Industry 4.0

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Abstract

At Hannover Messe in 2011, an annual German industrial fair, a term called Industry 4.0 was first mentioned. It defines the fourth industrial revolution. Industry 4.0 focuses on how to integrate new technologies and digitization to gain manufacturing advantages. It visualizes a fully automated manufacturing system with total adaptability and minimal environmental impact while improving product quality.

The purpose of this report is to identify what can create value for manufacturing companies when implementing Industry 4.0 concepts. Since Industry 4.0 consists of many different aspects and areas this reports mainly focuses on how to create value in terms of costs, lead time and environmental impact. In order to answer these questions a literature study was done together with semi-structured interviews with employees in major Swedish manufacturing companies.

The main conclusion of this report is that Industry 4.0 certainly can create value for manufacturing companies when implemented. Costs can be reduced with automated machines and predictive quality, lead times shortened by using models that can predict failure and a decreased environmental impact can be achieved by implementing Industry 4.0 tools. However, it also highlights the difficulties when trying to implement Industry 4.0 in practice and were theory lacks application in practice. Finally, the report concludes that further research should investigate in how companies are implementing Industry 4.0 concepts into their businesses and how a business can ensure that it generates value.

1 Introduction

This chapter will present an overview of the reports purpose and the background to Industry 4.0. It also concerns the method behind the report and its limitations.

1.1 Background

Industry 4.0 originally originates from a strategy project within the German government. In 2011 at Hannover Messe, a German annual industrial gathering, the expression Industry 4.0 was presented. Industry 4.0 is an expression that defines the fourth industrial revolution. Since then it has been widely spread and accepted as the future of manufacturing, both by governments and companies.

Continuously increasing global competition leads to new challenges for manufacturing companies. The demand for productivity, flexibility and more complex products are increasing while resources are limited. Manufacturers needs to develop their processes and adapt to the new environment to be able to deliver sustainable solutions that satisfies the markets demands and to stay competitive. With new tools and knowledge within Big Data analysis, companies now have the possibility to analyze and draw conclusions from a wide range of data that is collected throughout the manufacturing process. Manufacturers can use this data to further optimize their production.

Industry 4.0 is a combination of production methods with new information and communication technology. The growing digitization of the economy and in society fuels the development. A manufacturing process where machines, logistics, materials and people are connected with the possibility to communicate directly is called a smart factory. Smart factories are determined to be the future of manufacturing. The integration of different parts of the manufacturing chain across company departments is meant to create more flexible and efficient production (Federal Ministry for Economic Affairs and Energy, 2018).

In order to develop countries, industries have been expanded vastly in order to satisfy society's demand of improved life quality. Industry has been a big factor to ensure employment meanwhile delivering products to consumers. In order to further improve quality of life, industries will continue to deliver customized products of high quality and create a better work environment for their employees. By doing this over time, industries and production has become one of the biggest contributors to global pollution and climate change. In order to maintain a sustainable production, industries have to undergo many changes and Industry 4.0 is one way to address this issue. In theory, Industry 4.0 can use new information technologies and provide new business models integrated with engineering processes in order to maintain high quality with low cost but also to operate in a flexible, efficient and pro-environmental way (Wang, Wan, Li, & Zhang, 2016).

Sweden has a long and successful background in manufacturing industry. It has been a fundamental cornerstone for the development of Swedish economy, with advances in technology and creation of job opportunities. The Swedish government has made initiatives in order to strengthen its domestic industry with investments in new technologies. Four key areas and challenges has been identified; digitization, competence, sustainability and innovation. Sweden depends on its industry to stay competitive and conduct global trade. It is then crucial for Sweden to adapt and implement new technologies to remain as one of the front runners in this industrial transformation (Näringsdepartementet, 2015).

1.2 Problematization and purpose

Research has provided information about different techniques and technologies to allow companies to implement Industry 4.0 but lack research in how companies in their daily business implement and use theory to get a competitive edge. The broadness of Industry 4.0 and Internet of Things leads to

endless possibilities and varieties of application in different markets. Previous research has established tools and applications on how to use Industry 4.0 but it is still unheard of a company with full scaled implementation. The technologies for smart manufacturing exists yet no business has committed and fully integrated their manufacturing with the Industry 4.0 concept.

The purpose of this report is to identify, in terms of costs, lead time and environmental impact, how Industry 4.0 can create value in manufacturing companies.

1.3 Research topic

How can Industry 4.0 create value in manufacturing companies?

1.4 Method

To analyze how Industry 4.0 can create value in manufacturing companies a qualitative research was the method of choice. Firstly, a literature study was done to get an understanding of the topic and to identify key factors that will be analyzed. Furthermore, an additional literature study was done together with interviews with employees from manufacturing companies.

1.5 Limitations

Limits of the research have been set due to the spread of Industry 4.0 and all of its different aspects and areas where it could be applied. Initially a brief summary of the subject Industry 4.0 is presented. This research mainly focuses on Industry 4.0's ability to create value in terms of costs, lead time and environmental impact within large manufacturing companies and how that generates value and strengthens their market position.

1.6 Glossary

- **Internet of Things (IoT)**

The network of devices and items embedded with electronics, software, sensors, actuators and connectivity that enable them to be connected and exchange information.

- **Smart machines**

Machines that can learn from experience and adapt their behavior meanwhile not being dependent on human interaction.

- **Smart factory**

Factories with the capability to make decentralized decision based on data acquired from machines and its automated processes within the factory. It uses IoT in order to acquire data and consists of smart machines.

- **Smart production**

Optimize production by having high levels of adaptability. It achieves this by using advanced technologies to analyze data in order to make correct decisions.

- **Radio Frequency Identification (RFID)**

An automated identification technology that uses electromagnetic fields to identify and track tagged objects.

- **Big Data**

Voluminous sets of data where traditional analytical tools are not sufficient. Consist of three concepts, volume, variety and velocity. Collected throughout processes and analyzed in order to identify trends.

- **Cyber-physical systems (CPS)**

Computers and algorithms that control or monitor mechanisms. It is connected to a network and its users. It is an embedded system that can control a process i.e. process control systems and robotics. It transfers data from physical objects and transforms it to readable digital data.

- **Digitization**

The process for converting technology from analog to digital. Making data readable by computers that results in a digital representation or a digital image for a signal. Connect technologies and products with machines and human interaction.

- **Cloud computing**

An information technology that allows access to shared sets of data. It allows for communication and analysis in real time data. It is a platform within the network.

- **Artificial intelligence (AI)**

Computer systems that can complete tasks that normally requires human interaction. The system can make decisions, translate information and evolve from previous experience in order to achieve its goals.

2 Industry 4.0 according to theory

This chapter presents how Industry 4.0 is described according to theory. The concept is described under the following four subchapters; industrial development, cornerstones for Industry 4.0, macro and micro perspective of Industry 4.0 and Industry 4.0 readiness.

2.1 Industrial development

Prior to Industry 4.0, three other major industrial revolutions have taken place. The first one evolved in the second half of the 18th century and proceeded into the late 19th century. During this period, entities started to develop mechanical production facilities. From late 19th century, the use of electricity and the use of labor defined the second industrial revolution. In the final quarter of the 20th century the use of computers enhanced dramatically and started the third industrial revolution. This led to development in advance electronics and information technology. Businesses and society is now entering the fourth industrial revolution. Technologies are now able to process and feed real time data between humans and machines in order to create decentralized intelligence instead of centralized control systems. Basic principles for this revolution is the ability to use information through the process chain in order to optimize production flow and change the behavior accordingly (Hermann, Pentek, & Otto, 2016).

2.2 Cornerstones for Industry 4.0

Industry 4.0 includes a wide range of strategies, technologies and analysis. It was first mentioned as part of a project in order to strengthen Germanys manufacturing and production. The concept, funded by governmental bodies, was authored by an assembly of representatives from academia, politics and business. The vision of Industry 4.0 is that it will provide significant economic growth through improvements within engineering, material consumption and manufacturing. Smart factories and smart production are two areas within Industry 4.0. A smart factory defines a factory that is integrated with technologies such as Internet of Things (IoT), Cyber-Physical Systems (CPS) and data analysis (Brettel, Friederichsen, Keller, & Rosenberg, 2014). This is made possible because of emerging technologies and advances within IoT, big data analysis, Artificial Intelligence and cloud computing. Businesses can now integrate these technologies in order to achieve great improvements. Smart products and machines can integrate together and compute, communicate and control meanwhile maintaining autonomous. In this way, large sets of data can be acquired for big data analysis to find ways to optimize manufacturing. With a cloud service integrated throughout the Industry products can identify themselves, where they came from and where they are going. Within the smart factory, Industry 4.0's vision is to integrate subsystems and change the traditional factory to a factory with high flexibility and manufacturing system where processes are easy to reconfigure. This is one essential part in order to be able to create customized manufacturing in small batches. By making physical resources able to communicate with each other and to humans, information will flow freely within the manufacturing process. This will generate more data for analysis in order to determine the status of the process chain (Wang, Wan, Li, & Zhang, 2016). Information flow between devices and humans are keys for smart factories. This will provide information in real time in order to monitor and optimize movements of material, orders from customers, production status, energy consumption and feedback from machines and product quality (Hermann, Pentek, & Otto, 2016).

Since the concept of Industry 4.0 originate from the German government and Industry, several German companies and government departments have been involved in definitions around the concept. One of these departments that have been closely involved is the department of Innovative Factory System at the German Research Center for Artificial Intelligence which analyzed the idea of smart factory and found the following four enablers; Smart Planner, Smart Products, Smart Machines and Smart Operators. The Smart Planner operate with real time data and optimize processes within the production where the Smart Products have the intelligence to know their entire production process while continuously communicating with Smart Machines. Smart Operators are in this sense referred

to as human operators that control and supervise ongoing activities. They are mentioned as "smart" since they operate with an innovative network created by highly evolved ICT (Kolberg & Zühlke, 2015).

Horizontal integration is another pillar within the concept of Industry 4.0. This integration is based on cooperation between related companies which would form an efficient flow of information, finance and material between companies. New business models can emerge together with new value networks (Wang, Wan, Li, & Zhang, 2016). If the flow within the network works efficiently across company and department boundaries, productivity can increase. With increased productivity, global optimization for companies and their production processes gets reachable. This global optimization would create incentives for companies to focus on their core competencies within the network which enhances their competitive advantages against other networks. All in all, the changed opportunities for business models of manufacturing companies can lead to a switch in their offering. From an offer of superior products to an offer of superior manufacturing capabilities, which could be a unique selling point. However, building the flow of information, finance and material is not a simple process. The flow must be built upon trust across company boundaries when sharing critical and possibly sensitive information with competitors. There are findings indicating that successfully implementing the flow triggers innovation but also learning within the companies. If information is supposed to be shared successfully between organizations, they have to be synchronized to ensure that customer needs are still meet and in focus. Standards of data-transfer and utilization is another important part that has to be created throughout the industry. Here, supply chain designs are crucial to create possibilities of adaptation of routes and schedules. It is also important to be creative in this process to ensure that lead-time and inventory level lowers. It is obvious that data concerning customer satisfaction and delivery reliability also have to flow through the network while being the center point of the production. To be able to track goods through the production process different information and communication technologies (ICT) has been developed. Radio Frequency Identification (RFID) is often mentioned when examining Industry 4.0. RFID can communicate information such as status, entire work instructions and also log the production process. Since the price of RFID and other technologies has decreased dramatically over recent years they attract more interests which could mean that data easier and cheaper can be obtained. The positive things with these techniques are the availability of internet connection which through networks can increase and help communication between different levels within the network. This advanced communication together with virtualization gives significant optimization opportunities. In contrast of today's manufacturing process, tomorrows manufacturing process with Industry 4.0 will be less dependent in which order different processes is done or even in which order they pass through different factories or companies. How engineering workflows and services are supposed to be integrated end-to-end using CPSs is one very important issue of the Industry 4.0 concept. It is important for manufacturing companies to create and enhance value-added services which help differentiate them self on the market. By doing so, competition on the market can be met not only in the factor of the specific product. This creates possibilities of larger value capture which help creating a strong competitive position. Also, new possibilities from data gathering of smart products can create completely new businesses but also new businesses around the product/system. This could be met by updates and services which create new types of value (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

New opportunities within energy management can also be found by implementing Industry 4.0. The belief is a new paradigm of energy measurement, through smart meters and other tools, which will provide data to monitor energy consumption in different stages of production. Providing a more environmental friendly and sustainable future in manufacturing is crucial. IoT implementation can offer real time data to establish links and understandings of the behavior of energy consumption and in the end result in a more efficient energy usage. Analyzing collected data throughout the process chain can show were energy wastes occurs. Machines will then be able to automatically adapt to a more energy efficient configuration. This way speed and other parameters can be changed into more

optimal settings while maintaining the current demand from customers and flexibility (Shrouf, Ordieres, & Miragliotta, 2014).

There are three dimensions that outline Industry 4.0; horizontal integration, end-to-end engineering across the entire product life cycle and vertical integration with networked manufacturing systems. Horizontal integration runs across the entire value creation network within a company but also between competitors. It refers to these intelligent linkages which have the possibilities of enhancing product value for the entire product life cycle but also enhancing value between different value chains. This is performed through digitization of value creation modules.

End-to-end engineering refers to intelligent interlinkages in the entire product life cycle, which is from raw material acquisition via manufacturing systems, product use to end of product life. As for the horizontal integration, end-to-end engineering holds important elements of digitization.

Vertical integration and networked manufacturing systems refers to intelligent interlinkages and digitization between hierarchical levels of the value creation process. It creates interlinkages between manufacturing stations, cells, lines and factories. Also, it connects important activities in the value chain such as technology development together with marketing and sales.

All of the communication via the interlinkages are possible through technology that is connected to a cloud and thereby connecting the different processes. Data is also gathered to the cloud from embedded components and sensor systems that form the base for the CPS. The CPS continuously exchange data in real time via the cloud and can thereby influence and suggest changes in the manufacturing process. One important thing to note regarding the CPS is that they interact with operators which mean that it important to create understandable human-machine-interfaces.

2.3 Macro and micro perspectives of Industry 4.0

Industry 4.0 can be viewed from two different perspectives, the macro and the micro perspective. The macro perspective includes horizontal integration, end-to-end engineering and sustainable manufacturing. The micro perspective includes horizontal integration, factories, vertical integration and networked manufacturing systems and sustainable manufacturing.

Horizontal integration in a macro perspective: Value creation modules, i.e. factories, in networks are defined as interplay of value creation factors. These are for example equipment, human, organization, process and product. These modules have linkages throughout the products life cycle which creates an intelligent network of modules that include different products entire value chains. Factories that in the sense of value creation modules are embedded in a flow of data can be referred to as smart factories. Here, smart products are manufactured with renewable energy from smart grids and from big data knowledge which affect the decision-making process throughout the product life cycle. The smart grid is dynamic in the sense that it can change its role depending of the current energy situation in the grid. This means that it matches energy generation of suppliers using different renewable sources (Stock & Seliger, 2016).

End-to-end engineering in a macro perspective: The end-to-end engineering refers to the linkages of stakeholders, products and equipment for the entire product life cycle, from raw material acquisition to end-of-life. A virtual network holds the entire span of phases of the product life cycle which consists of products, stakeholders (customers/workers/suppliers) and manufacturing equipment that interchange data. Data is interchanged between the raw material acquisition phase, manufacturing, product development, use, service and end-of-life phase. For example, the end-of-life phase consists of data of reuse, remanufacturing, recycling, recovery and disposal together with information about transports between the phases (Stock & Seliger, 2016).

Sustainable manufacturing in a macro perspective: New business models will be created with sustainability as one of the main prioritized areas. This can have a positive or at least less negative impact in the environment of society by solving social problems. The sustainable business models have

to be competitive in the long-run. Thanks to the value creating networks new opportunities will be generated for closed-loop product life cycle. This helps products to become new, remanufactured products which can provide it with competitive advantages (Stock & Seliger, 2016).

Horizontal integration in a micro perspective: Integrating smart logistics to the smart factories create capabilities and new possibilities for factories. Automated transports will be used while continuously interchanging data with the smart modules. This creates a decentralization of the coordination of suppliers and products. The interchanging of data is made possible through different identification systems, for example RFID technique or QR codes, which creates a wireless localization and identification of every single piece of material in the value chain (Stock & Seliger, 2016).

Factories in a micro perspective: Smart factories will expand its renewable energy proportion from its own sources while having the ability to use the external smart grid. By doing this, the factory can be both a supplier and consumer at the same time via their energy management system. An essential resource flow for the smart factories will be capability of fresh water supply via water reservoirs (Stock & Seliger, 2016).

Vertical integration and networked manufacturing systems in a micro perspective: The linkages between value creation factors, such as product, equipment and human, and value creation modules from manufacturing stations is described by vertical integration and networked manufacturing systems. It also consists of interlinkages of for example marketing, sales and service. The value creation module in a factory refers to an embedded CPS. Sensors are used in the manufacturing equipment for the purpose of gathering data of value creation factors, but also in a monitoring purpose. This means that the sensors monitor different processes like cutting, assembly or transport and can respond thanks to real-time data and thereby create changes. All of this is done via the cloud (Stock & Seliger, 2016).

Sustainable manufacturing in a micro perspective: Installing sensors on current manufacturing equipment is an important part not only for the cost perspective, but also in the sustainable perspective. Since manufacturing equipment have a lifetime of many years, sometime around 20 years or more, it is important not to discard well-functioning equipment early in a non-cost-efficient way only due to the availability of new technology. This is why it is important that sensors are created so that they can be mounted on existing equipment.

Humans will in continuously have an important part of the value creation where three different sustainability approaches can be used; Increasing training efficiency via ICT technology like virtual reality displays, increasing intrinsic motivation and creativity via CPS approaches or by implementing concepts of gamification to support decentralized decision-making, increasing extrinsic motivation through incentive systems for workers by using gathered data from the product life cycle to provide feedback (Stock & Seliger, 2016).

One of the essential advantages of Industry 4.0 is the concept of holistic resource efficiency thanks to smart logistics, the smart grid, the self-sufficient supply or the customer.

Designing products for closed-loop life cycles is another sustainable objective that creates possibilities for reuse and remanufacturing (Stock & Seliger, 2016).

2.4 Industry 4.0 readiness

There are many difficulties in order to understand how ready a business is to start implement Industry 4.0 within different business units. Different parts of a business will not have the same maturity level in regard to Industry 4.0. To understand a business current state a tool called VDMA can be used to decide the Industry 4.0 readiness of that business and its units. It was commissioned by IMPULS Foundation of German Engineering Federation (shortened as VDMA) and conducted by industry experts together with Cologne Institute for Economic research and the Institute for Industrial Management at RWTH Aachen University. This model consists of six different key dimensions: Strategy

and organization, smart factory, smart operations, smart products, data-driven services and employees. These six dimensions has an Industry 4.0 readiness level that consists of different requirements that must be met in order to advance in levels. The model defines levels between 0 – 6 which represents different states of where a business is in Industry 4.0 and their readiness to implement Industry 4.0 infrastructures and technologies (Lichtblau, o.a., 2015).

3 Empiricism

To answer and analyze the research topic an interview study was done to gather data on practical use of the concept within different businesses. To review the interview structure, see appendix 1.

Semi-structured interviews were made with three different persons from two of Sweden's 30 biggest listed companies which are market leaders within their field, see Table 1. Company X is a manufacturing company that operates worldwide and produces many different products. Their primary manufacturing lies in industrial tools and equipment. In order to see the variety of perspectives of Industry 4.0 within a business, two persons at different hierarchical positions were interviewed from the same company, named company Y. Company Y is a world leader in manufacturing products from raw materials. The interviewee's names have been anonymized to Johnson, working at company X, Spieth and Woods, working at company Y.

Table 1 - Table of interviewees and their positions

Interviewees	Company	Position
Johnson	Company X	Manager, System Software department, R&D
Spieth	Company Y	Manager, Control Systems
Woods	Company Y	Head of Strategy, Group executive board

Further exploration was done by investigating reports from companies and institutes. This provide information about their engagement and approach towards Industry 4.0. It will also provide information about difficulties and challenges met in their work with Industry 4.0 and digitization.

The information gathered from the interviews and business reports gives the foundation of data needed for mapping it against theory and to draw conclusions. At this point an answer to the research topic will be possible.

4 Analysis

This chapter presents data collected from the three semi-structured interviews. The data is mapped against theory to provide knowledge on how the theoretical view of Industry 4.0 stands towards manufacturing companies view of Industry 4.0. The interviews were conducted in Swedish and all quotes have been translated.

To get an understanding of how companies view the concept of Industry 4.0, the interviewees were initially asked about their vision of Industry 4.0. When asked about this, Woods, member of the group executive board at company Y, said:

"I don't see it as a revolution, rather an evolution"

Woods continues:

"We have abstained from the concept of Industry 4.0, we don't use that description. It's because it is perceived as something like automotive industry, German and something new and there is nothing correct about that"

Clearly Woods don't see the concept of Industry 4.0 as something closely related to the impacts of the three previous industrial revolutions. Johnson, manager at company X, says:

"It's about faster time to market. … We have to talk about these buzzwords, big data, internet of things etc. If we don't mention them, then people believe that we don't know them."

Spieth, manager at company Y, says:

"We are in Industry 3.5. We view the concept that you collect a lot of data, process it and make informed decisions"

This means that the concept of Industry 4.0 is not viewed in the same way that theory describes it. Industry 4.0 is described in theory as the next revolution in industrial manufacturing for business and society. Even the name, with 4.0 in the end, indicates this. With that said, elements in Industry 4.0, and especially digitization, is not neglected as important for businesses. Woods says:

"We have formulated a digitization strategy which is founded on three cornerstones:
1. What shall we do with our products? How can we make them more digital?
2. The customer interface. This is not something new for everyone, but it is new for us. How can we make it more efficient? How can we reach further out in the world through digital tools?
3. Where can you use digitization within operations?
The most important thing now is to work with availability, to prevent maintenance. And also to use the technology of sensors and big data to create more efficient flows."

As Industry 4.0 heavily emphasize the importance of digitization and automation, its importance for businesses and products are well understood by the manufacturing industry. When asked about difficulties of Industry 4.0, Spieth says:

"The technical part is not the difficult thing, I see the organizational part and the cooperation as the challenge. The technical part will be solved, we have embryos, but it will need a whole new way of working. You work more horizontally in Industry 4.0 which we are not use to. We need to work more together. That is probably the biggest challenge"

Here, the technical part is not viewed as the biggest challenge, it's the new organizational form that will inherent challenges. This refers to the horizontal micro perspective of Industry 4.0 where smart factories, smart logistics and automated transports interchange data via different identification systems. However, Woods sees other difficulties:

"I believe that the difficulty is the human factor and the new technology, that you may not have knowledge about, that have to be combined. We have a situation with a lot of extremely clever people that really want to work with new technology, that want to learn new things. But the question is: How do we ensure that they get the competence and resources they need?"

Competence and resources are identified by Woods as keys towards further digital interaction between human and technology. This is also acknowledged in the literature of the concept Industry 4.0 where it is said to be a key element in smart factories. Regarding difficulties of Industry 4.0, Johnson answers:

"We have a number of systems from different directions that are supposed to be integrated. All types of integration take time and create problems"

Johnson underlines the difficulties of the micro perspective of horizontal integrations challenges in connecting different systems. When asked about possibilities and value creation in Industry 4.0, Spieth says:

"We have different things we work with. For example, predictive maintenance where we want to know when something gets broken so we can exchange that part the day before. Predictive quality is also interesting. We test everything which we have to according to standards to classify it. Some products do we actually not have to test but we do it to verify that our process works the way it's supposed to."

Predictive maintenance is an area where, thanks to big data models and sensors, maintenance can shift from being reactive to proactive. Both company X and company Y lift the possibilities of Industry 4.0 of transforming maintenance towards a proactive standpoint. Johnson says:

"You can talk about being reactive and proactive. We and our customers want to go towards being more and more proactive"

Being proactive stands out as a requested ability for what Industry 4.0 could do for them, both from the company itself but also from their customers. Regarding possibilities of creating value, Woods says:

"We have a couple of use cases we work with. We work very close to our customers and there are many intriguing pilot initiatives. … We are having discussions with a subcontractor about creating a manufacturing system where the product, thanks to its marking, knows through the cloud what kind of product it is and its abilities and also that it can talk to the next machine in line. So that the machine can calibrate itself according to the products unique parameters. The subcontractor says that if the product can hold this information, we will see a raise in productivity. Today we need a human operator there to help the machine to calibrate."

The cloud becomes an important part in the manufacturing process to create the ability of communication between the product and the machine. This is mentioned in the theory of Industry 4.0, where cloud services, via for example RFID technology, can be an integrated part of the manufacturing process in the way of helping products to identify themselves, to know where they came from and to know where they are going. In these cloud services, big data models are, according to theory, providing

optimization abilities. Collected data is thereby an important aspect of the cloud services. From the question about what data is collected today, Spieth says:

"On some areas we collect all kinds of data. We don't have a strategy or plan for how we collect it depending on what kind of answers we want, which is instead something we have started looking at now. We are running a pilot case now … were we have started discussing how we collect data and what kind of data you need. We are now in a conceptual phase, but we think that we will go on to testing phase soon"

According to Spieth, projects regarding data usage and data collection have been initiated and are soon going to testing phase. It seems that data collection projects are a natural direction, Johnson says:

"We are doing data collection, a lot of it is done by data services but we look at it manually. … We do not have an automated flow. Sometimes it costs more to do the implementation and to get it stable than what it cost to manually look at four different places to check that: Yes, we know where we are"

Johnson recognizes cost as a problem towards further implementation of automated data gathering and data services. On the same question about what kind of data are collected today, Woods answers:

"Across the different productions sites we only collect commercial data. We don't collect any operative data across the sites. On a production site, you collect data from each line. We have done a project where we try to visualize the operative data for the whole site. In that project we had an online scorecard where everyone could see how all the lines performed. There is still work to do there. So that we can get better in taking into account the whole sites data collection. Right now I would have to say that a lot of this is only done locally on the sites"

In the project Woods talked about, real time data were used to create the online score card. This is a form of human-machine interaction. When asked about real time data usage, Woods says:

"All control units work with real time data. In the long term you may not need a control unit for each line. If you build a production site today from scratch you would maybe build one control unit. And maybe not personal riding but more cameras and sensors and put all people on the same place."

Real time data is used in company Y primarily for control purposes with a human operator monitoring it. However, according to the theory of Industry 4.0, real time data can be used in a much wider range without human interaction which could generate further optimization possibilities. As companies increase their connection to the internet, IT-security have become of larger importance. Woods says:

"IT-security is very important, we take it seriously and I have an IT-security manager working on it. We have probably high risk since we have a lot of intellectual property that many would want. I could see that company Y would get exposed of a hacker attack by a competitor, by another country or another party. I could also see that someone would try to bribe an employee. So what do we do? We have a transformation-agenda where we do external tests where we ask an external part to try to hack in to our systems and see what they find and to see what kind of weaknesses and vulnerabilities we have."

Spieth continues in the same area:

"We work actively with it. We have worked with it a couple of years. … The problem is not if you get in to our systems, or of course it's a problem. For machine security you are mostly worried of script kitties, where one downloads some cool internet tool and then shuts down an entire production site. It is both parts, the part that you steal data and the part where you can cause problems."

IT-security is recognized as an important area were continuous work is demanded. This area does not get the same attention from the theory around Industry 4.0.

When asked about increased value creation, Woods mentions a new project that is focused around a smart product. Woods says:

"We have launched this concept of a smart product which is completely new for company Y. We sent out a press release and said that we want to create this smart product, so we invited customers and partners to help us defining what it can be. … We have worked with that concept and are going live now with some new solutions where you, via image recognition, can take a photo on the number, which is printed on every product, and get information on what it contains, when it was manufactured, if I can do certain things with it etc. We connect the products individual with digital information and a number of services around it"

This project, containing company Y:s smart product, has several similarities to what theory describes as smart. It is described as smart if they operate with an innovative network created by highly evolved ICT which fits Company Y:s new concept. Another element of the theory surrounding Industry 4.0 is customized manufacturing and customized products, where it is pointed out as important to meet customer needs. When asked about customized manufacturing, Spieth says:

"A lot of what we produce today is actually customized"

Woods answers on the customized manufacturing question:

"I actually visited a car manufacturer recently and they build different cars all the time. … It's a long way from Henry Ford's manufacturing process. … The same thing doesn't exist in our industry, I think we are more locked in this charge. It doesn't get efficient. … We are working with the question: How can we shorten the series as short as possible? We are trying to shorten the series with preserved efficiency. The traditional way of our manufacturing is: the bigger our batches are, the better it is. This creates long lead times and high work in capital. But we have pushed ourselves so that we have as short series as possible without losing to much."

Customized manufacturing fits company Y:s manufacturing process partly. Johnson says:

"We have clients that do it. But there are very big structural investments that's needed. … We can't see that our customers in general move towards this. We have earlier worked with customized solutions for our customers. But there are laws in the way. For example, who decides how much a screw is tightened in an airbag if the system does it by itself? Who takes the responsibility?"

Customized manufacturing seems to exist close to company X too, even though there exist certain legal obstacles.

An important aspect of Industry 4.0 is how the concept can help companies lower their environmental impact. Woods says:

"We have a sustainability strategy that constitutes of different parts where the first part is that we shall be fossil free in 2045. Our manufacturing sites are among the most effective in the world but we aren't satisfied yet. … The second part is that until it's accomplished, we shall use our products to help customers to save and gain environmental advantages thanks to our product. We help them to lower their gas usage etc. We are close to selling enough of these kinds of products that it creates a positive net of CO_2 emissions"

Company Y is continuously working with the environmental issue in several ways, which also Spieth says:

"We have tried to save electricity. This work was initiated around 2011 when we started to shut certain manufacturing tools off when they weren't used. Now we focus on our new way of manufacturing our products, without causing any CO2 emissions in the process itself"

Saving electricity is mentioned by Spieth, which theory of Industry 4.0 emphasize. In the theory, smart grids are mentioned as possible ways of reducing electricity need from external parts. Johnson does also mention electricity as something they work with regarding the environmental question:

"We look at electricity consumption in the form of standby time. … We look at electricity consumption in all our products, but also in batteries and charging time. … We have a team that work with eco-design, to have correct material in our products. … It has always been important with sustainable productivity, it shall be sustainable for the individual, the environment and the economy"

As the positive environmental aspects are underlined in the theory of Industry 4.0 as an integrated part, company X and company Y provides a clear view that the environmental aspects of their manufacturing process are important and is a natural part of their work.

5 Results

This chapter will present results from the analysis and actions within Industry 4.0 that can enhance the value of a manufacturing process.

5.1 General

First of all, Industry 4.0 is not viewed as a revolution but a natural evolution by implementing new technology. Many areas that are included in Industry 4.0, has been done by companies for a long time. For example, to save documents and use versioning in a cloud service is not perceived as Industry 4.0 but are included within the concept. However, manufacturers are rather emphasizing on digitization and its importance for staying competitive. This means that they have strategies and projects that investigates what areas to invest in. When investing in an area of Industry 4.0 implementation, companies tend to miss the bigger picture. The goal with the investment is often to solve one particular problem in the organization or an isolated issue. The investments miss out on the company-wide value enhancement (Gates & Bremicker, 2017).

To work in a horizontal micro perspective is viewed as a challenge and requires organizational changes with new ways to work. The technical implementation is not viewed as a major difficulty but something that will require major investments. Integration of systems is something that takes time and can create problems.

Fully Industry 4.0 implemented manufacturing is not viewed as the goal. Companies rather researches in what areas they can save money or create value by using concepts from Industry 4.0. Sometimes it is cheaper to do something manually rather than develop and quality assure an automated process. Industry 4.0 can help companies improve their profitability but not in all areas. To define return of investment is difficult and no research currently exists. To gather knowledge within the company is viewed as important in order to understand new technologies and on how they can generate value.

Control unit's work with real time data and present it for the line operator. There is no automated analysis of the data, instead the operator relies on experience to make decisions. In the future it may be possible with only one control unit for a whole site which would operate with the help of cameras and sensors.

5.2 Costs

With technological advances, prices for automated machines has been decreasing significantly. This has given manufacturing companies possibilities to cut their costs by replacing people with machines. Meanwhile, the competence for installation and to operate and maintain automated production systems are increasing. New machines can operate together with results from big data analysis in real time to change their behavior accordingly (Tilley, 2017). Cameras can be used to find defects on products before they leave the factory via image recognition.

Costs can also be cut by using technologies that allows analysis of machines to predict failure, called predictive maintenance. Data of a machines wear and tear is possible to gather and then inserted in a mathematical algorithm to predict failure. To be able to predict machine failures manufacturers can schedule for maintenance and escape production stoppage and save a lot of money. Being proactive in general by analyzing data is something both manufacturers and their customers strives for.

5.3 Lead time

Automated testing is viewed as one important factor in order to shorten lead time. This create a faster time to market that creates value. By implementing Industry 4.0 it can be possible to produce smaller batches with the same efficiency as big traditional manufacturing batches. Predictive quality and predictive maintenance is also ways for companies to decrease their lead time. To be able to ensure

quality from gathered production data and schedule maintenance gathered from machine data lead time can be decreased.

5.4 Environmental impact

Manufacturing industry has a major impact on the environment. It produces emissions, leaves material wastes, consume resources and affects people's health.

By using data collection and analysis throughout the manufacturing process, machines that does not execute operations on a component can switch to standby mode in order to save energy. In this area thorough analysis has to be done. Companies want to lower their energy usage by designing smart products and smart processes. This would save energy through the lifecycle of the product.

In order to minimize health risks and provide a secure and comfortable work environment for persons in industry, companies invests in ergonomic design in order to reduce sound and vibrations. Automated systems can also complete tasks were otherwise a human has to be in a vulnerable or exposed position. This improve personal safety and an automated system can also be optimized for less environmental impact (Westerlund, 2017).

6 Conclusions

This section will present the conclusions drawn from this reports research and answer how Industry 4.0 can create value in manufacturing companies.

For starters, Industry 4.0 is not viewed as a revolution, rather as an evolution. Companies has to adapt to new technologies rather than fundamentally change their business models. Instead of creating new ground in manufacturing it is viewed as implementing Industry 4.0 in areas where it can create value. The challenges lies in integrating different systems within the manufacturing process and how a business shall tackle new organizational models that comes with horizontal integration.

There are ways a manufacturing company could create value by implementing Industry 4.0 technologies. Costs can be reduced by implementing digitized tools and automated machines. By collecting and analyzing data from machines a proactive approach can be used to minimize risks for production stoppage. With the help of big data analysis it is possible to find optimal energy solutions for a whole production line in order to minimize energy consumption. This will not only lower the manufacturers cost but also contributes to less consumption of resources.

Automated testing can ensure quality and shorten lead time. This means a faster launch to markets for new products. By analyzing production data it may be possible to ensure a specific quality of a product without conducting further testing. This would save both time and money in the production process.

Industry 4.0 can be used in ways that lower manufacturer's environmental impact. Not only in regard of emissions, by using less energy and optimizing resources, but also in a social way by helping human resources to a more stress and risk-free work environment.

A big difference between theory and practice is that theory sometimes forget the magnitude of investments that has to be made in order to fully implement Industry 4.0. In theory it all seems simple and logical but sometimes it lacks purpose in practice and does not have any definable improvement of value.

7 Discussion

This chapter will discuss the results and conclusions together with limitations and parts that's excluded or not taken into account when answering the research topic.

Most interesting is the revelation that Industry 4.0 is viewed at as an evolution and not a revolution. The interviewee's stated that it was the natural way for them to evolve and adapt their optimization by learning how to implement new technologies and tools. Industry 4.0 is more of a buzzword that has to be mentioned from time to time to clarify that they know and work with it. They also see the tremendous upside by a full Industry 4.0 implemented manufacturing process. However, the investments are very expensive and sometimes not realistic for a business. All areas within Industry 4.0 are not applicable for all manufacturing industries. It varies on the complexity of the products that are being manufactured.

New implementations will mean that established work processes and information flows will have to change. This will create difficulties for businesses that tries to implement Industry 4.0. The requirements of strong leadership and clear organizational change will be crucial. Since the techniques are new, companies are being cautious about doing major investments and changes.

A central aspect of Industry 4.0 is data collection and the ability to analyze voluminous data. The new ability to analyze data and how to collect enormous amounts of data requires storage. This storage becomes very valuable for the companies and thereby at risk from competitors and other entities. IT-security then becomes an even more important matter for companies. Companies are aware of it and invest more in protecting their data and their networks.

If a business stays active and continuously enhances their knowledge of how new technology work and how they can use the technology in order to increase their value, they could get a competitive edge. These businesses will have enormous potential in increasing their profitability.

A point to keep in mind is that, since only two companies are interviewed, the conclusions and results of this report will not cover all markets. The limitation of interviews makes the research to mainly focus on large manufacturing companies. The interviews will provide a bias view since the interviewees will present them and their company in the best way possible and the secondary data will be hard to verify.

The initial aim of the report has changed as part of the ongoing work. This because of the lack of information to the field and the vast variety of Industry 4.0. Data from businesses has been difficult to aquire in order to determine their status of Industry 4.0 involvement.

7.1 Further research

In order to further research the impact of Industry 4.0, researchers have to study how companies are implementing Industry 4.0 and were the value can be found. It is still very uncertain how to determine a return on investment when breaking in to new territory with new technologies.

It would be interesting if future research investigates if Industry 4.0 is more applicable to the automotive and truck part of the manufacturing industry. Since Germany has a large automotive and truck industry, this could indicate that their creation of the Industry 4.0 concept is more applicable to this part of the manufacturing industry. A comparison between different segments in the manufacturing industry regarding Industry 4.0 applicability would also further investigate the possible future spread of the concept.

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9 Appendix

1. Interview structure

To fulfill the aim and purpose of the study the interviews where divided into three main sections: The company and Industry 4.0-, data- and environmental questions.

Interview questions
The company and Industry 4.0
- What are your vision within the concept of Industry 4.0 and what possibilities do you see?
- How far are you in the transformation towards Industry 4.0?
- What do you focus on in this transformation?
- What difficulties do you encounter during the implementation of Industry 4.0?
- Does the right competence exist?
- How can Industry 4.0 create value for your company and for your customers?
- How do you involve the customer in your manufacturing process?
- In what way do you see that your company could move towards customized manufacturing?

Data
- What data do you collect today and how is it collected?
- Do you collect all possible kinds of data?
- What data do you use?
- In what applications do you use the collected data?
- What advantages does it provide?
- Do you work with real time data?
- How does man and machine communicate?
- How is data used in decision making in manufacturing, management and strategy?
- How have you worked with optimization of processes earlier and what possibilities to further optimization do you see with Industry 4.0

Environmental
- How can Industry 4.0 give a more environmental friendly manufacturing?
- Do you see any results?