Industry 4.0 and its impact on Cross Company Networking and the Supply Chain

Author: Patric Siek
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT,
This paper is devoted to show the influence of Industry 4.0 on manufacturing companies. It focuses on the effect of Cyber-Physical-Systems and the Internet of Things on the Supply-Chain and highlights the role of Cross-Company-Networking. Furthermore, the possible influence of Industry 4.0 applications is discussed and evaluated. Therefore, this paper should also be seen as an extension of the current literature towards Industry 4.0, as it gives a general overview of its development and consequences. To generate this overview and fill the existing research gap, secondary literature was reviewed in combination with a semi-structured interview with multiple organizations concerning the research topic. The final stage of this paper involves a discussion and analysis of the findings from the interviews as well as predominant research. The discussion will evolve around the research question and critically asses the perspectives taken. The study reveals several influences that Industry 4.0 applications have on business processes. New systems generate new, efficient processes, but the implementation itself implies barriers that are yet too big to encompass. Thus, the study shows that Industry 4.0 has significant impact on manufacturing organizations. The impact itself however, depends on several factors like size, resource availability, readiness, courage and the company culture itself. Results show that smaller companies struggle with the implementation of Industry 4.0 applications as cost and uncertainty are too high. Larger companies are less reluctant to implement Industry 4.0. But other barriers like cybersecurity and a lack in qualified employees slow the implementation process down.

Graduation Committee members:
First Supervisor: Mr. Robbert-Jan Torn MSc
Second Supervisor: Mauricy Alves da Motta Filho PhD

Keywords
Industry 4.0, Supply-Chain, Cross-Company Networking. Internet of Things, Cyber-Physical-Systems

1. INTRODUCTION

The paper at hand will study and discuss the influence of Industry 4.0 and its possible applications. At first this paper will give an introduction to the topic of Industry 4.0 and highlight the main variables that will be studied and discussed in a later section of the paper.

The ever-lasting need for organizations to adapt to its relative environment triggered a new wave of innovations, that combine the physical world to digital systems. Physical production processes like production lines are interlinked with sensors that interact with machines and humans via the internet or telecommunication networks. This stream of new technologies is embedded in the word – Industry 4.0 – which focuses on the "establishment of intelligent products and production processes (…) and flexible production (in) complex environments" (Brettel et al. 2014). Intelligent products and production processes describe automated systems that gather data during the production process. This data can be directly linked to the production manager in order to speed up the product innovation process. Flexible production describes the ability of machinery to change its purpose. Machines can change the type of product its producing or factors like capacity and volume. The term "Industry" has many several definitions and hence meanings. This Paper will focus on the definition for the term industry: "A particular form or branch or branch of economic or commercial activity" (Industry – definition by Oxford Dictionaries, 2019). Industry 4.0 is a stimulus program, triggered by the German government to boost the economy by combining physical and digital systems (Lasi et al. 2014; Brettel et al. 2014). Industry 4.0 affects all dimensions of an organization, the technical-, the organizational-, the human-, and the business model-dimension (Bischoff et al. 2015). The horizontal and vertical differentiations of the value chain are interlinked and the centralized systems become more decentralized (BMWi, 2015). Meaning that organizations or some departments in organizations are able to work closer together by Industry 4.0 applications. The control is given to local managers. Systems of this new technical revolution are the Internet of Things, Cloud computing, Artificial Intelligence, Big Data and Sensors. All with an important role in boosting efficiency in manufacturing processes and other applications by combining Industry of scale with industry of scope through the concept of "through the concept of Mass Customization". Meaning that personalized products can be produced on massive scale, through flexible processes (Pillar, 2006; Brettel et al. 2014).

But Germany is not the only country that launched an economic stimulus plan (Industrie 4.0). Also, other countries like Japan-4.1J (Kagermann et al. 2016), China-China 2025 (Wübbeke et. al 2016), USA-Advanced Manufacturing Partnership 2.0 – AMP 2.0 (MIT, 2014) and the Netherlands-Smart Industry launched plans regarding Industry 4.0, in order to boost their economy by implementing new innovations.

Industry 4.0 applications enhance the supply Chain and Enterprise Resource Planning by the Internet of Things (IoT). The IoT enables companies to inter-connect their systems and work on a real-time basis. This leads to machine-to-machine communication with sensors via the internet (Manavalan, Jayakrishna 2018).

The academic relevance of this paper will be the direct connection of the impact that Industry 4.0 applications have on the Supply Chain processes and especially Cross-Company Networks. As there is a knowledge gap in existing literature in this field, this paper aims to fill this gap by secondary and primary research. Recent research has been done on the impact of I4.0 applications on the Supply Chain and its impact on Cross-Company-Networks, but not in combination with each other. Furthermore, the paper will give general insights into Industry 4.0 trends, applications and the discussion surrounding these core factors. The research framework will be based on the following hypothesis: The emerging Industry 4.0 applications (IoT, CPS) will positively influence Cross-Company-Networks as well as the efficiency of the Supply Chain processes.

As a practical tool the paper can be used as an overview for Industry 4.0 and some of its applications, especially the use of Cyber-Physical-Systems and the Internet of Things will be highlighted during the study. It poses an example for organizations that yet did not implement any Industry 4.0 applications, as the effect of these applications on Cross-Company-Networking and Supply-Chain is shown.

In the literature research this paper will focus on literature about Industry 4.0, Supply-Chain in combination with Industry 4.0, technical aspects of Industry 4.0 applications and the influence of Industry 4.0 on Cross-Company networking. But the main focus lies on the Influence of Industry 4.0 on Enterprise Resource Planning and how the emerging Industry 4.0 changes the needs of the industry.

The research of the study is deductive, as it is mainly based on existing papers and findings. The rest of the information will be gathered by expert interviews with medium/large companies in the manufacturing sector, with links to Industry 4.0 emergence. These findings will mark the main discussion surrounding my qualitative research question that is displayed in the following section 2, Research Question and Sub-Questions.

The outline for the paper will be as follows. In the beginning there will be a literature review about Industry 4.0, Cross-Company networks and the Enterprise Supply-Chain. After that, the paper will discuss the most important Industry 4.0 applications and technologies for manufacturing companies, especially the Internet of Things and Cyber-Physical-Systems. Then the findings of my study will be presented and evaluated in terms of changes in the Supply-Chain with the emergence of I4.0 with regards to the new technologies. In the following section of the paper we will discuss which role Cross-Company networking takes in this context (also by findings). The last part will discuss about possible limitations and future research in this field.

2. RESEARCH QUESTION AND SUB-QUESTIONS

The research of this paper will mainly focus on the Impact of Industry 4.0 applications on the Supply Chain and the influence of Cross-Company Networking. In order to give an appropriate overview of these dimensions this study will be conducted through a multi-firm study, with Primary (field) research and Secondary (desk) research for collecting the necessary information. The influence of Industry 4.0 on the Supply Chain is posed in the following research question:

What are the expected changes of the Supply Chain in hindsight of Industry 4.0, with focus on Cross-Company Networking, where organizations cooperate, by combining core-competencies?

In order to fully understand the main research, some sub-questions need to be highlighted. The questions will add additional dimensions to the main research question in order to fully understand the impact of Industry 4.0 applications.

What is the impact of Cyber-Physical-Systems on the Supply Chain and Cross Company Networking?

What is the impact of the Internet of Things on the Supply Chain and Cross Company Networking?

3. LITERATURE REVIEW

The following section of the paper will present the state of the art in terms of the three most important dimensions of my research – The influence of Industry 4.0 In general, how Industry 4.0 affects Cross-Company Networking and how Industry 4.0 affects the Supply Chain.

3.1 Industry 4.0 Applications

The word Industry 4.0 is a collective word for several emerging applications for technology sector. The term Industry 4.0 describes the trend of manufacturing companies to change towards more autonomous and digitalized processes (Oesterreich & Teuteberg 2016). In the following section this paper will discuss the main applications of Industry 4.0, its technical possibilities and the opportunities as well as threats they are able to give for companies that are willing to implement these technologies.

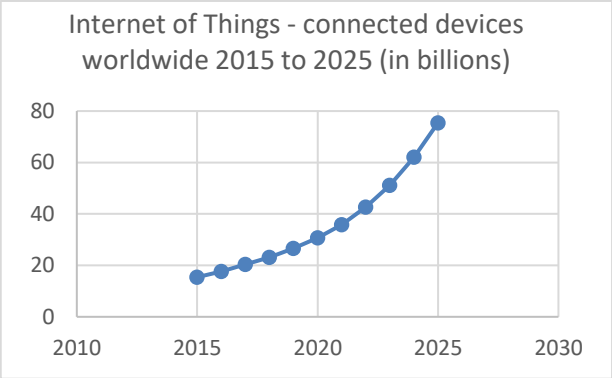
3.2 Cyber-Physical-systems

The main driver of Industry 4.0 is the interconnection and communication between humans, machines and products (Brettel et al. 2014). "The term Cyber-Physical-System (CPS) refers to a new generation of systems with integrated computational and physical capabilities that can interact with, and expand the capabilities that can interact with humans through many new modalities" (Baheti & Gill, 2011). These systems allow devices/embedded systems to connect to the internet and to build large networks via the internet. These systems can regulate themselves individually, gather data and distribute it via the Internet. In a business setting they can be used to gather data from machines and give information about failures or act as a quality monitor. "In the future, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems. In the manufacturing environment, these Cyber-Physical Systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently." (Working Group Industrie 4.0, 2013). CPS can acquire and process data, this enables these systems to fulfill certain self-controlled tasks and the interaction with humans through the use of interfaces (Brettel et al. 2014). The CPS uses the data from user information as well as the manufacturing process to lead their path independently through the supply chain. This leads to an automation of processes as CPS are connected to physical entities that are controlled by the CPS through sensor feedback. The enhanced data flow enables better customization strategies, in which Mass-Customization (MC) is now possible (Brettel et al. 2014) (also see appendix: Figure 2 and 4). Managers of these systems need qualified employees that can set up these systems and maintain them. As CPS are largely automated and self-controlled the management of these systems is focused on monitoring of efficiency and the control of data. As these systems are increasingly implemented in organizations, CPS could build self-controlled, automated networks in the future that regulate certain tasks themselves without the need of human labor.

3.3 Internet of Things

The Internet of Things (IoT) sets the infrastructural implications for Industry 4.0 and is one of its main drivers. The Cyber-Physical systems can connect and communicate through the internet or mobile network. "The network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment" (Gartner, 2017). Through the use of IoT, processes can be coordinated and steered from everywhere at every time (Oesterreich & Teuteberg, 2016). The IoT is build on the following four principles. 1. The saving of individual information on the object, 2. Interconnecting devices, 3. Individual decision-making on the basis of locally analyzed information and 4. Individual services on demand in real-time, event-oriented control of processes (Bischoff et al. 2015) (Appendix: Figure 4). The IoT is a vastly growing technology, 2015 only 15,41 billion devices where connected in comparison to now 2019, where 26,66 billion devices are connected. The prospective for connected devices in 2025 is about 75,44 billion which is five times the amount as in 2015 (statista, 2019) (see appendix: Figure 1). It is used to interconnect systems and make data available on demand.

3.3.1 Figure 1: Development of connected devices



The information flow is enhanced by the IoT as also CPS are a part of this system. In a concrete business setting the IoT can be used as a connecting "device" that interlinks all processes and information from sensors and display them on an interface. The interface can show all the necessary information about a production process. The focus for managers lies on the monitoring and advance of these systems. As more devices are connected to the IoT, the more information can be gathered and used. In the future, as in the example of a smart factory, all devices are connected and all processes as well as information can be controlled from one single point of the company and all necessary information can be distributed to employees via the use of wearables (Wang et al. 2016).

3.4 Other Industry 4.0 applications

Cyber-Physical-Systems and the Internet of Things are not the only technologies that emerge in the Industry 4.0. There is a variety of other applications. Robotics, Digital intelligence, Cloud Computing, Big Data, Augmented Reality and 3D-prinzing (BMWi, 2015). Virtual Reality and Augmented Reality act as a mediator between Cyber-Physical-Systems and the user. "Virtual Reality allows the user to simulate and interactively explore the behavior of a CPS-based production system. This is accomplished by recreating a realistic mapping of manufacturing processes." (Gorecky et al. 2014, p.290). 3D-printing gained in significance in the last few years. It enables a new way of production combined with flexibility in which three-dimensional products can be "printed" from raw materials. Products can be designed on an user interface and then produced instantly. This novel production process is nearly limitless and already widely used in the health sector, to produce drugs and prosthetics and also in the aerospace, automotive, manufacturing, defense, entertainment and architecture sector (3DInsider 2019). This paper will focus on Cyber-Physical-Systems and Internet of Things due to the research scope on Cross-Company Networking and the Supply Chain. IoT and CPS are the main actors in this

context. The other applications however, also play a role in this context, but compared to CPS and IoT they only play a marginal role as Big-Data, Cloud-computing and digital intelligence not directly influence the relations between organizations. But as Data gathering and flow becomes more and more significant in the Supply-Chain, these systems will be regarded, but not highlighted in the paper.

3.5 Industry 4.0 implications

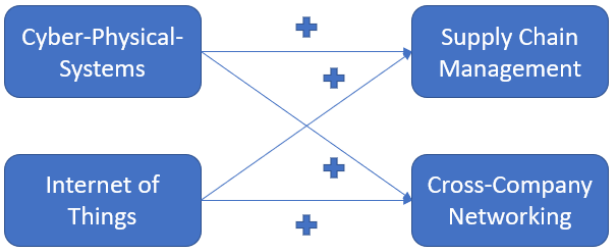
The article of Brettel "How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective", gives a state of the art of Industry 4.0, its emerging technological applications with hindsight to the Supply Chain and the rising importance of Cross-Company Networking. As the need for more customer centric production emerges, companies need to adapt to these changes by implementing new technologies. This is where the Industry 4.0 applications grow importance. Cyber-Physical systems (CPS) combine the Digitalized processes with the manufacturing processes as well as human interaction (Bischoff et al. 2015; Römer, Bruder 2015). Machine-to-machine communication and Sensors enable a more efficient way of Mass customization. These applications make the supply chain more independent as machines can take on certain self-controlled tasks (Bischoff et al. 2015). Applications like the Internet of Things use sensors to collect data. This data is used in Individualized production mechanisms. The dilemma between the economies of scale and scope can be addressed by the concept of Mass Customization (MC) and automation through the use of Industry 4.0 applications (Brettel et al. 2014; Working Group Industrie 4.0, 2013). Industry 4.0 allows the combination of Economies of scale production with economies of scope production through IoT, Sensors, Real-time data. As the complexity of products and processes increase "Horizontal Integration in Collaborative Networks" becomes more important. The implementation of Industry 4.0 applications is crucial for the future of manufacturing companies. Large companies can bear the cost of implementing these technologies. Small and medium size entrepreneurs however can suffer under the upcoming Industrial revolution 4.0, since I4.0 applications and their maintenance require significant monetary and non-monetary investments. (H. W. Lin et al. 2012). This opens an opportunity for Cross-Company networking and cooperation. Cross-company cooperation describes the process in which organizations build networks, in order to combine their core competencies – stay profitable and flexible (Brettel et al., 2014). The aim of the Cross-Company networking approach is to use the core competencies of every member of the network in order to generate more net-profit, agility, competitiveness and customer satisfaction (H. W. Lin et al. 2012). Building partnerships and strategic alliances leads to an open strategy, with reduced danger of ending in isolation (Bischof et al. 2015). Advantages for Small and Medium sized Entrepreneurs are the attainability of resources, exploitation of network effects as well as financial possibilities (Geissbauer et al. 2014; Bischof et al. 2015; H. W. Lin et al. 2012). Another major factor is that the networking leads to a decentralized mass customization possibility, while novel production strategies like Agile Manufacturing can still be used, which is a main concern of industry 4.0. Core competencies can be used to maximize efficiency as well as profitability as the interconnected Cyber-Physical systems of I4.0 enable real time data, that further interlink the processes of the Supply Chain and production cycles. The advantages of decentralized mass customization, calls for a need of extensive and effective coordination as well as improved data, information and knowledge transparency (Brettel et al. 2014; H. W. Lin et al. 2012). A major drawback of Cross-Company Networking (CCN) is that the current systems that interconnect the network are expensive and costly to maintain, new systems however are of help and diminishes the risk for high investments (H. W. Lin et al. 2012). Additional, the horizontal cooperation is in need for an extensive coordination as well as communication (Oesterreich & Teuteberg, 2016). Multiple production-sites have to work together across company boundaries. The right use of Information Systems (IS) thus becomes crucial for the efficiency of the Supply Chain. Available data of all sources, needs to be available throughout the whole Supply Chain in order to guarantee competitive advantage, flexibility and enhanced performance. This is where non-technical factors play a significant role. Communication across company borders is a major source of competitive advantage. The aspect of trust is crucial for a close company collaboration. Managers these days however are not used to sharing crucial information with other companies. Communication and information sharing, becomes key, since CCN can leverage or hinder the innovation- and production processes down the value chain. Through the extensive use of new ICT applications like sensors, the Supply Chain can be optimized by monitoring large amounts of product data (Inventory level, lead time, position of products etc.) in real-time. To exploit these features, the Supply Chain needs to be adapted. Synchronization between organizations is crucial, lead times and inventory levels need to be in symbiosis to allow flexibility as well as customer satisfaction.

4. CONCEPTUAL FRAMEWORK

The following research framework was developed during the research for the influence of industry 4.0. Several scientific papers were compared in order to find a gap in the current research. After an evaluation of possible actors and factors, the factors mentioned in the framework seemed most significant for a research in this field. Existing research strongly emphasized the impact of industry 4.0 applications on manufacturing companies, but not in concrete terms of CPS, IoT in combination with SCM and CCN.

The following research framework is a guideline for the research of this paper. The framework is an illustration for the following hypothesis; The emerging Industry 4.0 applications (IoT, CPS) will positively influence the number of Cross-Company-Networks as well as the efficiency of Supply Chain Management processes. In the context of the research the independent variables are; Industry 4.0, Cyber-Physical-Systems, Intern et of Things and Customer Profiling. The dependent variables are as follows; Supply Chain and Cross-Company-Networking.

4.1 Framework: Influence of CPS and IoT on SCM and CCN



This framework is made in accordance to the main hypothesis of this paper and aims to find out whether the propositions between the main factors that are visualized in the framework are regarded as relevant by the industry. In order to do this, the results will highlight some aspects of these technologies that might have an effect on SCM or CCN. Meaning, that main aspects of these technologies will be used in order to give an indication for the possible effects.

5. METHODOLOGY

5.1 Research Design

In order to study the mentioned research topic, this paper will use a Multi-case study design. The previous research and literature dealt with a lot of topics concerning Industry 4.0 and its applications. The existing research is hardly concerned with the impact of Industry 4.0 on the Supply Chain and Cross-Company Networking, which leaves a research gap. By using a qualitative Multi-case study design, this paper aims to find out how Industry 4.0 affects the Supply Chain and Cross-Company-Networking. In addition to this, the paper will make use of secondary data. Studies by other researchers are used in order to strengthen the arguments that are made during the research or to enforce and critically review the arguments made in the interviews. This enables the paper to make use of a bigger sample that will be more representative for a large population. The results of this paper are based on the interviews and secondary data. In a later section of the paper the results from the interviews will be compared to the results found in the secondary data.

As technology implementation is a never-ending circle for organizations in order to survive or guarantee competitive advantage, companies try to find the technologies which fits them best. As there is a knowledge gap of the impact of Industry 4.0 on manufacturing companies and their SCM and CCN. This

problem is suitable for a qualitative research as implementations for optimal usage of technology can be extracted out of this.

In order to generate findings for the study, an overall of four companies were Interviewed. Since the research is aimed at manufacturing companies, all of the interviewed participants are actors in this sector and thus affected by Industry 4.0, mainly managers and Chief Technology Officers were the contestants. These interviews were held personal, via a phone call or other means like “Skype”.

5.1.1 Data Collection

The outcomes of the qualitative multi-case firm study are used in order to provide implications for the impact of Industry 4.0 on manufacturing companies and their Supply-Chain and Cross-Company-Networking strategies.

At first, secondary research will be conducted to get a general grip on the topic of Industry 4.0, its applications and to formulate a valid research topic. Information concerning Industry 4.0 and its applications like Internet of Things (IoT), Cyber-Physical-Systems (CPS) and Cloud-Computing will be gathered. Once enough secondary information was gathered from existing literature, an Interview, was developed. The interview was developed in order to close the knowledge gap of missing literature, namely the influence of Industry 4.0 on the SCM and CCN of manufacturing companies. The approach of the interview is a semi-structured, which means that not all questions are clear before the interview or written down in the original question sheet. Some questions can arise during the process. The interviews where either conducted personal, through phone calls or via “SKYPE”, depending on the interviewees’ preferences, the location and time availability. The interviews were conducted in English and German, depending on the location of the company. The duration of the interviews was between 10 minutes to 20 minutes, due to the factor of time and availability. Three out of the four interviews were recorded, the other participant asked for it to be without recording. They were then transcribed either in English or German, depending on the language that was spoken.

6. RESULTS & ANALYSIS

The following section will discuss the results that were collected during the research for the theory of the paper. A total of four interviews were conducted. The interviewees vary in industry as well as size. Reaching from small enterprise paint producers to large building material enterprises that act on a multinational stage. The interviewees had a good overall overview of their relative company strategy and technical equipment as well as a deeper understanding of Industry 4.0 related topics as they are managers or Chief Technology Officers. The vast range of size and occupation of the studied companies enables to study the effect of Industry 4.0 not just on the Supply-Chain and Cross-Company-Networking, but also the effect that size has on Industry 4.0 implementation. The interviewees were asked to answer the questions from the interview that is shown in the appendix (section B) as well as some additional questions that were unplanned and came up as follow up questions to get a deeper understanding. In order to strengthen the representative ability, the paper makes use of secondary data that is presented and critically reviewed at the end of the results.

6.1 Readiness for Industry 4.0

The study shows that the companies have huge discrepancies in their knowledge about Industry 4.0 and in the degree to which it is implemented in the organizations strategy, especially in the automation of processes and the use of robotics (Bos, 2018). For some of the companies the Industry 4.0 is still a vague concept. They are aware of its existence and some of its applications, but they are still far away from implementing it into their day to day routine, in comparison to other studied companies that are already using Industry 4.0 applications frequently and successful. After analyzing the results, it became clear that one of the main factors for Industry 4.0 implementation is the size of the individual company.

6.1.1 Small and Medium sized Enterprises

Small and Medium sized enterprises are categorized by their size and annual turnover. In this paper we will use the defining criteria of the European Union, since there are many definitions varying from country to country. According to the EU Small-and Medium-sized Enterprises (SME’s) have less than 250 employees and an annual turnover of less than $50 million. Industry 4.0 and its applications like Internet of Things, Cyber-Physical-Systems, Big Data and Robotics are a fairly new but fast emerging topic. As the study shows, Small-and Medium sized Enterprises are not ready yet to implement Industry 4.0 applications. Main factor for this being, are the costs. However, these companies already installed a widely used product-and process- tracking system. In fact, all studied organizations already implemented this system to some extent. But in terms of manufacturing techniques itself, like robotics, the SME’s lack in progress. The studied companies are aware of the emerging Industry 4.0 and its opportunities. But as the cost of implementing I4.0 technologies like (CPS, IoT, Robotics, Big Data systems, etc.) can be enormous, the SME’s seem to be reluctant to the implementation process as the risk of failure could result in the company’s decline.

“The implementation of Industry 4.0 applications in Small and Medium- sized Enterprises will probably still take like 5 to 10 years.”

“Especially the SME’s are not ready yet since the costs are still quite high (…) and can exceed four times the price of current systems.” (translated from German)

An additional factor than the cost, is the uncertainty. SME’s lack of role models that show how the transition can be done. Clearly, in short term an organization needs to make costly investments and the change process takes a while. But SME’s are not certain yet what the long-term outcome of the Industry 4.0 applications is, since they have no data from other SME’s to compare to.

6.1.2 Large enterprises

According to the definition of the European Union, enterprises are considered large if they have more than 250 employees and an annual turnover that exceeds $50 million. As we found out earlier the size of a company plays a significant role in the implementation process of Industry 4.0. The large companies that were studied during the research strengthened this assumption. Industry 4.0 applications, especially in the sector of ICT, are widely used in all studied companies. Automated systems that gather and distribute information throughout the value chain are extensively implemented. The new implemented systems proved to increase efficiency and effectiveness of processes and communication. Large enterprises have the advantage of more monetary and non-monetary resources available. Thus, the investment in Industry 4.0 is less risky and the organizations are able to afford these systems in the first place. An additional advantage of large size of organizations is that they are mostly spread into several divisions and departments, which means that a company can first test a new system, before implementing it on a larger scale. This can be done by implementing a new system in a single division or a small batch of the company. The outcome can then be analyzed and in case of success these systems could be implemented throughout the whole organization either in a radical or incremental change process. The results of the interviews show that exactly this is the case. Industry 4.0 applications are implemented in a small batch and then implemented further throughout the whole organization in an incremental process, from batch to batch. But for now, the implementation of Industry 4.0 applications is still at its beginning.

7. RISKS AND OPPORTUNITIES OF INDUSTRY 4.0

The fact that many organizations, especially SME's, still see Industry 4.0 as a rather vague concept leads to several different perspectives on this topic. Some see the emerging Industry 4.0 as an opportunity, while some others regard it as a threat. In order to give an overview on these perspectives towards Industry 4.0, the following section of the paper will conduct a SWOT analysis. The results and information in this section are based on the interviews and secondary data. (See appendix: Figure 3)

7.1 Strengths:

The following section will highlight the strength of the theoretical and practical implementation of Industry 4.0 as it is perceived by the contestants.

The clear focus and strength of Industry 4.0 lies on efficiency. The results show that all of the interviewees named efficiency as main strength and characteristic of Industry 4.0. Higher efficiency is always a crucial topic to manufacturing companies, since it enables competitive advantage and guarantees the survival of an organization.

The tendency of gathering and managing rich information is also perceived as a major strength. As more information is gathered, the organizations can become more flexible and efficient. Customer needs are tracked down throughout the value chain and manufacturing processes can become more efficient as it is perceived bey some contestants.

Applications like the Internet of Things and Cyber-Physical-Systems are a main feature for efficiency. Problems can be detected and information can be delivered to everyone on demand. This enables an enhanced customization possibility that is especially in focus of large enterprises as well as facilitated problem detection.

7.2 Weaknesses:

In the following the weaknesses will be highlighted, that might affect the companies that implement Industry 4.0 applications.

The main weakness are the costs and the change process. All interviewees named the costs as a main concern of Industry 4.0 applications. Especially the Small-and Medium- sized Enterprises seem to be reluctant towards Industry 4.0 because of the cost factor. This factor becomes even more unpredictable in terms of future consequences. As one interviewee (case 2) mentioned: *"In the short-term Industry 4.0 applications are not profitable, but they will probably become profitable in the long-term"*. As Industry 4.0 is a fairly new topic, there is a lack of evidence in the sector.

An additional weakness as perceived by the interviewees is the technology dependence and the loss of expertise. The technology itself enables an enhanced efficiency, but in case of a breakdown of a system the organization is forced to stop its activities. The chances of a breakdown are especially high in the implementation phase of a new technology, which leads us to another weakness, the change process. A new technology in a company always means a change in the daily routine of employees. Some employees might react positive towards the change, while other employees might take a reluctant perspective towards the implementation. As time is a valuable resource for every organization, this factor plays an important role as well. The longer it takes to implement the change, the more money will be lost during this process. Especially the SME's see this as a weakness towards their company. In the past, new systems showed to have less efficiency at the beginning of their implementation as they define a new process. These technologies are called disruptive technologies, as they build a whole new understanding of how a process is to be done (M. Dowling & S. Huesing, 2004). But even if the efficiency is reduced at the early days of implementation, they are still worth implementing as they become more efficient in the long-term perspective and exceed efficiency compared to the technology that was used beforehand.

7.3 Opportunities:

The following section will show the opportunities that Industry 4.0 opens up for organizations that implement these applications. Especially the representatives of the large companies see Industry 4.0 as an opportunity for better customer and strategy alignment. New applications like the Internet of Things and Cyber-Physical-Systems enable an enhanced information gathering process, flow and interconnection. This leads to facilitated mass-customization for large organizations, with products that are optimized to fit customer needs. It became clear throughout all interviews that the focus of Industry 4.0 profitability lies on the long-term perspective, even that Industry 4.0 is costly and time-consuming to implement, phrases like *"Industry 4.0 leads to a more efficient Supply Chain"* (translated from German) show that the organizations are well aware of the advantages and opportunities of Industry 4.0 applications.

7.4 Threats:

As some interviews and secondary literature shows, there is a significant threat of Job-loss in the industry. However, the results also show that the Industry is aware of the fact that some jobs will be created during the change process, which ends up in a lose/win situation. But the contestants fear that this change process will mostly affect older, experienced employees as they are most likely to be unable to keep up with the change towards a new comprehensive technology. The workplace will change and the job tasks with it (Wolter et. al, 2016).

Based on the results of the interviews a clear tendency towards more and more use of technology becomes visible. On one side this has a lot of positive effects, like enhanced efficiency, less need for monitoring, further automation, independent value chains and enhanced customer alignment. But on the other side the organizations fear to become too reliant on technology.

"There is too much reliability on technology and machinery" (translated from German)

Drawbacks of this implication are especially visible and threatened in the case of a complete breakdown of a system. In a worst-case scenario, a significant part of the companies' operation needs to be stopped and are unavailable until the system is back up running again. In addition to that, many companies fear the lack of qualified employees that can run and maintain the new systems of Industry 4.0. And as the technological implementation is progressing, the lack in qualified personal becomes increasingly evident. *"The biggest danger is the lack of qualified employees that can operate and maintain the new systems, as it is already the case in nowadays businesses*" (translated from German).

Another major threat mentioned in some cases, was the possible failure to implement new systems correctly, which is an existential threat especially for SME's that invested a significant amount of capital into the new system. If an organization fails to implement a new technology or takes too long to implement it, the results can be contrary to the expected ones. This is a main threat for SME's and a main reason why many of them are reluctant towards the Industry 4.0 implementation. Large enterprises are able to implement new systems step by step, batch by batch. This diminishes the risk of complete failure as a potential failure or inefficiency of the system can be detected before it has major negative influence on the organization itself.

7.5 Figure 3: SWOT analysis – table with strategies:

The organization	**Strengths – S** 1. Enhanced efficiency 2. Interconnection of systems 3. Enhanced data flow 4. Problem detection	**Weaknesses – W** 1. Costs of system 2. Uncertainty of outcome 3. Few evidence 4. Loss of expertise
Opportunities – O 1. Mass-customization options 2. Interconnection of organizations 3. Long-term profitability	**SO strategies** → Attack strategies = Leverage strengths to maximize opportunities → make use of technological advantage to Mass-Customize	**WO strategies** → Reinforcement strategies = Counter weaknesses by exploiting opportunities → Use advantage of new systems to generate long term profitability and regain cost
Threats – T 1. Dependence on technology 2. Lack of qualified employees 3. Implementation failure	**ST strategies** → Develop strategies = exploit strengths to minimize threats → Use technology to gain advantage and focus on security issues	**WT strategies** → Avoid strategies = Counter weaknesses and threats → Secure IT-structure and employ qualified personal before full implementation of I4.0

8. SECONDARY DATA COMPARISON

The secondary data review is used in order to strengthen the arguments that were made during the research. A critical review of studies that have already been done by other researchers shows the representative power of the findings. An additional critical reflection highlights differences of the results and may bring some new insights into the topic.

The main source used as secondary literature is an updated version from the McKinsey report on the development of Industry 4.0 in manufacturing companies from April 2015, "Industry 4.0: How to navigate digitalization of the manufacturing sector" – version 2016. The research for this report included a survey that was send and filled out by 300 industry experts in Germany, the US and Japan. It focuses on the attitudes towards Industry 4.0 and the progress of implementation. The reason why this paper focuses on this secondary data is based on several factors. The paper gives a review over time on several industries. The sample includes more than 300 contestants that are varying from small to large companies. The surveys were filled out by industry experts in 2015 and 2016. The McKinsey report highlights the following developments of Industry 4.0.

The expectations towards Industry 4.0 applications are clear. 86% of the manufacturers that were asked regard Industry 4.0 as an opportunity rather than a risk and 90% say that competitive advantage will increase. But even if the vision into the future of Industry 4.0 looks promising, many actors are still waiting to see results. This covers the results of the interviews. All interviewed participants see Industry as an opportunity to gain competitive advantage in the future and are optimistic about its influence on the industry. Furthermore, McKinsey states that the expectations grew compared to 2015. In Germany and Japan, the expectations stayed unchanged, but in the US the expectations rose about 44%. In terms of actions taken, McKinsey states that 56% of German and 50% of US organizations made a good process in implementing Industry 4.0 applications. But only 37% of manufacturing companies made a good/substantial progress. In comparison to the results of the interviews there is clear discrepancy. Three out of four contestants stated that they made a significant progress. This could be due to the time differences of the studies. While the McKinsey study focused on the development from 2015 to 2016, the questions of the interviews were not time-bound, so they involved several years of progress. In addition to this, the sampling of participants also plays a major role. While we can assume that the sample of the McKinsey study is representative for the whole population (300 surveys), we also must assume that most of these companies were SME's, since they make the majority of companies compared to large enterprises (World Bank Group, n.D). As we found out earlier in the paper the size of the company is important in the context of Industry 4.0 implementation. 75% of the interviewed companies in the research were large in size. Thus, the difference of the findings can be explained by the sampling and the involved distribution of size, as large organizations are able to obtain monetary and non-monetary resources easier. The most significant difference can be seen in the implementation barriers. As McKinsey elaborates, the biggest threat of companies in terms of implementing Industry 4.0 is the difficulty of coordination across different organizational units, concerns about cyber security and lack of courage to push through a radical transformation. The outcome of the interviews however shows a different outcome. Especially the SME's see the cost-factor as the major threat of implementing Industry 4.0 applications. For large companies, the cost-factor is a rather secondary threat, as they know that the implementation increases profitability in the long term. The major threat for large organizations covers the McKinsey report only in some points. Number one concern was the factor of cyber-security. The organizations fear an unintentional spread of information. As industry 4.0 applications increase the connectivity towards networks in the internet, the possibility increases that data can be stolen and servers hacked. As one interviewee mentioned, some organizations employ hackers just to breach the security of competitors in order to extract data. In general, the main results cover each other. The optimism for Industry 4.0 is high, while the implementation is still at its beginning. Companies implemented some applications but it is far too early to say that a transformation towards Industry 4.0 found place.

9. HOW I4.0 AFFECTED THE COMPANIES

In the following paragraph each company that was studied and interviewed during the research is listed. The key features are

listed as well as their progress and vision in terms of Industry 4.0. A generalized discussion can be found in the conclusion.

9.1 Case 1: Building material producer

This company is one of the leading flooring material-producer in the world and is located in several countries across the globe. Their focus lies on the production of floorcoverings for all kinds of purposes. Reaching from customer-designed to industrial-purpose floorcoverings. The emerging Industry 4.0 had a medium impact on some departments of the company. The company is large in size and hence has the capabilities to implement new technologies easier (Deloitte, 2015). The industry 4.0 applications are well fitting for this company. Personal customization for the products is a major driver of the company. The new I4.0 applications enable the company to be more efficient and to carry out processes more effective. However, Industry 4.0 applications are yet only implemented in some divisions and the implementation process is at its beginning. In order to increase the efficiency even more, the company plans to implement Industry 4.0 applications even further, than just for the mass-customization and efficiency purposes. But currently the Industry 4.0 is not a main concern for the company.

9.2 Case 2: Paint producer

This company focuses on the production of paint, especially for the automotive industry and is in close cooperation with them. The effect that Industry 4.0 had on this company is marginal. As we found out earlier in the paper the size plays a significant role in adopting Industry 4.0 applications in the manufacturing sector as secondary literature also states (Deloitte, 2015). The organization is aware of the emerging technologies and its advantages and opportunities. The possibility of implementation has been a topic in some discussions, but the technologies which are currently used in the company are up-to-date and well fitting for the organizations purpose. Thus, the risk of implementing Industry 4.0 is to high compared to the possible outcome. The interviewee estimated that they are ready to adopt Industry 4.0 applications in 5 to 10 years.

9.3 Case 3: Construction-chemistry producer

This company focuses its business on the production and distribution of Construction-chemistry products and is a leading figure in its relative environment. The influence that Industry 4.0 applications have is medium. They are aware of the situation and know that Industry 4.0 and the use of new technology becomes more and more important. The biggest difference of the company's vision is that their focus lies heavily on the demographics. Their main change factor to change is to attract young customers and the new technologies are a way to achieve this. The organization is in the process of implementing I4.0 applications in an incremental manner. So far, some new technologies have been implemented like an enhanced data gathering through system that gathers data from production processes and uses artificial intelligence to predict future changes and needs. The vision for the future is clear. The strategic focus is on embedding new systems into the existing processes in order to enhance efficiency. However, the company will only implement these systems in divisions that have a proven rise of efficiency due to new systems beforehand.

9.4 Case 4: Dry material construction and plaster plate producer

The following company focuses its business on the production of plaster plates and dry construction work. It has been very successful for several decades and is one of the leading companies in its relative industry sector in Europe. Thus, the organization is large in size with far more than 250 employees spread across Europe. The impact that Industry 4.0 had on this organization varies across the divisions. The manufacturing division for instance is largely automated and the use of robotics is spread through the whole manufacturing process and combined with IoT technology to interlink and monitor the production process. Other departments, such as the information-processing center is out-of-date and as the representative of the company states, needs immediate and widespread replacement. The organization is at the beginning of Industry 4.0 implementation, but the vision for the future is clear. The company is certain that I4.0 grows in importance. Hence, they want to keep on implement new applications and systems in divisions that can make extensive use of the new technologies, like the "Track and Trace" system that is used throughout the whole value chain.

9.5 Figure 5: Company characteristics:

Organization:	**Case 1:** Building material producer	**Case 2:** Paint producer	**Case 3:** Construction-chemistry producer	**Case 4:** Dry material construction producer
Size:	Large	Medium/Small	Large	Large
Industry 4.0 influence:	Medium but in some divisions extensive	Medium - insignificant	Medium	Medium but in some divisions extensive
Future ambition:	Further implementation of I4.0 applications	Wait for evidence, implementation of I4.0 in 5-10 years	Further implementation of I4.0 applications	Further implementation of I4.0 applications

10. CPS AND IOT EFFECTS ON CCN AND SCM

10.1 Effects of Industry 4.0 applications on Cross-Company-Networking

The following section will present the findings of how the Industry 4.0 applications – Internet of Things and Cyber-Physical-Systems affect Cross-Company-Networking and will hence answer the sub-research question on how Cyber-Physical-Systems and the Internet of Things influence Cross-Company-Networking and the Supply Chain. This section will be divided into two parts and only focus on the influence of CPS and IoT, since these two variables are the main research focus. First, the effects of these Industry 4.0 applications on SME's will be discussed and the in the second part the effects of IoT and CPS on large scale enterprises.

The results of the study show that SME's behold the Internet of Things and Cyber-Physical-Systems as a clear opportunity to increase the cooperation with industry-like organizations. The awareness for the opportunity for horizontal integration in cooperative networks is visible for SME's. Results show, that there is a strong believe in the sector that Cyber-Physical-Systems and the Internet of Things can play a significant role in enhancing Cross-Company-Networking and process effectiveness. Inside of the organizations these systems are already used to improve communication and the data gathering processes in order to optimize the products and customer satisfaction. SME's are at the beginning of Industry 4.0 implementation and use applications on a small but effective scale. The major problem still exists. SME's are yet reluctant to implement Industry 4.0 applications because of the costs and the uncertainty of the final outcome. The prognoses of the sector for the future are promising. Industry 4.0 applications are likely to be implemented in 5 to 10 years, after the technology proved itself to also be effective for smaller enterprises. Further research

can be done in a few years in order to evaluate the concrete influence that Industry 4.0 applications had on the SME's.

Large enterprises show the same enthusiasm towards Industry 4.0, with the only difference that they are in front of SME's in terms of the implementation of these systems. This also accounts for The Internet of Things and Cyber-Physical-Systems. These systems are widely used inside the organizations itself, but also crossing company borders. The IoT and CPS connect and interlink systems of several suppliers and retailers. This enables close cooperation and hence more efficiency. But this only happens to a marginal degree and with contractors of the company.

Reason for this being is a general problem in the Industry that became visible during the research for the study. Companies are increasingly reluctant to share information. This problem raises a huge barrier for the opportunity of Cross-Company-Networking. An effective cooperation needs and relies on the sharing of crucial information. This problem does not only apply to large enterprises but also to Small- and Medium- sized Enterprises. In order to discover and penetrate the full potential of Industry 4.0 applications, the organizations must become more open to information sharing and not just to contractors in joint-ventures. If crucial information is shared throughout the whole value chain via IoT and CPS, every organization can fulfill its core competency more efficient, due to combination and availability of data. This cooperation can become especially rewarding for SME's as this opens an opportunity for risk reduction by risk sharing. The study shows that all interviewees receive Industry 4.0 to be an opportunity for Cross-Company-Networking, but as long as the information sharing remains passive, the full potential of Industry 4.0 applications in combination with Cross-Company-Networking can never be reached.

10.2 Effects of Industry 4.0 on the Supply-Chain

The results for the influence of IoT and CPS on the Supply-Chain are clear and show a significant positive effect. Cyber-Physical-Systems and the Internet of Things are extensively implemented into existing systems and processes. Data is gathered at several points throughout the value chain, in larger organizations this is also done across company boarders. The Organizations know when their product is delivered or where its current location is. Products and processes are monitored by Industry 4.0 applications. Thus, problems and irregularities can be detected and transmitted across several instances and solved much faster as. This shows that the Supply-Chain is already under the significant influence of Industry 4.0 applications. The Cyber-Physical-Systems gather data from suppliers and producers and link them to the responsible figures in the Supply-Chain. These systems are also used in order to detect problems and track down products. The effect of these systems is significantly positive. The new systems IoT and CPS enable a more efficient production, more data and hence more possibilities in terms of customization and problem detection. The human being is a part of the system and connected to the IoT. Especially in the Supply-Chain the implementation of Industry 4.0 systems made significant progress. By now, the whole industry uses these "Track and Trace" systems, no matter the size of the organizations. The enhanced use of CPS in combination with IoT prove itself to be effective and organizations regard these systems as an important asset in order to keep up with competitors.

11. LIMITATIONS

The first limitation that we need to account for is the sample and its size. The sample was not random. It is based on company approval and hence might not represent the full scope of variety in the relating sector. The sample size used for this study is only 4. A sample of that small size implies that the sample is limited the representation of the research. Small sample sizes have the danger of representing unusual findings. Larger sample sizes allow for some unusual findings, since the normal distribution accounts for some unique cases. This implies that the research might include results of companies that do not act as the rest its sector.

In addition to that, the fact that being a single coder limits the possibility to compare interpretations and assumptions to other opinions. Meaning, that if only a single interpretation is used to analyze and interpret findings, this leaves room for interpretation and differing opinions. For this reason, many researchers suggest to use at least two coders in order for the research to increase its reliability. This leads us to the next limitation. The "Built-in" bias. The fact that research is often done by a single person implies some limitations to quantitative research. The researcher is focused on his own values and beliefs and can structure interviews or surveys in a manner that it favors his research goal.

Another limit to the research is that all of the studied companies are located in Germany. Some of them are interacting globally, but the companies are all directed from Germany. That limits the research in variety. Since Germany is one of the leading countries in the implementation and research of Industry 4.0 some other countries may have a different perception of technology and business operations. This might lead to different results than in other countries, where the implementation of Industry 4.0 is less ambiguous or favored.

The limitations were listed in order to prevent readers from drawing concrete conclusions. The study however gives a new perspective on Industry 4.0 and the influence of its applications. In order to give a full perspective on that topic, further research in this field has to be conducted. Emphasize can be put on how quick the changes occur and which changes occur, especially in the difference between the size of companies. Another main focus can be put on Cross-Company-Networking and if the industry readiness towards more cooperation increases.

12. CONCLUSION

The following section will conclude the main findings of the study by highlighting the most important findings.

The paper gives a new insight into Industry 4.0, its progress and especially how Industry 4.0 applications influence the way organizations do their business. Concluding we can say that the impact that Industry 4.0 has on manufacturing companies is medium. Organizations are aware of it and use it in some cases and departments. But yet its far too early to speak about an implementation of Industry 4.0. Companies are experimenting, and in some cases widely using I4.0 applications, especially tracking, monitoring and ICT systems. But the trend for the future is clear. New applications and systems are strived to be implemented further and further throughout the whole industry. Another major finding is the influence of size on the progress and readiness of organizations to implement Industry 4.0. SME's are reluctant towards implementing new systems as it opposes a major threat to their livelihood. The cost-factor is simply too important as I4.0 systems are costly. Time plays an important role. SME's wait until the cost of Industry 4.0 applications reduce and prove themselves to be effective, also for medium and small sized companies. In addition to this the uncertainty of the outcome plays a major role. SME's lack in evidence from

competitors or industry-like organizations that already implemented the systems as they keep it secret in order to gain competitive advantage.

The study shows the importance that Cyber-Physical-Systems and the Internet of Things have on organizational processes, especially Cross-Company-Networking and the Supply-Chain. Cross-Company-Networking will grow importance in the future. Emerging technologies will enable a closer and facilitated networking across organizational boarders. But the research reveals that the industry needs to become more open in terms of data sharing in order to fully penetrate the opportunities of Industry 4.0 systems like IoT and CPS. The influence that Industry 4.0 applications have on the Supply-Chain are already obvious throughout the whole industry. New systems that are automating the supply chain are widely used as well as self-controlling systems (CPS). These systems proved to be profitable and making the overall production process more efficient. Even in SME's these systems are widely used in order to detect failures and monitor the quality of the production processes. The human became a part of the system. Failures and data are directly linked via the Internet of Things to employees and analysts.

In general, we can say that the Supply-Chain becomes more and more automated as new systems automate the processes. Systems control themselves and the human becomes a part of this system as they are interlinked via data that is gathered during the processes. The cooperation with other companies is expected to grow in importance. Supply-Chains across boarders are expected to be interlinked and hence the horizontal differentiation reduced. Cross-Company-Networking will grow in importance as well, but as the study shows, the industry needs to renew its way of operating with each other, as the sharing of information is a crucial topic in order to generate maximum profitability of Industry 4.0 systems. But we need to keep in mind that Industry 4.0 implementation is still at its beginning and that further research in the future needs to be made in order to show the whole influence of Industry 4.0 applications on organizations. It is clear that companies must face some specific and new challenges that are linked to the implementation of industry 4.0 applications. Companies must attract new employees that are qualified to run and maintain the new systems. The interlinkage and rise of information must be effectively controlled in order to use the information in the right manner. An additional challenge that was also frequently mentioned during the interviews, is cybersecurity. Organizations need to take care of their IT-systems in order to keep crucial information secret. These challenges are only a few of a variety of problems that still need to be detected during the advancing possibilities and implementation of industry 4.0.

13. ACKNOLEDGEMENTS

To all the people that supported and influenced me to go this path, you encouraged me to go my way no matter what. A special thanks goes to my first supervisor Mr. Robbert-Jan Torn MSc who enabled me and helped me with feedback in order to write my thesis. I would also like to thank my second supervisor Mauricy Alves da Motta PhD and Prof. Dr. ir. Henseler who supported me with important information at the introduction to the thesis. To all people that helped me during the research and that gave insights into their organization and personal thoughts. To my parents that always stood by my side and supported me no matter what.

14. REFERENCES

Acatech & Forschungsunion. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0.

Bahetti & Gill, (2011). Cyber Physical Systems | IEEE Control Systems. Society.

Bischoff, J. (2015). Erschließung der Potenziale der Anwendung von "Industrie 4.0" im Mittelstand.

Bos, J. (2018). Reluctance in Industry 4.0 use within SMEs: empirical findings - University of Twente Student Theses.

Brettel et al., M. (2014). How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective.

BMWi. (2015). Industrie 4.0 Volks- und betriebswirtschaftliche Faktoren für den Standort Deutschland.

Deloitte. (2015). Industry 4.0 - Challenges and solutions for the digital transformation and use of exponential technologies.

Dowling, M., & Huesing, S. (2004). Die Theorie der Disruptive Technology. Retrieved June 18, 2019, from https://www.researchgate.net/publication/29864755_Die_Theorie_der_Disruptive_Technology

Eagleton & Manolopoulou, C. (2017). British Museum - The Industrial Revolution and the changing face of Britain. https://www.britishmuseum.org/research/publications/online_research_catalogues/paper_money/paper_money_of_england__wales/the_industrial_revolution.aspx

European Comission. (2015). User guide to the SME Definition. Retrieved June 13, 2019, from https://ec.europa.eu/regional.../sme/smedefinitionguide_en.pdf
Encyclopedia Britannica. (2019, May 23). Industrial Revolution | Definition, Facts, & Summary. Retrieved June 11, 2019, from https://www.britannica.com/event/Industrial-Revolution

Gartner. (2019). Internet of Things Defined - Tech Definitions by Gartner. Retrieved June 11, 2019, from https://www.gartner.com/it-glossary/internet-of-things

Gorecky et. al, D. (2015). Human-machine-interaction in the industry 4.0 era.

Lin et. al, H. W. (2012). Design of a Global Decision Support System for a manufacturing SME: Towards participating in Collaborative Manufacturing. Retrieved June 11, 2019

Kagermann et. al, H. (2018). Industrie 4.0 im globalen Kontext " Strategien der Zusammenarbeit mit internationalen Partnern - acatech.

Lasi, H. (2014). Industry 4.0.

MIT. (2014). MIT AMP 2.0. Retrieved June 11, 2019, from http://web.mit.edu/pie/amp/

Mokyr et. al, J. (2000). The Second Industrial Revolution, 1870-1914.

Manavalan et. al, E. (2019). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements.

McKinsey & Company. (2015). Industry 4.0 How to navigate digitization of the manufacturing sector.

McKinsey & Company. (2016). Industry 4.0: How to navigate digitization of the manufacturing sector.

Oesterreich & Teuteberg, T. D. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry.

Pillar, N. D. (2019). Mass Customization.

Sentryo. (2017). Industrial revolutions: the 4 main revolutions in the industrial world. Retrieved June 11, 2019, from https://www.sentryo.net/the-4-industrial-revolutions/

Statista. (2016). IoT: number of connected devices worldwide 2012-2025 | Statista. Retrieved June 11, 2019, from https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/

Study.com. (n.d.). The Second Industrial Revolution: Timeline & Inventions - Video & Lesson Transcript | Study.com. Retrieved June 11, 2019, from https://study.com/academy/lesson/the-second-industrial-revolution-timeline-inventions.html

Römer & Bruder, T. (2015). User Centered Design of a Cyber-physical Support Solution for Assembly Processes.

The Economist. (2012). The third industrial revolution. Retrieved June 11, 2019, from https://www.economist.com/leaders/2012/04/21/the-third-industrial-revolution

Wang et al., S. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook.

Weber et. al, E. (2016). Economy 4.0 and its labour market and economic impacts.

World Bank Group. (n.d.). SME Finance. Retrieved June 18, 2019, from https://www.worldbank.org/en/topic/smefinance

Wübbeke et. al, J. (2016). Made in China 2025 - The making of a high-tech superpower and consequences for industrial countries.

Zhou, W., & Piramuthu, S. (2012). Manufacturing with item-level RFID information: From macro to micro quality control.

3DInsider. (2019). How To 3D Print - Beginner's Guide To 3D Printing - 3D Insider. Retrieved June 11, 2019, from https://3dinsider.com/3d-printing-guide/

15. APPENDIX A

Figure 1: Connected devices worldwide:
(data from: statista, 2016 - *https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/*)

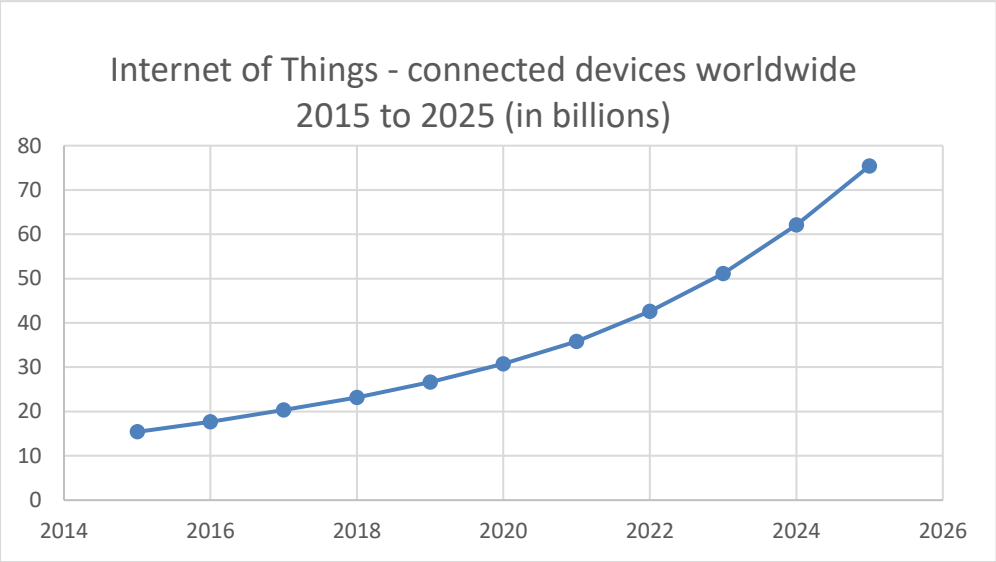


Figure 2: Future independent supply chain:
(data from: H. Lasi - *https://link.springer.com/article/10.1007/s12599-014-0334-4)*

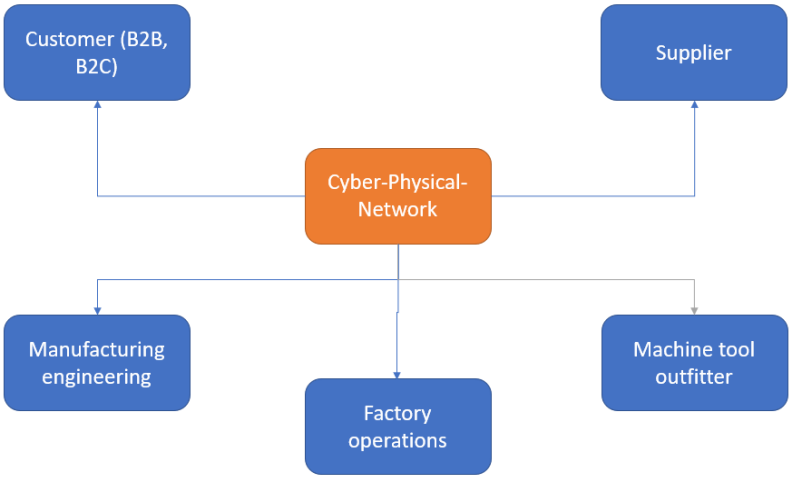


Figure 3: SWOT analysis

The organization	**Strengths – S** 1. Enhanced efficiency 2. Interconnection of systems 3. Enhanced data flow 4. Problem detection	**Weaknesses – W** 1. Costs of system 2. Uncertainty of outcome 3. Few evidence 4. Loss of expertise
Opportunities – O 1. Mass-customization options 2. Interconnection of organizations 3. Long-term profitability	**SO strategies** → Attack strategies = Leverage strengths to maximize opportunities → make use of technological advantage to Mass-Customize	**WO strategies** → Reinforcement strategies = Counter weaknesses by exploiting opportunities → Use advantage of new systems to generate long term profitability and regain cost
Threats – T 1. Dependence on technology 2. Lack of qualified employees 3. Implementation failure	**ST strategies** → Develop strategies = exploit strengths to minimize threats → Use technology to gain advantage and focus on security issues	**WT strategies** → Avoid strategies = Counter weaknesses and threats → Secure IT-structure and employ qualified personal before full implementation of I4.0

Figure 4: Cyber-Physical-Systems and the Internet of Things

(data from: Bischoff, 2015)

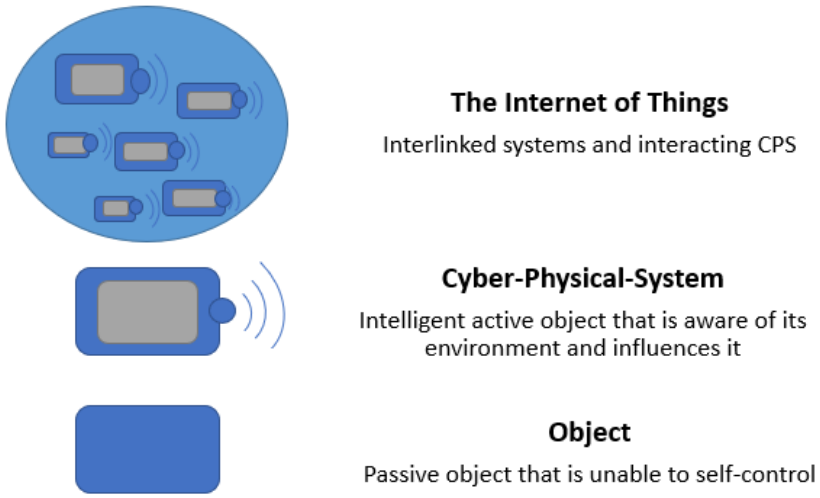


Figure 5: Table of company's characteristics

Organization:	**Case 1:** Building material producer	**Case 2:** Paint producer	**Case 3:** Construction-chemistry producer	**Case 4:** Dry material construction producer
Size:	Large	Medium/Small	Large	Large
Industry 4.0 influence:	Medium but in some divisions extensive	Medium - insignificant	Medium	Medium but in some divisions extensive
Future ambition:	Further implementation of I4.0 applications	Wait for evidence, implementation of I4.0 in 5-10 years	Further implementation of I4.0 applications	Further implementation of I4.0 applications

16. APPENDIX B: INTERVIEW QUESTIONS

Interview Questions:

Q1: Do you think that Industry 4.0 is a crucial topic for your company?

Q2: How do you think Industry 4.0 will affect your company? Or how did I4.0 affect your company?

Q3: Did your company already implement Industry 4.0 applications? And if yes, what where the effects?

Q4: What do you think are the biggest threats of Industry 4.0?

Q5: What do you think are the biggest advantages of Industry 4.0?

Q6: What are the effects of the Internet of Things on Supply Chain Management?

Q7: What are the effects of the Internet of Things on Cross-Company-Networking?

Q8: What are the effects of Cyber-Physical-Systems on Supply Chain Management?

Q9: What are the effects of Cyber-Physical-Systems on Cross-Company-Networking?

Q10: What are your open thoughts about Industry 4.0?

Extra Questions:

1. What is the biggest barrier in implementing Industry 4.0?
2. Would you say that you are still at the beginning of the Industry 4.0 implementation process?
3. What role do the cost play in the implementation of Industry 4.0 applications?