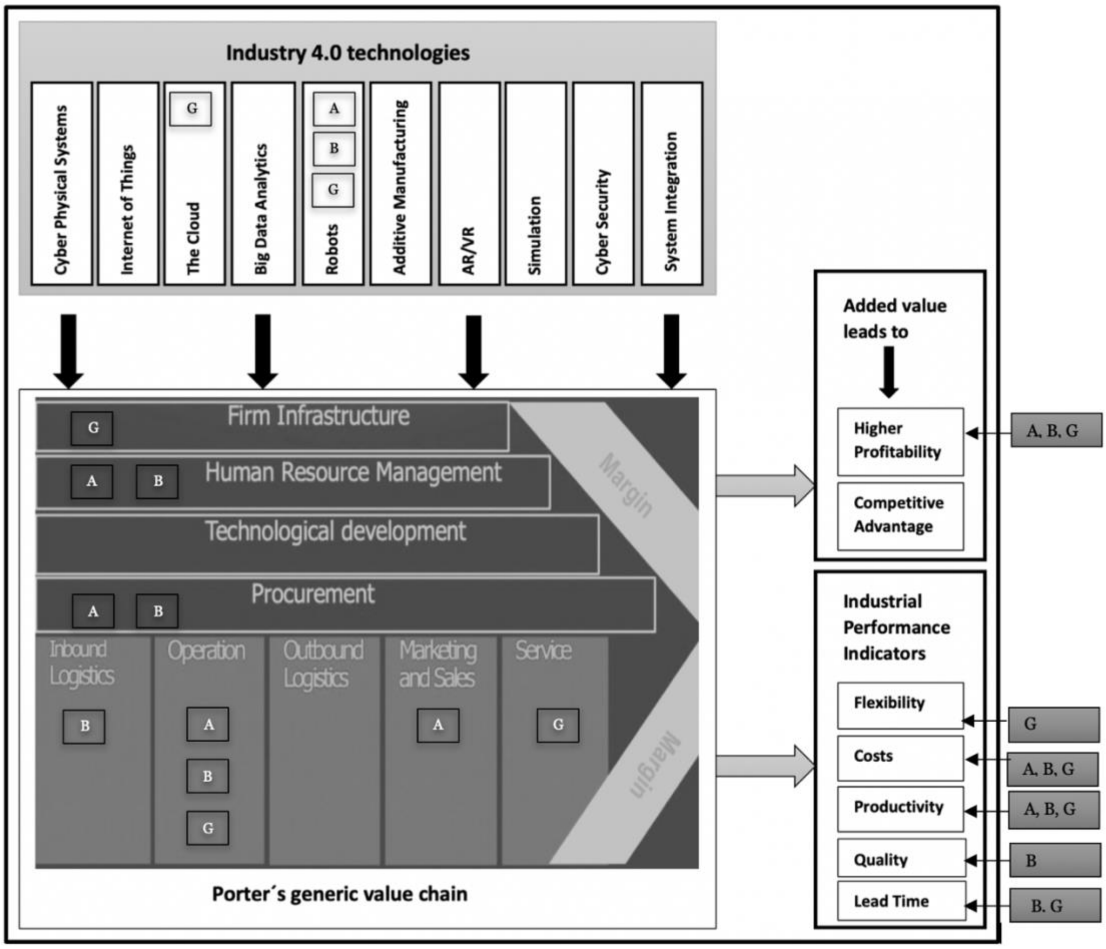
Case Companies	Primary Activities					Support Activities			
	Inbound Logistics	Operation	Outbound Logistics	Marketing & Sales	Service	Procurement	Technology Development	Human Resource Management	Firm Infrastructure
Alpha		x		x		x		x	
Beta	x	x				x		x	
Gamma		x			x				x
Impact of Industry 4.0 found in literature	x	x	x	x	x	x	x	x	x

The technological developments, connection and integration with the help of Industry 4.0 impacts the entire value chain of a company from the product development phase to production to the delivery and so on (Ganzarain & Errasti, 2016; Bär et al. 2018; Oláh et al. 2018). However, this was not the case in the findings from the empirical data. According to the findings all three companies agreed that the manufacturing function, that is part of the operation activity is the most impacted part in manufacturing SMEs. Comparing this to the literature based on operations activity the results are in line with the existing research. On the contrary, none of the companies saw an impact on outbound logistics and technology development and only one company saw an impact on inbound logistics, marketing and on firm infrastructure. Both Alpha and Beta see an impact on their procurement and human resource management activity in line with the research. The finding in human resource management activities are in line with the literature as it is mentioned by Pereira & Romero (2018); Müller et al., (2018b) that Industry 4.0 will impact the job profile and skills and the companies will have to frequently provide training to their personal.

Bär et al., (2018) suggested that Industry 4.0 leads to interconnectivity and integration within different departments of an organization, between suppliers and customers which can lead to operational improvements. Five performance indicators flexibility, costs, productivity, quality and lead times were used to assess the impacts of Industry 4.0 on manufacturing SMEs. All these were found in findings with costs being mentioned by all companies, followed by productivity and quality by Alpha and Beta and lead time by Beta and Gamma. However, only Gamma mentioned flexibility. Whereas, Moeuf et al. (2017) found flexibility and productivity as the two main performance indicators that SMEs aimed to improve.

After analyzing the findings were mapped on the analytical framework proposed in section 3.5 and seen in figure 4. Furthermore, all three case companies pointed out that they have higher profits after the implementation of Industry 4.0. All the Industrial performance indicators like flexibility, costs, productivity, quality and lead time were mentioned by all the respondents. However, none of the managers mentioned the important sustainability impact of Industry 4.0 and its technologies on the manufacturing SMEs. The expectations from Industry 4.0 is that it can lead to the transformation in not just manufacturing but the society as well with the aim of achieving economical, ecological and social benefits. In other words, focus should equally be on achieving economical, ecological and social benefits which are objectives in reference to the

Triple Bottom Line of Sustainability (Müller & Voigt, 2018a). At the case companies, the focus was primarily on economic aspects and not the social and environmental aspects in the Industry 4.0 context. This could be because of the two reasons, the relative newness of the Industry 4.0 concept in the Industrial sector and the adoption and implementation of Industry 4.0 and its technologies by manufacturing SMEs could be motivated by the economical and other improvements in industrial processes.



Legend: A=Alpha; B=Beta; G=Gamma

Figure 4, Mapping of impacts of Industry 4.0 technologies on manufacturing SMEs [Source: Own elaboration]

5.3 How can SMEs be prepared to manage the impacts of the Industry 4.0 technologies?

The finding brought forward some interesting suggestions that respondents from the three companies made. All the three respondents pointed out the importance of manufacturing SMEs like theirs to take external help in educating and training their personal to enhance their skills and knowledge. All respondents had somewhat similar ideas like hire skilled and knowledgeable consults, newly educated university students with technical knowledge and even take help from governmental and private organizations. However, respondent from Alpha was the most enthusiastic of all as he pointed out the need to do current state analysis of the current manufacturing and even suggested the managements to visit other SMEs in the similar situation to know how they are tackling their problems. Respondents from both Alpha and Beta stressed the importance of investing in education and training of the existing workforce so they can take up new challenges that will come in the wake of Industry 4.0 implementation. Müller, et al., (2018b); Pereira & Romero (2018) put forward a similar suggestion where they suggested of providing frequent training to personal and how the SMEs will be more likely to dependent on university graduates for technical skills.

Furthermore, respondent from Alpha even pointed out the importance of the managers to educate themselves. Respondent from Beta also pointed out the challenges of attracting and hiring skilled professionals to companies as theirs as they are situated away from big cities. Interestingly, respondent from Gamma said he was skeptical of trendy concepts like Industry 4.0, but he concluded that he is positive towards the implementation of Industry 4.0 if it helps to create value.

6 Conclusions

This chapter aims to present the conclusion of thesis, implications, limitations and recommendations for future research.

6.1 Conclusions

The purpose of this thesis was to understand impacts of Industry 4.0 on Swedish manufacturing SMEs. To fulfil the purpose of the research three research questions were formulated. The research looked into the extent to which manufacturing SMEs were using Industry 4.0 and the impacts of Industry 4.0 and its technologies on value chains of manufacturing SMEs. Thereafter, suggestions were provided to help these SMEs to prepare themselves for the impacts of Industry 4.0.

The literature review on Industry 4.0 showed that relatively new concept came in prominence in last decade and lot of research has been focused on the multi-national companies (MNCs) hence the SMEs have been neglected by the research community. Firstly, there is limited literature on Industry 4.0 and its technologies in the SMEs context. Secondly, the impacts of Industry 4.0 concept and its technologies on specifically manufacturing SMEs has also been neglected. With the help of literature review, ten main technologies that form the basis of Industry 4.0 in the manufacturing context were found. Thereafter, Porter´s generic value was used to bifurcate the different activities which form the value chain of these companies and how these activities are separately impacted by Industry 4.0 and its technologies. Furthermore, five industrial performance objectives that the SMEs are hoping to improve with the help of Industry 4.0. Finally, an analytical framework was formed to see the impacts and how these impacts are helping to improve the industrial performance. Thereafter, it helps to understand how the impact on different activities is helping companies to increase added value and improve their performance objectives leading to higher profits. Using a multiple case study approach, three manufacturing SMEs were selected. The time and resource restrictions favored the case company's selection. Thereafter, data was collected with the help of semi-structured interviews.

The analysis of empirical data revealed that case companies were aware of Industry 4.0 and how it will bring upon a new age of manufacturing. All three companies were users of Industry 4.0 technologies where different types of robots was main technology identified, however; one of the companies also used cloud-platform. Operation activity was identified as the one which was having most impact followed by procurement and Human Resource Management and Inbound logistics and even Firm Infrastructure. These impacts led mainly to the reduction of costs, increased productivity, increased quality of products, increased flexibility, reduction in lead time and all these were found in the case companies. After mapping the findings on the analytical framework and analyzing it was identified that the use of Industry 4.0 may lead to higher profits for the companies. Interestingly, none of respondents saw Industry 4.0 and its technologies impacting the sustainability aspect and their focus was mainly on economic aspects and not the social and environmental aspects.

Some interesting suggestions like educating and training of personal, taking external help of skillful consults, hiring and attracting new university graduates to SMEs, interacting with industry peers on the Industry 4.0 concept were provided by the respondents. An interesting aspect that came forward from this thesis is that manufacturing SMEs are still in the initial stages of implementing Industry 4.0 with main goal of increasing profits due Sweden high cost environment. Conclusively, the answers of all three questions fulfills the purpose of the thesis. However,

6.2 Implications

This thesis has compiled the main Industry 4.0 technologies that can impact the manufacturing SMEs and with the help of Porter´s generic value chain and Industrial Performance indicators, a framework was developed by the author. There is limited research done on Industry 4.0 on the manufacturing SMEs context, therefore; this thesis contributed to both theory and provides suggestions to managers. The primary contribution of thesis work is the framework which is a contribution to the theory. This framework can be used both by researchers and managers in the future. The researchers can use the framework to look at Industry 4.0 as a source of competitive advantage in manufacturing SMEs. Furthermore, the researchers can look in all the individual activities of Porter´s generic value chain mentioned in section 3.3 with a perspective of understanding how Industry 4.0 and the main technologies are and can impact these activities. As mentioned previously, the concept of Industry 4.0 is relatively new to the SMEs and given the number of SMEs creating value for their customers and their importance in the industrial sector, the researchers should look into subject with greater interest.

The managers can use the framework to firstly map where the impacts of the implemented Industry 4.0 technologies are in the value chain of the company. Secondly, they can also see what kind of performance improvements they can make using this. Furthermore, the theory provided in the literature review of impacts of different technologies on the different activities of value chain can guide the managers to understand which technologies are useful in which activities of value chain. The suggestions provided by the industry peers are also a major advantage for the managers who are either looking to implement Industry 4.0 in their companies or are in the initial stages of implementation. Although the managers did not mention the sustainability aspect, but they can increase awareness for sustainability along with economic benefits of Industry 4.0. Here they can draw inspiration from the Triple Bottom Line of Sustainability which has economical, ecological and social as they are already seemed to be achieving economic benefits.

6.3 Limitations and Future Research

Despite fulfilling the purpose of the thesis, to understand impacts of Industry 4.0 on Swedish manufacturing SMEs, there were some limitations. Firstly, all the ten identified Industry 4.0 technologies were not found to be implemented in SMEs, so the analysis and the research questions were answered based on the technologies found. Secondly, Porter´s generic value chain leads to competitive advantage and higher profitability. This study only focused on impact of Industry 4.0 leading to higher profits and not competitive advantage. Thirdly, there was a constraint of time and resources as the author was alone which led to a smaller sample of three manufacturing industries.

The findings from the multiple case study cannot be generalized due to the smaller sample and the use of purposive sampling for finding the manufacturing SMEs. A bigger sample and the prior knowledge and information of manufacturing SMEs using more Industry 4.0 technologies could have been beneficial. Furthermore, there is no quantitative data in some to either back up improvements based on Industrial performance indicators or the increase in profits.

The finding and limitations of the thesis leads to guidance to future research. First and foremost, future research can be done in developing the framework further and researches can go deep and research an activity or certain activities of value chain in detail. Another aspect to look at will be how some of the activities for example, technical development is impacted by the some of the main technologies. Furthermore, it would be very valuable for the company to understand the impact of Industry 4.0 technologies on the competitive advantage of manufacturing SMEs. Lastly, using quantitative data to support the qualitative data can also bring another perspective.

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Appendices

Appendix 1: Interview Questions in English first followed by same questions in Swedish
In English

- What does digitalization of the company mean to you? Do you have a strategy for Industry 4.0?
- What Industry 4.0 technology/technologies have you implemented in your company?
- In which departments were they implemented?
- What are the main drivers/reasons for the company to invest in such a technology or technologies?
- How were these changes implemented? Slow and continuous adoption or a sudden radical change?
- How did you prepare your company for this change? What steps did you take before bringing in the technology?
- Can you explain the benefits of Industry 4.0 technology/technologies for your company after implementation?
- Where do you see the impacts of the technology/technologies that you have implemented? Have they also impacted other departments?
- (As in which activity of the value chain? Inbound logistics, Operations, Outbound logistics, Market and Sales, Service, Procurement, Technology development, Human Resource Management, Firm infrastructure)
- What kind of impact has the technology/technologies in the manufacturing?
- How do you think Industry 4.0 technology/technologies has impacted your company? Can you provide some examples?
- How did the Industry 4.0 technology/technologies contribute to the value chain of your company? (Profit margin increased/Increase in KPIs?) Can you give any concrete examples?
- Do you plan to invest more Industry 4.0 technologies in the future? Which ones? Which department?
- What can SMEs do in general to prepare themselves to manage the impacts of the Industry 4.0 technologies or digitalization in your view?

In Swedish

- Vad vet du om Industry 4.0?
- Vad betyder digitalisering av företaget för dig? Har ni en strategi för Industry 4.0?
- Vilken Industry 4.0-teknologi/teknologier har ni implementerat i ert företag?
- I vilken avdelning har de genomförts?

- Vilka är de viktigaste drivkrafterna som fick företag att investera i en sådan teknologi/teknologier?

- Hur genomfördes dessa förändringar? Var det en långsam och kontinuerlig adoption eller plötslig radikal förändring?

- Hur förberedde ni ert företag för denna förändring? Vilka steg tog ni innan ni började med implementation av teknologi/teknologier?

- Kan du förklara fördelarna med Industry 4.0 teknologi/teknologier för ditt företag efter genomförandet?

- Var ser du effekterna av den teknologin som ni har implementerat? Har implementationen också påverkat andra avdelningar?

- (Som i vilken avdelning i värdekedjan? Inkommande logistik, Operations, Utgående logistik, marknad och försäljning, Service, Procurement/inköps, Teknikutveckling, Human Resource Management, Firm infrastruktur)

- Vilken typ av påverkan har teknologi/teknologier på tillverkning?

- Hur tror du att Industry 4.0 teknologi/teknologier har påverkat ert företag? Kan du ge några konkreta exempel?

- Hur bidrog Industry 4.0 teknologi/teknologier till företagets värdekedja? (Vinstmarginalen/Nyckeltal för verksamheten **KPI** ökade?) Kan du ge några konkreta exempel?

- Planerar ni att investera mer Industry 4.0 teknologi/teknologier i framtiden? Vilka? I vilken avdelning?

- Vad kan små och medelstora företag (SMEs/SMF) göra i allmänhet för att hantera Industry 4.0 eller digitalisering enligt dig?

Appendix 2: The research process used in the literature review

Table A: The literature search process

Step	Focus area	Screening round	Article evaluation criteria	Delimitations
1.	"Industry 4.0 and its technologies"	1st screening	Abstract screening and key words	2016-2019, English language
2.		2nd screening	Introduction, discussions, conclusions and findings screening	
3.	"Industry 4.0 and Value Chain "	1st screening	Abstract screening and key words, discussions, conclusions and findings screening, book contents	1985–2019, English language