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The Impact of Industry 4.0 on supply chain management.

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Abstract

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Abstract

The main purpose of this study is to identify and analyse the impact of Industry 4.0 and the related technologies on the Supply Chain Management as well as to provide recommendations for the Small and Medium sized enterprises.

This research primarily relies on the quantitative research data for the analysis. The secondary data used in the research has been gathered from internet articles and books.

The results show that the industry 4.0 has a significant impact on the supply chains and that the technologies of the fourth industrial revolution allow for the supply chains to operate in real time with as little as possible human disruption, however, at the current moment Industry 4.0 is at its infancy and the level of implementation is still small. The SMEs and large enterprises have different methods of implementing f technologies and the number of resources available thus the methods for implementation are different.

Keywords

SC, SCM, Industry 4.0, logistics

Contents

1 Introduction

1.1 Background

From the first time a human made a spear to hunt animals, humanity was always striving to improve the tools that it had: from a sharp rock to a spear the humanity took a biological leap in terms of survival. However, it didn't stop there: materials improved and with it the instruments improved as well, yet those tools no matter their complexity still needed to be produced and as the ancient tribes grew thus did their needs in more larger quantities of tools. This way Industry Zero came to be, when several people among the tribe had dedicated themselves to be craftsmen to serve the needs of a tribe.

Much later in the history of mankind, a second leap was made. Industry 1.0 started from the refinement of ores to make better tools to using the power of wind and water for the milling stones. We started using the world around us for our benefit and the industry followed.

Industry 2.0 was much closer to our time and it this leap was made by the humanity discovery of electricity, new ways of transportation and communication. Now the world was much closer together and that made rise to the advanced supply chains that could span countries and continents. Production lines were first introduced and now items could be produced in quantities never imagined before.

Industry 3.0 is the era in which most of the world industry is in. This era had brought the robots and internet to the forefront of industry, and it had changed it from its core. Now the information could be moved and stored digitally as well as it being able to get that information from around the world in a moment notice. This led to our modern supply chains that are extremely complex and use the variety of modern technologies to get a product to the customer. World had changed like never and some were thinking what the next step in industrial evolution would be.

New leap came into play in the form of Industry 4.0 – the whole new era for the industry where the automation is brought to a new level with the introduction of fully autonomous systems that do not require human interaction. Before such automation was only mentioned in the science fiction, where the factories worked without any human workers. Now it becomes possible with the introduction of new technologies for example Internet of Things (IoT) which allows for the connection of the electronic machinery and sensors, creating a local version of the World Wide Web within the modern factories. (Epicor 2021) However, the manufacturing of goods is only a small part of the modern supply chains that

span continents and countries with many intermediaries in between and with that in mind the companies around the globe are now thinking how the supply chains of the future would look like. Now the question is who will win in this race and how the smaller companies could participate in it. (iED 2019.)

1.2 Objectives

Industry 4.0 was born and contributed to the development of three main areas Biotechnology, Digital and Physics. By using three main core elements Artificial Intelligence (AI) which helps computers automate intelligent behaviours like humans, Internet of thing (IoT) where millions of physical devices all over the world are connected to the internet and Big Data which is capable of handling large data over the short period of time. This revolution can change the entire landscape of the economy, of course, it will have a great impact on businesses in all areas, especially supply chain management. (Haradhan, 2019.)

With predictive capabilities technology such as sending alerts about the risk of equipment failures or calculating the amount of raw material, Industry 4.0 not only helps companies produce products more efficiently, but they can also keep systems smooth. By collecting and processing big data, machines can identify capabilities to improve operations, optimize systems, and fix problems faster than humans. It creates the opportunity to customize and adjust processes quickly without much cost.

The main purpose of this study is to give a deep understanding of industry 4.0 and as well as its impact on the already existing supply chain to SMEs who want to gain an advantage over the competitions. Applying a new system requires a significant amount of human, financial resources, and infrastructure. As the result, entrepreneurs will understand the requirements of development and their limitations for instance the requirements of quality, structure and educational and professional skills of the industrialization, modernization, and international economic integration to have a strategic vision and take drastic action to seize opportunities and solve challenges. Enterprises need to create added value by quality, performance, process.

Through this research, SMEs can adapt quickly as well as change the way they operate by applying business management software to be able to catch up with the industrial revolution 4.0.

1.3 Thesis question

All of this defines the main question of the research: **How does the industry 4.0 impacts Supply Chain Management?**

Sub questions that allow for a better answer are:

- What are the positive and negative changes of the SC affected by the industry 4.0?
- How can other SCM implement those technologies and what are the issues associated?

1.4 Delimitations

Delimitations are utilized by the researcher to maintain the cohesiveness of the research as well as allowing to better analyse the available data on the subject. Within those set boundaries, the main question can be answered directly.

The boundaries of this research are primarily concerned with the concept of Industry 4.0. As it was stated previously, the main goal of this research is to delve into the affect of Industry 4.0 related technologies on the Supply Chain Management. By no account does this research analyses the overall industry move to such technologies or the concept of Industry 4.0. This research does bring up the basic explanation of the concepts that are related to the topic to ensure that the reader with any level of the previous knowledge of the subject would gain value from reading this paper. The moral side of the automation, illegal private data gathering, and the industrial espionage are briefly mentioned in the end of the paper but only in the context of advanced technologies in industry 4.0 and their implementations within supply chains.

1.5 Thesis structure.

The thesis structure is as follows:

1. Part one introduces the reader to the topic with the background to the research as well as the main objective and limitations.
2. Part two introduces the reader to the idea of Industry 4.0 and the technologies associated with it.
3. Part three focuses on the negative and positive impacts of the industry 4.0 on the SCM and how they were made.

4. Part four focuses on providing examples of successful implementations of technologies associated with Industry 4.0 to the SC and how it was performed.
5. Part five provides the instruction for the implementation of the previously mentioned technologies for the SC as well as the analysis based on the previous data

1.6 Limitations

There were certain limitations regarding this study. The biggest limiting factor was the lack of the primary data for the research. Such data implies gaining information from the direct sources by utilizing interviews, questionnaires, and surveys. However, due to the idea of industry 4.0 being not fully realized, makes it hard to find a Supply Chain Manager who is working directly with such technologies or even knows about the industry 4.0 especially during global pandemic when the social contacts were limited.

For this reason, secondary data became a primary source of information which included previously done research and studies on the similar topic as well as articles and journal publishing. Because of it the following research lacks the reliability present in similar studies that could obtain the primary data.

2 Research Methodology

2.1 Research method

Choosing the right research method is one of the main factors that determine the success of the research project. Each research problem will require a different research method. Choosing a method that is not suitable for research could completely undermine it. Therefore, it is important to choose a right research method for the research field to get a persuasive result. This chapter goes into more details about the preferred research methods used in this study.

The qualitative and quantitative research methods are both suitable methods for research. The difference between them lies in the idea that the qualitative method relies more on the spoken and textual words as well as any visual data while the quantitative method implies the usage of numeric data to answer the question and it needs to cover a large research area, as well as being statistically significant. The sample size varies depending on the need of the researcher.

Quantitative data due to its nature is already organized and can be analysed by using graphs, statistics, and diagrams while the qualitative data must be organized by the researched in form that could be more easily applied to the research by using definitions, and terms associated with the study topic. Quantitative research has the purpose of developing and using hypotheses, theories, and mathematical models related to phenomena. Central to quantitative research is the measurement process. They provide connections between mathematical expressions and empirical observations of quantitative relationships. Quantitative research is often applied when the research model is specific and clear and tests the research hypothesis derived from the theory. (Streefkerk 2019.)

For this research qualitative research method was chosen as a primary method due to the data having to be explained by using definitions as well as having to utilize words to explain and analyse the data.

2.2 Research strategy

Empirical and theoretical research are two main approaches when we discuss about research strategy. Theoretical research method is a method of gathering information through available materials such as books, newspapers, and articles for the purpose of searching and selecting basic concepts and ideas as a theoretical basis for the topic, forming scientific hypotheses, predicting properties of research objects, building

theoretical or practical models. initial experience. Researchers need to focus on collecting and processing information including the theoretical basis related to their research topic, specific research results that have been published in publications, statistical data. While empirical research requires practical experience by observe the phenomena to help researchers collect information or generate new ideas. However, there is the limitation relating to the new topic that leads to the focus of this thesis is theoretical. In this study, we try to utilize both methods. Simultaneously, the information collected through empirical methods gives extremely valuable information about the subjects being studied. Then the researcher will be able to verify the hypothesis with the existing theory and test the reliability of the theory through practical observations. Then, comparing the results of previous theoretical studies with those observed through practice. From there, researchers can see the difference between practice and theory and find ways to supplement the shortcomings as well as correct them making the research more objective and complete. (Dan 2017.)

2.3 Methods of collecting data

There are two methods that researchers can utilize to collect data. One of them is gathering Primary data, which is the data collected by the researcher specifically for the purposes of the research. This is performed by ways of conducting interviews, questionnaires and surveys which are usually prepared by the researcher for his or her study. This makes Primary data collection a reliable way of getting data because of its unbiased nature and its accuracy is mostly influenced by just the accuracy of the questions asked of the control groups chosen for the study. Another benefit of using Primary data comes from its always up to date status which makes it easier for the researcher to rely on it. Moreover, the author of the research will always have a full ownership of the data used.

On the other side, the Primary data takes a significant time to acquire and analyse especially if the control groups have a big amount of people within them and connected to that are also the costs associated with questionnaires that are done by mail or in person. However, the primary issue with this method especially for this research is the sheer complexity of the topic which makes it close to impossible to find people for interviews as well as making questionnaires and surveys provide little to no value for the research.

A second option is Secondary data gathering. This type of data gathering is done by collecting information relevant for the research: all literature data from definitions of related terms to the study done on the similar topic. Its main benefit comes from its accessibility which allows the researcher to access it in a short amount of time for little to

no money which is dependent if the material is publicly available or not. The analysis of secondary data is also its positive side since it can be done in a short amount of time due to the data being already processed by the third parties unlike the raw information from the primary data. Additionally, analysis of secondary data can help to unveil additional insight into pre-existing research done on the topic and expanding it in many ways.

However, Secondary data suffers from the lack of reliability due to it being provided by the third parties, which the author would have to verify the integrity of in the similar studies to find similarities or conduct his own research into the matter. In similar manner to the Primary research, the difficult research question might cause issues with the secondary data: if the topic is new and for not explored as well as others, it would mean that the Secondary data that would be directly related to it, would be limited and the researcher would have to go through a large quantity of data that is connected in a very minor way.

For this research the Secondary data gathering method was chosen due to the complexity of the research question as well as lack of contact with people related to it for the Primary data to be successfully gathered.

3 Industry 4.0 what is it and the technologies

3.1 Chapter introduction

The main purpose of this chapter is to explain the concept Industry 4.0 and related to it technologies. The relevance of this topic is due to its value to the rest of this research as it provides information with is a basis for the further analysis of the Industry 4.0 impact and as such it is important to understand all of the related terms to his study.

3.2 History of Industrial revolution.

Industry 4.0 is a complex topic to be immediately analysed through any lens especially when it comes to Supply Chain Management. For this reason, this part is to introduce the reader to this concept as well as what technologies are currently associated. Industry 4.0 is described as a new phase of the Industrial evolution that is only beginning in our modern world and it can change the world in many ways that will be mentioned in this study.

To better understand what Industry 4.0 is, it is better to first look at the first industrial revolution and how it affected the world of that time. The first industrial revolution started in England of the 18th century, and it was a long process that had allowed many countries to reach the status of global political and economic superpowers. (Yen 2020.) The first introduction of a steam engine is one of the examples of technologies that were introduced during that time, and it had changed the way the supply chains worked. New steam powered transportation allowed for the raw materials to be delivered to the massive factories that now had steam powered machinery which allowed for a significant boost of production efficiency compared to the factories of the past. (Zeidan 2019.)

However, the Industrial revolution affected more than just the supply chains: the banking system had to be re-imagined funding the industry as well as the rapid urbanization which was the effect of the job creation process. Moreover, the population of countries that were undergoing this revolution had significantly increased, Great Britain is a perfect example having doubled its population from 1850 to 1900. The economic influence was also quite significant: USA GDP had doubled to the 1.7 % which was the highest GDP of the country in the past. (Bureau of economic analysis 2020)

Advancements in agriculture, improvement of salaries and living conditions, an increase in the level of education are all just a small number of changes to the world of that time. With

that in mind, one could understand that the impact of the industrial revolution goes much further than just changes in supply chains and job creation.

3.3 What is Industry 4.0

Industry 4.0 is described as the fourth industrial revolution which is defined by the inter-connectivity of the industrial systems by utilizing Internet of Things (IoT), automatic machines, real time data storage and analysis, and other technologies.

Unlike the previous three industrial revolutions, which formed and developed based on the achievements of the three scientific and technical revolutions, the fourth industrial revolution developed based on all three revolutions. The breakthrough achievements of the third industrial revolution, especially the Internet technology, have completely changed the social aspect of life as well as significantly boosted the global economy.

In addition to the achievements of the third industrial revolution, fourth industrial revolution is also based on the latest scientific achievements in such fundamental areas as nanomaterial-based sensing technology. electronics and bio-electromagnetics capable of converting extremely weak signals into electrical signals such as thought waves, extremely weak infrared radiation, artificial intelligence is capable of decoding and analysing extremely large amounts of information at extremely fast speeds, including information such as intuition, thought waves, and emotions. Supercomputer that uses photons of light instead of using electronic signals as in electronic computers, has extremely fast computing speed, with the ability to store information far beyond electronic computers normally, technology for making materials from atoms. (Nexcom 2014) the Internet of Things, using a generation of computers with artificial intelligence, allowing the construction of smart factories and enterprises. New achievements in the field of molecular biology, synthetic biology and genetics, with the support of modern tools, help to quickly decode genomes, deeply understand the genetic code, have can help edit the genetic code to cure genetic diseases, create new agricultural crops with features that are adaptive to drought, saline water or resistant to pests and diseases The Fourth Industrial Revolution has the following characteristics:

1) Growing at an exponential rate, rapidly transforming industry in every country.
2) Taking place on a global scale, changing all production, management, and administration systems, service, human entertainment.
3) Based on a flexible production platform, incorporating all stages of design and production in it, test, respond quickly to the needs of the market, even to the individual. (Brkljac & Sudarevie 2018.)

4) Not only creating a symbiotic environment between humans and robots, but also creating a symbiotic environment between the virtual world and the real world.
5) Opening the era of intelligent robots, completely replacing humans in many different fields of activity.
6) Opening the era of waste-free product manufacturing technology. (Lackey 2019.)
7) Sensor technology is widely used with the result that by the middle of the 3rd decade of this century, 10% of the population will be wearing clothes connected to the Internet, 10% of glasses connected to the Internet, using implanted mobile phones, 30% of company audits are done by artificial intelligence. (I-Scoop 2021.)

The key word is inter-connectivity: different departments within company can achieve perfect symbioses by sharing the data that is stored and analysed in real time by the computer systems. The management will not be disconnected from the lower management since there will be no delay or distortion of the data. Moreover, there will be no need for a long analysis since the artificial intelligence systems would sort the raw data in predetermined databases or perform the analysis outright. The machinery within the manufacturing department could send the real time data on the amount of raw material available hence that the procurement department could order them or if one of the machines has a decrease in the productivity a sensor could send the request for the maintenance crew to perform repairs. (Higgins 2021.) Those are just a few instances that define the fourth Industrial revolution and many more will be presented within this study.

However, data is not the only thing that makes up the concept of Industry 4.0. The other two are as important: automation and AI.

Automation had started from the time of the first industrial revolution when the value of machinery had shown itself. The process of automation is better explained as a process of creation and usage of the technologies that allow for the goods or services to be produced/provided or delivered with as little or no human intervention. From assembly lines to transportation everything can be technically automated, in the modern world it means robots, sensors, AI and machine learning algorithms. (Rudisail 2021.)

3.3.1 Robot

Robots are one of the most recognized parts of automation in the modern world. The first patent for a simple crane robot that was lifting pallets was submitted in 1954 and from there robots had been given more and more significant roles within the manufacturing process. (Davids 2021.) They are primarily used for menial tasks where the speed and the operating time are of value. Robots have quite a few positives that make them a vital part

of the automation process and industry 4.0. Robots can operate 24/7 with only having to be repaired or performed maintenance on when they start losing their effectiveness. (Acieta 2021.) Besides, they are highly flexible since they rely just on their programming to know what to do, and that software can be updated as well as easily applied for large quantities of robots. Incredibly cost effective especially compared to a worker that performs the same task.

As robots of such kind are getting cheaper and cheaper to produce more and more companies can purchase them to utilize in their manufacturing side of the company. According to the International Federation of Robotics (2020) around 2.7 million industrial robots are currently in use around the globe with the largest consumer being China and Japan in Asia with 140 and 49.9 thousand units adopted per year (Institute for Security & Development Policy), the USA is the largest consumer with 33 thousand units in the North America and Europe with Germany and Italy with 20.5 and 11.1 units accordingly. (Berger 2014.) Moreover, the Corona-virus pandemic that had started in 2020 had shown the benefits of robots and their demand had increased accordingly. (Heer & Bieller 2020.) As well as giving rise in popularity to the collaborative industrial robots that are operating in similar manner with the difference being of higher level of control by the human. Such robots allow for human precision and decision making while the work is still performed by humans.

However, it does not mean that any company can purchase enough robots in order to replace the work force working now. While robots can work 24/7, without the built-in infrastructure within the company, they will not generate enough value to cover the expenses related to their maintenance.

In conclusion, starting as a niche and not the most effective solution in 60 years robots are now well integrated into the manufacturing part of the companies and as they are getting cheaper more and more companies can obtain them for their operations. It means that the idea of a fully automated factory, that will be discussed further into this study, is getting closer and closer each year.

3.3.2 AI

Artificial intelligence or AI is another part of the automation process. While the robots as stated previously are used for task that do not require any mental skills or work with data, primary use of AI in industry is for the data analysis. Main purpose of AI is opposite to that of robots – it is used to work with large amount of data by analysing it. Data analysis has always been an issue, especially in companies that operate on the global scale, when the

supply chains are spanning continents, even the small change within them structure can have unexpected consequences. (Dilmegani 2021.) This is the reason why AI takes such a crucial role in automation and Industry 4.0 – if the data flow is always consistent and up to date, AI can analyse a large quantity of data without any major issues. With the right algorithms, AI can analyse trends, predicting changes in sales, analysing efficiency of different segments of the supply chains and a variety of different tasks.

According to the recent MIT Technology Review (2020) survey that included over 1000 executive from 11 different industries around the globe, that 97% of the companies included in the questionnaire are going to utilize the AI by the end of 2020. Even though those companies' revenue was in most cases more than 1 billion dollars yearly it shows how those companies had recognized the value that the AI provides. This survey provides an additional insight as to how AI is used across different industries and with no surprise it is primary used for handling data. (Tschandl 2017.) For energy companies AI helps with diagnostics and monitoring for financial service companies AI is utilized for fraud detection while companies such Amazon and Walmart successfully utilize the AI for the purpose of inventory handling which allows them for a much better decrease in costs of inventory management. (MIT technology review insights 2020, 10.)

An interesting fact is that 66% of the executives are willing to share their internal data to others to help with the development of the new AI models that would allow for them to be more efficient and provide more value. (MIT technology review insights 2020, 4.) Sharing of internal data of any company is always a risk due to the high risk of competitors using it for their benefit and gaining advantages. Which means that with more than half of the participants sharing their willingness to commit to such share of data means that in their opinion, the long-term potential for the AI to create more value, outweighs the risk of competitors gaining the upper hand in the short run.

With that in mind, it is easy to assume that sooner the companies would adopt Artificial Intelligence, then they would have a higher Return on Investment compared to the late adopters. Yet the same survey shows the opposite situation: the companies that started using the AI technologies as early as 2015 found themselves having a smaller than expected Return on Investments while the later adopters found it at a much higher level. This can be explained by the fact that AI is a technology that provides more value for the company and must be carefully adjusted to the task and environment in which it would operate. Without it the Artificial Intelligence would not have its 100% efficiency and as such ROI will be low as well. It means that the companies that had already invested in this technology must consider if they want to invest even more in AI in the hope that the

produced value in the future would outweigh the number of resources that were used. As time goes on the AI will become more and more fine-tuned and easier to implement and as such the ROI of the AI will increase as well. (MIT technology review insights 2020, 8.)

The survey participants provided additional information regarding the question of issues that arise while using Artificial Intelligence. With 51% of participants saying that the most common obstacle of using the AI on the company wide scale is the scale itself. For the AI to be utilized to the most of its abilities it is required to make significant changes to the older understanding of data gathering and analysis which. Secondly, the quantity, quality and availability of data. After the implementation of AI within the company, its integration process can be slow due to the company environment being unprepared for it. (Sassi 2021.) For the AI to fully utilize its potential it requires a large quantity of data to use as the base of AI analysis and if the company does not have a good data gathering system, the quality analysis of AI will suffer significantly with the company not gaining any value from it. A similar situation happens when the company gathers data that is of low quality since then if the data is wrong or incomplete it also affects AI decision making. Thirdly, the lack of data scientists and AI developers. In order to prepare the data capturing for the AI implementation, it is required to have staff with experience of working with such technologies as Big Data and others that allow for better information capture as well as storage. While the AI developers allow of the AI fine tuning. In both cases, big companies have a severe lack of specialists to implement AI to its full capacity. (Schlund 2020)

To conclude, AI continues to expand its presence within several industries, especially those that must deal with data storage in analysis on a constant basis. Technology, however, requires a solid foundation that must be prepared by the company and that in turn requires specialists that are trained in working with technologies of the fourth industrial revolution. AI is still a technology that is improving and will become more available as time goes on. The speed of that development relies on the companies that have used it for some amount of time and are willing to share their data for the progress of this technology.

3.3.3 Big Data

Modern manufacturing systems can produce an extreme amount of data that has to be stored and then later utilized by other technologies related to Industry 4.0. For this purpose, any company that wants to utilize the analytical capabilities of the industry 4.0 needs to have an ability to gather data by using sensors and algorithms as well as having enough storage where this data will be stored for time that it will be needed for. After that the raw data must be organized and analysed by either an AI or IT specialists.

There are many companies on the market that are already offering solutions for large quantities of data. An example of such a company can be Nexus Integra, a Spain based company whose main product is the solutions for Big Data and IoT. This company suggests that having a good integrated Big Data system can help any company by using advanced sensors and portable devices to improve inventory management. Sensors can identify how efficient is the storage facility is used or if there are any mistakes in how the inventory is being stored. By using the internal and external analysis that consists of the consumer purchasing history to predict demand of the consumers and predict the need for maintenance. By utilizing sensors, the company can track the current efficiency levels as well as patterns of breakdowns of the machinery. It can help to predict when and how a machine will get out of maintenance, reducing the cost of repair and allowing the manufacturing part of the company to maintain its efficiency. (Nexus Integra 2021.)

In short, the amount of data that the companies must deal with will not go down any time soon, what is more likely is that it will keep increasing and thus the companies must invest in the more Industry 4.0 technologies that can help with the data processing.

3.3.4 Cloud Computing

Cloud computing is a technology that allows for remote access to computer related services such as data storage, data analysis, servers, databases, and every other technology described in this research by utilizing the internet. (EXOR International updates) There are several ways as to how this technology is used such as public cloud, private cloud and hybrid cloud.

Public cloud is cloud technology that is provided by third party cloud computing providers. This type of cloud technology is a primary choice for companies that want to use advanced computing technologies but want to either outsource to costs of maintenance and staff or do not want to invest a significant portion of their revenue in order to acquire and successfully implement them. They will have a contract with one of many third-party cloud providers and for as long as it in place the company will gain remote access to all the computing power and technologies as well as the infrastructure needed to operate it. The disadvantage is, however, is that company will have to rely completely on the third-party provider to handle all of their data and while most of the providers claim that any data stored or processed is completely safe, there is never a 100% guarantee of that. (Microsoft 2021.)

Another disadvantage is that your technology level is also completely dependent on the supplier: as an example, if the AI technology would evolve and new iteration will appear

on the market a company cannot invest in it and will have to either hope that their trusted supplier would update its technologies or to change the supplier completely which takes time and negotiations as well as having to stop the data operations with the current supplier. As for the companies that provide it, practically every major IT technology provider offers their cloud technology. Examples of that would be Microsoft Azure, Adobe Creative Cloud, IBM Cloud Services and other. (CIPS 2018.)

Next is private cloud. It is cloud technology that is fully owned by the company that wants to use it. In this type, the company has already invested in the industry 4.0 computing technologies and now wants to utilize them for its Supply Chan remotely. (Microsoft 2021.) As many companies are operating in foreign countries, it is counterproductive to invest each time in the same technologies that are applied in the similar facilities that have access to a much better infrastructure for it. The distance is always a factor when it comes to constructing new manufacturing facilities or expanding warehouse network. If a company has already invested in Industry 4.0 computing technologies, it can create a centralized data-center and provide cloud access to all its facilities. Each region can have its data center or share one with another in this way minimizing the cost of expansion of the company presence as well as making it easier to upgrade and maintain it. The main disadvantage of this type is costs associated with it.

Hybrid cloud is a mix between private and public. By utilizing a mix between two of the cloud types of any company, you can achieve a much higher level of flexibility while gaining the advantages of both. (Zadara 2020)

Overall, cloud technology is a perfect solution for adapting the technologies of industry 4.0 for any company. Depending on the resources available and the size of the company, some would choose to outsource it while others would better create their own data center and provide cloud access to their facilities.

3.3.5 Augmented reality

Augmented reality is similar in its use to cloud computing with one difference while cloud technology allows for long-distance access to data, AR allows it to operate with physical space. The operator can use it to remotely work with machinery or to assist others. AR is a perfect replacement for the instruction manuals and the long training courses for the employees as with it any worker can just simply follow instruction that are given to him/her through the AR.

Moreover, it can be used for long-distance quality control: when a company manufactures a product that must follow very strict guidelines as well/or high quality, it needs a highly

trained professional team to ensure those standards are met. With AR the inspection and quality control can be done from any distance if both locations have access through internet.

The main benefit of this technology is the reduction of the training time required for the employees to operate at their 100% efficiency as well as minimizing costs associated with it, second benefit is easier quality control. (Caggia 2021.) As it stands this technology primarily benefits large companies that have a large amount of manufacturing facilities and/or if they operate with complex technology discussed previously.

3.3.6 Cybersecurity

With the amount and significance of data increasing, cybersecurity becomes more and more important for a company to keep their data safe. With IoT the number of devices connected between each other, especially in the manufacturing sector, is quite significant and as time goes one it will only increase. This makes a whole supply chain vulnerable to hackers attach that can utilize this connectiveness against itself.

An example of such attack can be DOS or known otherwise as the denial-of-service attack which overloads the servers that are handling and rerouting the requests from sensors and data banks with thousands of such requests from 100 of virtual addresses. Such an attack is almost impossible to identify the origin of and it can completely disrupt the company systems for as long as the vulnerability, through which attack was made, stays. (CIPS 2018.)

This with addition of malware or other harmful programs can help hackers to gain access to the inner workings of the company as well as any external operations and sell it to the interested parties or simply disrupt and damage the IoT based systems. Damage from such attacks is extreme and can cause a full disruption of the supply chain.

This is the reason why cyber-security develops alongside industry 4.0 technologies. Because of that, any company that want to protect itself from cyber-attacks needs to follow a number of rules such as creating contingency plans in case of a cybersecurity attack that would include all the possible vulnerabilities in the IoT systems as well as ways to quickly respond to them. The plans must be created and used in collaboration between different departments and IT personnel to ensure their effectiveness. They also need to Change and upgrade outdated systems with new security protocols as well as having a complete inventory of all systems that are based on computing technologies and make sure that if the some of the technologies are outsourced, that the supplier is trustworthy as well as their level of cybersecurity. The same is important if the technology is not

outsourced to always make sure that its manufacturer uses the most modern security standards. (Balbix 2021.)

Unfortunately, even by following every one of the aforementioned steps, attacks can happen: recently vulnerabilities in software are created by the hackers themselves by utilizing a supply chain attack, which targets at first not the company that uses the cyber-security system but the manufactures of cyber-security. There is no perfect solution against such attacks and in the future, on the contrary it is more than possible that cyber-attacks will increase in their complexity. Because of that cyber-security will always be a barrier for quick adoption and creation of electronic systems.

3.3.7 Internet of Things

Internet of Things (IoT) is a network of interconnected physical devices that utilize sensors, software, and the Internet to transmit and exchange data between each other. In industry it is known as Industrial IoT and it is used for Machine-to-Machine communication by means of the Internet, cloud technologies, machine learning algorithms and AI. Sensors are transmitting data through the server to which it is connected and from there this data can be applied in a variety of ways from data analysis to simply displaying the current device status for maintenance.

IoT plays a vital role in the new industrial revolution as a backbone of all the other technologies since it provides a framework for the data to be transferred across the computer system of the company and for this reason any company that wants to tap into the industry 4.0 must at first to establish IoT. The issue that many managers face is that they cannot fully grasp the idea of IoT: by just establishing IoT system within a company, it will not generate any value without other technologies of Industry 4.0. For example, the Big Data system allows for the data gathered by the sensors to be stored while AI will analyse and process it, then by operating with the cloud technology this data can be accessed by any department at any distance. Additionally, sensors would benefit more from automated systems such as robots. Without them, IoT is just a network without a purpose and its maintenance will overshadow all the value produced. (Cerasis 2021,7- 9.)

Overall, IoT has been increasing its presence in all parts of the supply chains from logistics to manufacturing. Value from IoT is generated from the technologies that rely on it and thus the better the sensors and the IoT network is in general, the better the sensors and the software are the better the technologies that rely on IoT will perform. Manufacturing companies benefit the most from implementing this technology due to its

connection to automation and data flow processing, but any part of the supply chain gains can benefit from being connected to one another.

3.3.8 Additive manufacturing

Additive manufacturing refers to the group of technologies associated with Industry 4.0 that construct 3D objects layer after layer of the plastics, metals, and concrete. It is a new step in the manufacturing process, and it is still relatively new even though some of the technologies have been in use for a long time. (Sirichakwal et al. 2016)

The first part of Additive manufacturing is Computer Aided Design or CAD that allows for the creation of 3D models of any product for the manufacturing process as well as creating digital prototypes. The 3D models can be tested in a digital environment with a variety of possible situations or environments with the help of mathematical calculations. The CAD will show if the model has any issues and how it is affected, this is especially useful for prototyping since it does not require an actual physical object be made. (Yang & Zhao 2015.)

The second part of the additive manufacturing is 3D printing. After CAD transfers the 3D model to the printer and after it is accepted, the printing process starts. It applies a thin layer of plastic, metals and concrete, depending on the product to be made, and then uses industrial laser to shape it. After completing all the layers, the final product can be removed and used immediately. Technology can vary from one manufacturer to another, but the idea remains the same.

As an example of additive manufacturing, it is best to look at the earliest adopter of additive manufacturing - the aerospace industry. The details that are usually produced for the planes are complex, produced in small quantities and require high quality materials which makes additive manufacturing a perfect solution. 3D printing is very material conservative as well as, by operating with 3D models for the printing, does not have any issues with complex structures. (Knofius at al. 2019.)

In conclusion, additive manufacturing is capable of completely changing the way manufacturing will operate in the future. The number of adopters of this technology rises every year and this means that it will continue to evolve as time goes on. It is possible that because of it not only the manufacturing but also the procurement

3.4 Chapter conclusion

The fourth industrial revolution is associated with a significant number of new technologies with each one having a big impact on one or more parts of the supply chain. Not all of them generate value in a direct way, some serve as support for others while some provide a base to build upon. Companies must not go blindly into this new era and the next part of this research will go into the details as to how each of the previously mentioned technologies impacts the SC to help with the choice of the correct ones.

4 The Impact of Industry 4.0 on supply chain management.

4.1 Chapter introduction

This chapter main purpose is to present and analyse the impact of the technologies of the fourth industrial revolution. The relevance of this topic is due to the general lack of concrete understanding of how each part of the supply chain can be changed by the new technologies.

4.2 Industry 4.0 impact on the global economy

The fourth industrial revolution has enormous economic, social, and environmental impact. These impacts are positive in the long-term, but also create many correction challenges in the short to medium term.

Economically, industry 4.0 has an impact on manufacturing processes and prices. Moreover, it also has a positive impact on global inflation. Implementing advanced technologies helps reduce energy consumption. Additive manufacturing which has the advantage of saving much more raw materials and storage costs than traditional cutting technology has greatly reduced the cost pressure that drives global inflation. (Pfohl et al. 2015.) demand by transitioning to a more efficient, intelligent, and resource-efficient world. However, this revolution is also creating challenges related to short medium-term adjustment costs due to the uneven impact on different industries: there are sectors that will grow strongly and there are others. (Schröder 2017.) industry will have to shrink significantly. Within each industry, including growth industries, the impact is also different between businesses, with the emergence and rapid growth of many companies creating more high-quality technologies and the shrinking, even the elimination of companies that cannot be able to catch up with this competition.

That may also lead to the redrawing of the economic map of the world, with the decline in power of many developed countries which based mainly on resource exploitation like Australia, Russia, Norway is going through a challenging process of economic restructuring. Saudi Arabia recently officially announced its plan to restructure its economy and make effort to reduce its dependence on oil. With exception of India, the remaining countries in the BRICS group are also facing many challenges as their economies are highly dependent on mineral resources.

Take the lead in technology if industry 4.0, the US is restoring its leading position on the ecological map. Several Asian countries such as Japan, Korea, and Taiwan have also

strongly participated in this revolution. China is a country that is likely to benefit. This revolution helps China to mitigate the impact of the ongoing adjustment after the hot growth period of the last decade. China is dramatically transforming its workforce structure. Of the more than 422.271 robots sold worldwide in 2018, 154.032 were installed in China. (World robotics 2019) Some European countries like Germany and Norway also want to take advantage of industry 4.0. (Bauer et al. 2015.) However, many other European economies seem to be short of breath in this race despite having a good human resource system, which is partly explained by the entrepreneurial spirit and environment to promote the development of new technologies compared with the US and Northeast Asian countries.

The power map of enterprises is also being redrawn: the once resounding and long-standing large corporations that have dominated the market for a long time are being started by young businesses recently in the technology field. Some typical examples are: companies such as Google, Facebook are growing rapidly, while other well-known companies like IBM, Microsoft, Cisco, Intel, or a series of large Japanese electronics corporations Ban is going through a difficult restructuring process. The collapse of big company like Nokia, or like the previous example from Kodak shows that the risk of wrong decisions that companies face in the already fierce competition is even more fierce in the current era. The era of this technology revolution is taking place very fast. In the field of manufacturing, traditional car companies are under fierce competition from emerging companies thanks to a new approach such as Tesla, which is ramping up the production of electric and self-driving cars.

4.3 Supply Chain and Supply chain management

The supply chain is a system that consists of multiple parties that participate in it with the primary goal of delivering goods or services to the consumer. Data and raw materials are the main flow for the supply chain with each part of the chain transforming them before it finally reaches the consumer. As with all parts of the business, the supply chains must be managed by someone.

Supply Chain Management or SCM is described as the process of control of all the activities of the supply chain from the logistical to manufacturing operations with the main objective of responding to the customer demands as quickly as possible. (Johnson & Pyke 1999.) Moreover, a good SCM can optimize the supply chain and allow for it to run more efficiently with the addition of managing the relationship with the suppliers and lowering the costs associated with supply chain. (Vorst 2004) In general, the modern supply chain is very complex often spanning countries and continents from the raw material suppliers to

the end customer and as such, the process of managing them had become harder and as such the process of managing them had become harder. (Verwijmeren 2017.) Because of that, the SCM is increasingly important especially in the context of this research, the new phenomena of Industry 4.0.

4.4 The impact of industry 4.0 on planning and scheduling

Process planning is the important step in SCM which helps look forward the whole process session and coordinate assets to balance supply and demand. This step contains all information about raw material, the manufacturing process to optimize the available resources and determine the schedule and future strategy. (Ashodian 2016.) While the smart machinery has no direct influence over the process planning or scheduling, it primarily impacts the information exchange and data gathering that is a prerequisite any planning. (Popa 2013.)

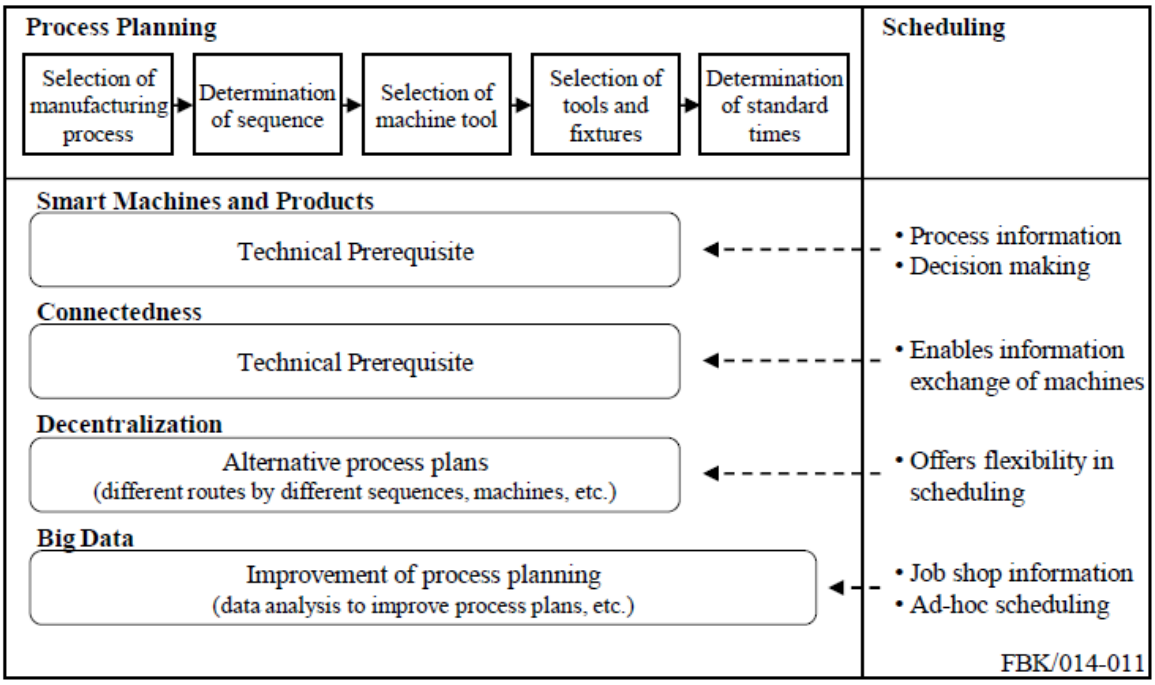

Figure 1 Impacts of Industry 4.0 on integrated process planning and scheduling (Procedia manufacturing 2019, 171.)

First, to come up with the best plan, the system automatically analyses information and data available on Big Data (figure 1). After analysis and evaluation, feasible options will be offered for manufacturers to choose the appropriate production process. Besides, the analysis system also automatically proposes the production sequence, suitable production tools as well as the corresponding time to produce according to each specific plan. Intelligent machines help managers process information and connect and exchange

information throughout the system, creating consistency throughout the system. From the analysed information, managers can still more easily choose the most optimal plan in complex conditions of product diversity. Moreover, having alternative process plans can make it more proactive in terms of any problems occurring during production. Most importantly, self-learning machines will update automatically with new information to improve and find new solutions.

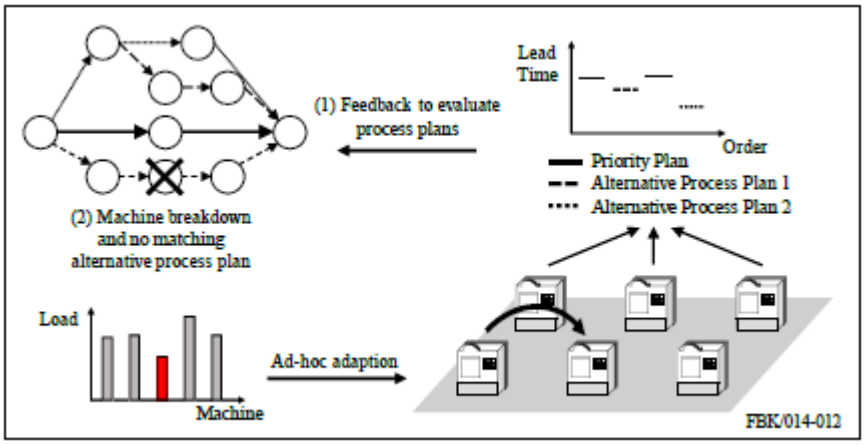

Figure 2 Extended methodology to integrated process planning and scheduling (Procedia manufacturing 2019, 172.)

By making information flow be always up-to-date and error free it allows for the planning and scheduling take less time and be more efficient due to the way data is handled within Industry 4.0 systems (figure 2). It second impact is on the planning methods: smart machinery allows for the manufacturing process to be much more flexible by allowing a quick change in the production depending on the needs of the company. As such new plans need to be drawn to always present an alternative solution to any issue that may arise. An example of that would be if a company must manufacture lines A and B which produce components for the line C, line A has a malfunction and as such cannot produce anything, with technology of Industry 4.0 this issue is quickly discovered, and the line B switches half of its production to for the whole manufacturing process not to stop even with the limited efficiency. For that to work, however, alternative planning must be performed hence that the workers would know what to do if such problem arise. (Meissner & Aurich 2019, 168-170)

Additionally, process planning and scheduling benefit from utilizing AI and Big Data systems to analyse the raw data of the different company operations in record times and with pristine precision which allows for a variety of things to be included in planning: such

as current machinery performance, sales and market changes, current material transportation.

4.5 The impact of industry 4.0 on procurement

Industry 4.0 can change the way the procurement works: with new technologies, described in the previous part, such as IoT and Big Data information flows much smoother through the company and as such every department or even every single chain of supply can be connected to one another by utilizing those technologies. (Rathore 2018.) Multinational companies are operating with extremely complex supply chains through which the supply of raw material goes to the manufacturing, however, how one can know how much is needed? Analysis of the market can determine the demand of the needed amount of material for a product that could be ordered or if the business operates directly with its consumers, a report of the stock availability in stores works as well. However, the procurement department usually has to deal with data that is already out of date by the time it arrives and because of that, the procurement decision often lacks clarity.

Procurement 4.0 is a new step of evolution of procurement in companies. First change that is easy to notice is in the flow of information between the company and its suppliers. Before the changes that came with procurement 4.0, supplier relationship was always an important part of any company that wanted to have reliable suppliers for its products, however, the value from those relationship was limited to the amount of data that could be given from the company to the supplier and then the opposite way. With the introduction of industry 4.0 technologies the flow of data had also changed:

1) Cloud technology allows for both the supplier and the manufacturer to utilize the same data network to better coordinate the supply of material. Additionally, the data accessed can be limited to avoid the supplier getting to know private company information.

2) Augmented reality (AR) serves as a help for the company by providing a way for long-distance supply expectation, meeting with the suppliers and solving issues with the raw materials. AR headsets can also provide all of the real time data related to the material movement as well as the current needs of different departments as well as the status of the raw material supply all at once. This allows for a much better and quicker sourcing due to the easy access to the data as well as not having to present physically in order to ensure that the deliveries are coming according to the schedule.

3) Additive manufacturing (AM) primarily affects manufacturing, however, since procurement and manufacturing are tightly connected, AM affects procurement as well. With quick prototyping, the exact number of materials needed for new products can be determined and ordered quickly. Moreover, 3D printing can change the way manufacturing works as well as changing completely the materials needed for it. Resin and metal of high quality will become paramount for the production and securing that supply will become very important soon.

4) Internet of Things (IoT) allows for the complete tracking of all of the materials that can help to mitigate any disruption within the supply chain as well as automating ordering processes by allowing orders to be made by the machinery itself. With that procurement can better satisfy the needs of manufacturing at any moment

In conclusion, procurement will change quite significantly soon with the help of industry 4.0 technologies. It is quite possible that with those changes the procurement part of the companies, will become much closer or even completely be integrated to the manufacturing.

4.6 The impact of industry 4.0 on manufacturing

Manufacturing is one of the important parts in SCM. In this step, raw material was turned into finished goods. The concern of most supply chain managers is finding the way to shorten the production time, reduce the product cost while still create a higher quality product to meet the customer satisfaction. (IBM 2020.) Because of Industry 4.0, manufacturing becomes more flexible and will be able to respond to the customers quickly. Implementation of industry 4.0 technologies for instance IoT, real-time monitoring, additive manufacturing, Big Data transforms traditional factory become smart factory which is enable digitization of manufacturing and through KPI by enabling to operate the supply chain process excellently. It improves the manufacturing processes in all aspects from sourcing raw material, usage and SCM to product design, distribution. In 2019 the market is value USD 71.7 billion, and it was predicted to go up to USD 156.7 billion by 2024. (Research and markets 2019.)

It starts with the raw materials, as mentioned before 4.0 industry using advance technologies which improves raw material quality and allows materials arrive on time. Moreover, using automation software in manufacturing instead of manual production help increase the quality and quantity of products compare with traditional production.

Smart manufacturing (SM) uses “big data analysis” that leads manufacturing with advances in volume, velocity, and various types of data to improve analytic capabilities and detect anomalies to reduce risks. (Moyne 2017) Many manufacturers use advanced analytics - the application of mathematical tools to evaluate practice - to reduce process flaws, cut the total cost and save time. Advanced analysis allows operation managers be able to check historical process data and identify relationship among manufacturing process and then optimize the relating factors which have the most effect. (Hozdic 2015.) For example: bio-pharmaceutical manufacturers such as vaccines or blood components. The manufacturing teams have to monitor more than 200 variables in the manufacturing process to make sure the ingredient is pure. There may be still an exhibit variation with yields from 50% to 100% although the batches were used an identical process. One of the biggest biopharmaceutical manufacturers try applying advanced analysis and it is successful in increasing 50% vaccine production- worth around USD 10 million in yearly- without additional cost. Advanced analysis can be an important tool to improve productivity, especially in any production environment where the process complexity. In fact, many companies successfully build on their ability to conduct self-imposed quantitative assessments far different from competitors. (Thoben at al. 2014, 4-14.)

Since 2013, many companies genuinely use the principles of industry 4.0 by implementing smart factory in their operation including Graben- Neudorf company. They use the cyber-physical production system (CPPS) to interlink all level of production system and decentralize the product control. (Meissner 2019.) Graben- Neudorf’s purpose is to achieve intelligent process with the error-free. According to the company report, the mobile assistance system helps them easier monitor their entire product system from receiving orders from customers to delivery products to them with high level of flexibility and optimize until they have the best result. They also use logistics assistants which can load heavy goods up to 1.5 tons and route themselves automatically as well as assembly assistants to assist the machinists. In near future, Graben- Neudorf will apply logistics capsules to independently load and delivery products without human. (Sew europdrive 2015.)

Additive manufacturing is a on its way to change how the manufacturing process works. With CAD and 3D printing the way the goods are made is starting to change, yet it is still not a fully realized technology and its impact on the industries is not as big as it could be. The biggest advantage of the additive manufacturing is its capability of producing complex objects straight from the raw material. For a significant number of industries, especially, those that are working with high-tech technologies such as aerospace and military industry, there is always a need for complex details. In the traditional manufacturing, the

lower-level parts such as screws and bolts have to be produced in parts and then assembled together in order to completely finish it, and after that that part will continue its way through the production line by combining them together for the final product. Additive manufacturing avoids this issue by working with the complete digital blueprint that can incorporate any design possible. The blueprint is made completely in the digital space and as a result the 3D printer would construct it layer by layer as one single piece. It significantly reduces the costs of manufacturing and, according to Henk Zijm (2019), it is possible that the weight of the final product could be lower up to 25%.

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Another impact is the 3D printing balance between the durability of the product made and the amount of the materials used. When it comes to manufacturing, it always hard to strike the perfect balance between the quality of the end product and the materials needed to produce it due to the number of factors that additive manufacturing solves:

Slow prototyping process: the time between the initial design of the product or detail to its first prototype can take month, after that the test has to be performed in order to determine the quality of the new product which will take additional time. With the introduction of 3D printing, rapid prototyping is a new reality when the new product could be tested in the digital environment and the first prototype made within an hour. This drastically affects how companies would treat the introduction of a new product or manufacturing of a specific detail to the manufacturing process.

Difference in raw material: depending on the goods that are manufactured, the raw

material can vary as well this creates additional pressure on both the procurement and manufacturing department due to the different types of raw material that each product requires, it increases the costs of manufacturing significantly and unfortunately it is unavoidable. Or at least it was, before the 3D printing: no matter the given objective the printing process requires much less material and usually only in one state (granular or solid) no matter the complexity. (Verwijmeren 2017.) It reduces the complexity of the raw material acquisition and allows to better manage the suppliers that do provide them.

There are additional benefits of the additive manufacturing that also have a big impact on it. High level of product customization is one of benefits of using additive manufacturing. Since each product has to be at first made as a 3D model in the digital form, this model can be changed without any issues directly from any company computer that has CAD as well as access to the original blueprint. Secondly, the time to market of the product manufactured by the additive manufacturing is significantly shorter than of product made by traditional means. It is based on the same principle of creating an object directly from the raw material from prepared blueprint. This way a company that utilizes this particular technology would gain a significant advantage over its competitors. However, even with all the listed advantages, additive manufacturing still cannot replace the traditional one due to several reasons:

While additive manufacturing is capable of producing any type of complex parts, it is still not capable of production on an industrial scale. Every 3D printer will be fully occupied with the construction in one object and cannot produce multiple of them. It means that the industries that need to manufacture goods on a large scale, cannot utilize additive manufacturing successfully. Even though the capability of 3D printing technology to manufacture complex parts, the industries that rely on them still have to conduct additional tests in order to be sure of their durability. It makes the value generated by rapid prototyping less for industries that require a high level of quality control.

Intellectual property and rights: the security of digital blueprints is under a threat to be either stolen or damaged during cyber-attacks which puts under threat the manufacturing process that uses 3D printing. In addition to that, the new market for digital blueprints creates a question of responsibility: if the parts or a product made using the bought blueprint are malfunctioning, who takes responsibility? A manufacturer or a blueprint maker? This puts additional pressure on the companies that would want to utilize additive manufacturing. (Zijm at al. 2019.)

Overall, this technology is unfortunately working better, at the moment, as a support for the traditional manufacturing process due to the aforementioned issues. This makes the

impact of it on the manufacturing part of the supply chain small but as the additive manufacturing continues to improve, it is quite possible that it will expand to a variety of industries as well as gaining bigger and bigger role within the manufacturing itself. As of now companies that want to invest in it, have to really consider if it will create enough value to cover up the costs associated with it.

4.7 The impact of industry 4.0 on Inventory control

In the modern supply chain management, it is crucial to focus on inventory control because it relates directly to cash flow. It is important to distinguish different types of inventories: visible form such as raw material, working in process, finished good inventory and non-visible form like memory card, server, bandwidth. Delays in any forms will create a domino effect, which ultimately affects both end consumers and shareholders. To reduce risks business should maximize the sales while holding as less as stocks possible.

The WMS will be the nerve of vast digital activity center, taking care of data collection and sending directives to mobile platforms. (Federal ministry for Economics and Energy) Then, the robot - industry 4.0 solution will take over and perform the task. Compared to humans, robots can operate much faster and more accurately. When inventory is managed correctly, it helps businesses reduce waste and avoids problems such as overstocking or under-stocking. Processes using robots will also be optimized to ensure environmental friendliness. That is using rechargeable batteries and automatic trips to charge stations for the robot. Modern technology allows workers to find and select items. The perfect integration of Industry 4.0 into the warehouse hub makes logistics and warehouse operations more efficient, a huge step towards the goal of improving delivery times. Systems with custom markings and barcodes - warehouses also bring benefit from enhanced profitability through better inventory management, more efficient operations. (Hoey 2019.) Industry 4.0 also contributes to inventory control which is also an important part of warehouse and SCM. Internet of thing-based sensor technology can allow for the automated tracking and analysis of all of the inventory locations and levels which makes it easier for the Supply Chain Managers to create an effective real time inventory tracking system.

In general, industry 4.0 affects inventory mainly on four aspects:

1) Inventory Process: The ordering and purchasing process is digitized and fulfills products automatically. When needed, based on available information and real time data, the system automatically processes and predicts the quantity of supply and demand, thereby automatically triggering new orders to

suppliers. For customers, the system easily responds to customer needs by relying on shopping history to know product type, quantity, and predicting customer needs at the right time. (Lackey 2019.)

2) Inventory classification: To manage inventory in the most effective way, managers often use the ABC classification method to classify goods of high value to goods of lower value in descending order. Type A is known as a 20% product set with 80%-euro value accumulation in inventory, and type C is a 50% product collection with 10%-euro value accumulation in inventory. Class B is the collection of the remaining 30% of products with 10% of the dollar value accumulated in inventory Industry 4.0 creates an environment where products are classified according to the ACB method and allows them to carry information about their value and location. The inventory profile is also automatically classified and updated. (Yuan 2020, 33.)

3) Inventory System Parameters: supply lead time is a very important parameter when it comes to the manufacturing process. The time needed for the supplier to know about the need and after that deliver the supply drastically changes, the way manufacturing planning is done. The more efficient the lead time is, the more amount of time for the final product to be made. Industry 4.0 allows for the significant reduction of supply lead time by making it possible to track all the goods that are currently being delivered and when. If the cargo will be delayed due to some unpredicted circumstances, the manufacturer can know about it immediately and adjust for this situation. With industry 4.0, all of parties in SCM can share updated information and it also has positive effect on other inventory system parameters such as: carrying and ordering cost, dynamic pricing, customer demand, selling price.

4) Inventory system review: There are periodic and continuous inventory types. Because of the high cost for advanced system, most of businesses choose using periodic review. However, Industry 4.0 creates a convenient environment for supply chain managers to use continuous review by proving all important information in real time. As a result, Industry 4.0 is moving from the periodic inventory evaluation to continuous inventory review in practice and allows businesses monitor and evaluate inventory continuously.

The main purpose of the inventory is to balance and predict for the supply and demand come from the uncertainties of the upstream (for example suppliers, manufacturers) and downstream (e.g., consumers). Too high or too little inventory will lead to negative effect

on SCM. To optimize inventory, the managers need to minimize the cost or maximize the customer services base on system parameters. However, inventory system is a very complex system which require high technology to evaluate available data. Industry 4.0 is gradually creating a new R&D model for inventory and optimization systems. It helps supply chain process is easier through deep data analysis. With all the analysis available, managers can adjust inventory policy and make the best decision.

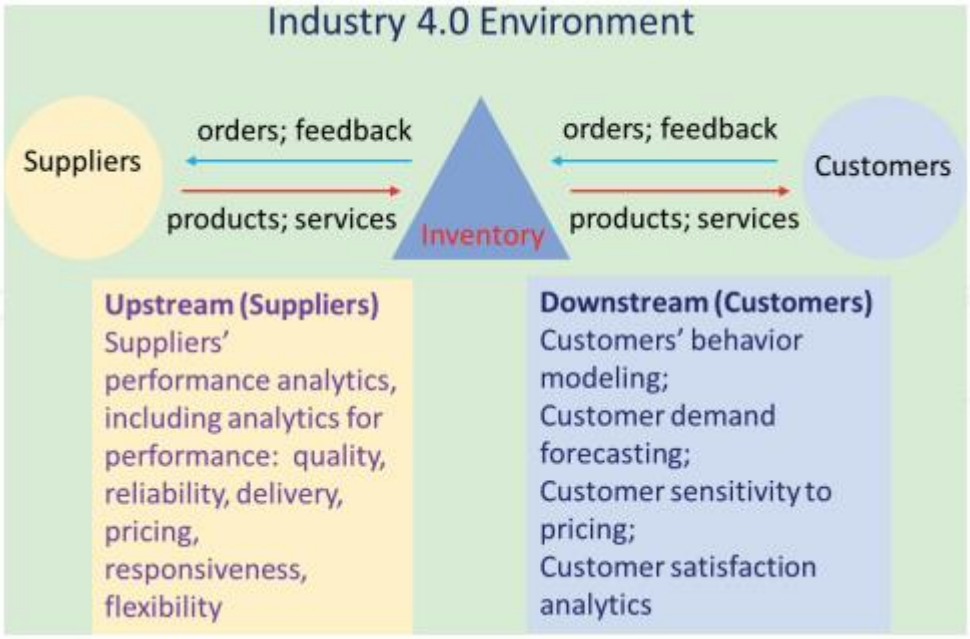

Figure 3 Integrative R&D framework for inventory systems modelling and optimization (Yuan 2020, 36.)

Starting from the upstream (figure 3): Industry 4.0 provide business intelligence tools to help reduce operational costs in inventory management. The system will evaluate the supplier performance and show which supplier is most reliable, flexible or provide the fast delivery. From there, inventory managers will know their suppliers well and choose the most suitable one.

Next is the downstream: to be successful business need to understand the customer first because if there is no customer there will be no revenue and no business. Through business intelligence and intensive data analysis system, the customer's behaviour and future demand will be predicted. Besides, it also shows customer sensitivity to the changing price to improve the accuracy of future supply.

4.8 The impact of industry 4.0 on delivery

Product and supply delivery is an important part of any supply chain. The faster the delivery time is, the better it is especially for the modern supply chains that can span multiple countries and continents.

The distribution institute is changing dramatically since the advent of Industry 4.0. Connected machines create an automated chain both inside and outside the supply chain. Smart delivery navigates the end customer's location under dynamic conditions. Delivery system capabilities can be simulated using event simulation to estimate the delivery time. Big data analytics evaluate and recommend the most optimal route for delivery. As companies have improved their ability to deliver products, The supply chains become more complex. Analytical system can estimate the lead times and product delivery deadlines in various workload scenarios.

However, technologies of industry 4.0 do not focus on delivery time but rather on delivery optimization. While using the modern transport allows for the efficient and fast deliveries, they are still prone to be delayed due to unpredictable circumstances. One delay of raw materials can completely change the whole production line plans and have considerable impact on company operation.

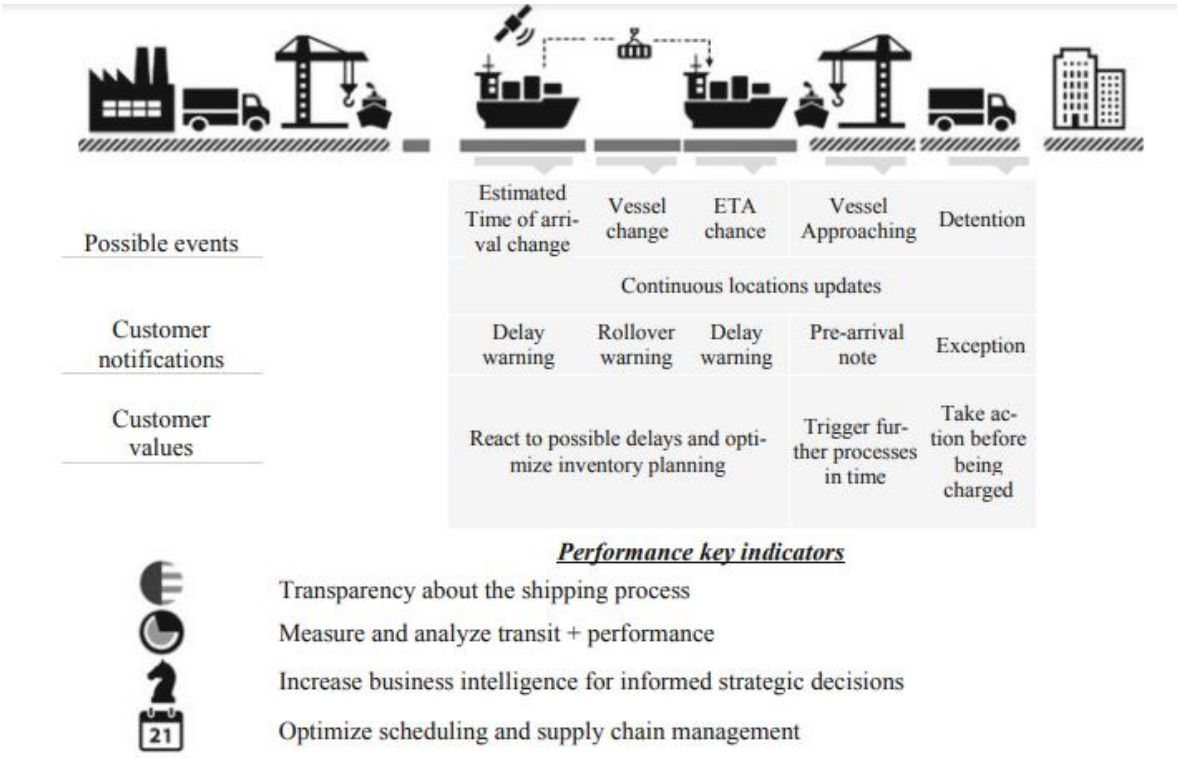

Figure 4 Smart coordinated delivery (Gunal et al. 2019, 83.)

It is impossible to predict all of the possible obstacles to the delivery, however, it is possible to make sure that if an obstacle would occur the supply chain world is not interrupted. The GPS technology already serves a double purpose of tracking the goods that are being delivered and also assist the driver by providing the best route to the destination (figure 4). A big number of transportation companies had integrated GPS of their trucks with the live operators that prepare the best delivery route in advance in order to avoid, as an example, right turns on the road, major traffic jams and roads that are blocked or undergo construction. Once the delivery truck is on the way, operators will overview the route and if there any issue along the route, it can be adjusted, and the driver would get the updated route immediately. (Adonis 2021)

With the technologies of Industry 4.0 the route management can be automated to provide much better results. Big Data technology can allow for the route information to be stored in order for then later to be analysed by AI in order to make a much better routes, moreover, after enough time and data given, AI can completely manage how the truck movement in real time by updating the routes in real time with a precision and speed that humans are not capable of. In addition to that, there is a possibility to run simulations to see what time is required to solve an issue that could occur during the delivery process. It can include simulations of the weather, traffic, truck malfunction.

Moreover, the simulations can help to understand the possible impact of deliveries on the environment: especially when it comes to the emission and noise levels. Most of the modern companies must follow the laws that regulate the environment impact of transportation. With the help of the digital simulations, carbon emissions and noise levels can be predicted in advance making it possible to plan, not only the most optimal routes, but also the ones that would lessen the amount of fuel used and to avoid more populated areas, if possible, to reduce noise. This way reducing the fuel costs and following the regulations.

For this to work however, the supply chain must have a high level of transparency. There must be a two-way data exchange between the suppliers and the company to ensure that if a disruption would occur not only will the supplier know about this issue but also the company that is relying on it. This way the disruption to the supply chain be minimized or it is possible to even create plans in case of one. The cloud network can be shared between the supplier and the company making it easier for both sides to share the large quantities of information or even develop tools that would assist in case of an issue with transportation.

To completely automate the deliver process, it is possible that in the future the drones and self-driving vehicles can take the place of the common means of transportation. While not fully possible now, several companies such as Amazon had already invested in it. If that would happen, the companies would require to either use VR/AR technologies in order to remote control them or use the automated system and AI to choose the perfect delivery route and adapt to the environment in real time. (Gunal et al. 2019, 84-91.)

A perfect collaborative system such as this one could make the delivery system a lot more flexible. Every delivery would be tracked in real time and the data would be available to both the supplier and the company. Additionally, all of the deliveries will be integrated into one delivery chain: depending on how overloaded one delivery company/supplier is, another supplier could take some of the deliveries from another one automatically. If one truck with materials is currently in the traffic jam, another one could pick up the materials from the same supplier and deliver them if there is a need for it. Such collaboration from suppliers, logistic companies and the manufacturers would work in benefit to all of the parties involved by making the supply chain more flexible and capable of adapting to any disruptions.

In conclusion, Industry 4.0 is introducing new ways as to how delivery system could operate. IoT and cloud network provide the opportunity for sharing and gathering data across the whole delivery process. The cargo itself can be tracked and the drivers can get assistance now not only from human operators but also from the Artificial Intelligence systems that would monitor and change the route in real time. The key word for Delivery 4.0 is collaboration. The true value from the technologies can only be gained if all of the parties involved in it would allow for the data sharing as well as cooperation of all of the operations. For this reason, companies must embrace collaborative relationships and work together with suppliers and logistics providers in order to embrace the technologies of the fourth industrial revolution. Industry 4.0 bring a more coordinated work and work more synchronously by using advanced logic to coordinate resources. In the future, major orchestration algorithms may be available.

4.9 The impact of industry 4.0 on customer service

Customer relationships are extremely important to manage for any company in any industry. While on a surface the technologies associated with the industry 4.0 do not seem to interact with the customers, however, it is completely opposite. Industry 4.0 provides a number of tools that can help the companies to better interact and improve the

relationships with their customers that are already used by a number of large corporations.

A company that uses the technologies of the industry 4.0 in order to create value along the whole supply chain are called DME or digital manufacturing enterprise. In general, the main difference between the DME and the traditional companies are that the DME take a more proactive role in their interaction with the customers. It means that they are capable of leveraging the data in order to predict the customer needs before even they would have them. Moreover, the interaction with the customer is done constantly due to the consistent data flow: as an example, if any product has a bad reception from any customer group, the issue that the customers are having can be swiftly resolved before it becomes a larger issue.

The main advantage that the technologies of the fourth industrial revolution provide is the ability to manage large quantities of data and in terms of customer relationships it means that it is much easier to manage the customer relationships. Customer preferences and demand is much easier to track by gathering data from different time periods and looking at the sales numbers of any company. That data can be then analysed, and future management planning can be made based on that data making it much easier to respond quicker to the customer demands. If the customers would be more catered to, the customer loyalty would increase as well. Which is especially important since the AI and Big Data technologies allow for gaining insight into multiple customers groups without having to dedicate a market analysis group to each one of them in case if the company wants to expand its customer base.

With the addition of a number of digital tools, companies are also capable of monetizing them by providing additional services that would go along with their purchase. The types of monetization can vary based on either the service or product provided as well as the company that offers it. This allows for the product to transcend its physical bounds and gain value in the digital form: the customer will get an additional insight into the product that was purchased or simply get access to more services that would go along with the product. If used correctly, the digital tools can bring an additional revenue flow to the company, which in turn would help to gain an advantage over competitors. (Cybernet 2021)

Not all the technologies have a direct impact on the customer relationships management, but a number of them do have a significant impact:

First, AR or the augmented reality allows for the customers to inspect the product in its full 3D form before purchasing it. This eliminates the need for the customer to go to a specific lace to buy it in order to see how it looks or works within a digital space. (Merlino & Sproge 2017.)

Second, AI can analyse the customer purchasing history and present offers that better suit the need based on that information. This technology is already used in variety of online shops and allow for each customer to have their own customized experience.

Third, GPS makes it easier for both the company and the customer to track the movement of the product. For the company the benefit is to see if there are any interruptions in the delivery process to notify the customer in advance, while the customer gets the benefit of knowing the location and the exact time of delivery. (Hood at al. 2016.)

Overall, the customer management 4.0 will be all about being proactive in terms of managing the customer relationships. Data will become the most important resource that if utilized correctly, can provide a significant competitive advantage. With new technologies customer needs can be predicted and reacted upon in advance thus allowing to a much more loyal customer base. Moreover, no matter the company size, Industry 4.0 makes it possible to introduce a product to the new market, to a new customer group with a more precise idea as to what kind of reaction will that product get.

4.10 Chapter conclusion

In conclusion, there are significant benefits that Industry 4.0 provides for SCM. Smart manufacturing, as an example, has enhanced operational productivity because it has leveraged advanced equipment, connected to data analysis systems. MIT study shows that 85% of employee downtime was cut and average productivity also increased by 11% thanks to the automation of production. PWC research about impact of industry 4.0 on business predicts that average productivity could increase by 18% within 5 years if there is a large-scale implementation of innovative technologies. The more the company is ready to work with new technologies the more they will provide benefit for it. (Globalluxsoft 2020.) Industry 4.0 helps increase efficiency and reduce operating costs. It is one of the main drivers of increasing revenue and GDP growth of countries. According to Globalluxsoft (2020), Germany's manufacturing industry has significant investment from the government, and they will be able to generate more than USD 32 billion in revenue compared with the same period last year. Industry 4.0 can track customer feedback in real time to provide better service and customer experiences. (Bradberry 2017.)

According to experts, the digital transformation process may not yet be successful if the right direction is not found with the right technology, but if it does not change, the business will surely fail and cannot stay in the market. Therefore, businesses need to identify digital transformation as a central strategy, a task of the entire organization and seriously implement it. (Roby 2020.) As the second fastest growing economy in the region, with a talented and creative young workforce, Vietnam has great potential in applying digital transformation and exploiting potential resources. hidden. Currently, labour productivity depends greatly on the technological revolution. Accordingly, a country that takes advantage of the 4.0 revolution will have high labour productivity and develop quickly. Therefore, for this 4th industrial revolution, it is necessary to take the initiative and follow up on it. At the same time, bold and strong steps must be taken to take advantage of the advantages brought by this revolution.

Enterprises also need to focus on some tasks to solve challenges in industry 4.0:

First, managers must pioneer in renewing thinking and awareness to improve competitiveness, because this revolution directly affects the survival of enterprises themselves. Cognitive change is a revolution taking place in the thinking of managers. To change perceptions, business owners need to be more proactive in the process of learning and updating new trends. Especially, technology trends can be practically applied to the management process of enterprises.

Second, in the context of Industry 4.0, digital technology is the factor that has the greatest impact on trends and methods of corporate governance. Managers must have knowledge and understanding of the application of technology in management and administration activities, including applying corporate management software to business processes to optimize resources and save costs. At the same time, the administrator needs to determine where the enterprise is in the industry 4.0, thereby determining the appropriate resources and approach strategy.

Third, invest and apply technology in SCM. The challenges of SC in Industry 4.0 can be completely solved if managers know how to apply software and technology solutions to help the business administration process optimize resources and save costs. Therefore, to adapt to the requirements of this revolution, enterprises must increase investment in equipment, technology, machinery and automation in production and their own business.

5 Analysis of successful technology implementations

5.1 Chapter introduction

The main purpose of this chapter is to present and analyse the examples of successful implementation of the technologies of the fourth industrial revolution. The relevance of this chapter is due to the lack of the successful cases of implementation within the industries and how the technologies are affecting the operations of the companies.

5.2 Amazon

The main purpose of this chapter is to analyse the examples of the successful implementation of the technologies of the fourth industrial revolution. By using the qualitative research method, the

Amazon company is one of the largest technology companies around the globe that focuses on electric commerce, cloud technologies, AI and digital streaming. Because of their focus, they are one of the earliest adopters of the industry 4. 0 technologies as well as working on creating some of them by themselves. The value of analysing Amazon lies in their expansive supply chain that spans multiple continents as well as their approach to adopting new technologies ahead of all of their competitors.

Amazon: automation and robots.

Amazon has been at the spearhead of the automation process in the past decade, and they had made a significant investment in the automation of the different parts of their company. In 2012 Amazon company had purchased Kiva Systems a manufacturer of the mobile robots and created Amazon robotics. Now this subsidiary company manufactures warehouse robots for the Amazon and by 2020 Amazon is using over 200,000 of them in all of its warehouses around the globe. (Kantrowitz 2020.) The robots used by Amazon serve a number of purposes within a warehouse thus being different by their roles and purpose:

The first type of robots is integrated with the shelves that are filled with the Amazon goods which are ready to be delivered to their customers. Since warehouses can be massive, finding a specific order of a customer to load it for a delivery takes precious time and this is where this robot comes into place: giving the product ID to the system will trigger the activation of the robot to go to the location of the shelve with the item and moving it to the packaging line for the human workers to package it for the following delivery. This way no matter the size of the warehouse, specific items can be quickly found and moved, making

the warehouse management much easier.

The second type of robots are robotic arms that are used in order to move up to 1300 kg of weight to the height of up to 8 meters. (Tracy 2016.) This robot type allows for a much quicker loading and unloading of goods to the trucks for their further delivery or movement within the warehouse for packaging as well as storage.

The warehouses themselves are also operating on the IoT system which allows for all of the robots within the warehouse to receive data from one another as well as from the human input and databases. Because of that Amazon warehouses are working like a clock: when a customer purchases a product his or her request is then sent to the local Amazon database which in turn send it to the local warehouse that has this particular item. After that moving robot bring the item to the packaging line where the product will be packed and then assembled in a bundle of orders from the same region after that the bundle will be loaded to the truck by robotic arm and send to the customer. At the same time the truck itself is connected to the Amazon database and depending on the order the customer can trace it from the warehouse to his or her house. (Edwards, 2020.)

However, Amazon is automating more than just the warehouses. From 2010 Amazon started to take a particular interest in the machine learning and automation, this way the "Hands off the Wheel" was born. While this program and brought many innovations to the company, one of their most successful changes was done to the retail department. For the company that specializes in the e-commerce, retail department serves a vital role: this department assigns the prices for the goods on the online marketplace, manages stock in the warehouses as well as which items need to be promoted and which need to be discounted. While important, having to have enough staff to manage one area is an issue especially for an international company such as Amazon. Therefore, it was one of the first departments chosen to be automated by using AI and machine learning algorithms. The idea of machine learning is simple: the AI will be fed the purchasing data of different customers from the area and in return it will predict the times when the warehouses of that area have to be restocked, when the prices should be lower and when should be higher as well as which items are best to promote at the specific point in time.

While easy on paper, this process takes a very long time - for Amazon and Ralf Hebrich, the director of machine learning from 2012 to 2020, it took three years. The main issue that Amazon had to face was at first the lack of data to give to the AI. It was not a common practice to keep the large quantities of data regarding all of the sales, hence this data had to be practically gathered from the ground up. However, from 2015 the AI had started generating value and from there on it learned more and more improving its

predictions. (Pathak 2020.)

As for the employees, instead of getting rid of them, Amazon has put them into the product and project management positions. This is a perfect solution that helps mitigate the damage done by automation: now the workers moved from simple tasks to the ones that are about inventions of new products and services as well as platform improvement.

5.3 Walmart

Walmart is a USA based retail company that operates in Europe, Americas and Asia. As in case with the Amazon company, Walmart supply chain is impressive, and the company is already making use of a number of Industry 4.0 technologies making it a perfect candidate for the analysis.

The most recent technological investment done by Walmart was done in 2018 when the company, according to Banker (2021), had spent over $11 billion dollars to innovate its supply chain. The new improved supply chain had focused on optimizing the efficiency of the inventory management, logistical and online retail operations as well as improving the customer experience. The latest acquisition of the Chinese Business to Business e-commerce company Yihaodian in 2015, also supports this idea: this allowed Walmart to improve their products life cycle as well as creating a digital factory as a testing facility for technologies of the industry 4.0 that could improve their supply chain.

There are several technologies that Walmart is currently is using to improve its operations. Bossa Nova robots are a Walmart solution for the inventory management. This robot scans shelves within the shops and can provide information for the customer about the location of each product location as well as updating the store database of the current inventory level. The inventory management is an extremely important part of the supply chain management and is responsible for a large part of costs especially for a retail company of the size of Walmart. Currently Bossa Nova robots are deployed in around 350 stores and if the technology proves to be more successful.

E-labels is another technology currently employed by Walmart and allows for the easier adjustment of price by having the labels be connected to the data storage from where the prices can be adjusted automatically whether there is a discount or a simple change in price for the product. (Souza, 2019.) As of now this technology is not implemented across a high number of Walmart store but with the introduction of IoT system this can change how the stores are handled by completely automating the process of adjusting prices.

The technologies of Industry 4.0 allow for the Walmart for an easier solution to the issues present in the delivery and sourcing operations. The main issue that most of the retail

companies face is the distance to the customer: online retail is highly competitive especially regarding the time required for the customer to finally receive the product ordered. The perfect solution comes from the delivery route optimization: when the product is ordered, a delivery label is created for the Walmart employees at the warehouse to find the product using the e-label. After that the AI will generate a fastest delivery route based on the customer adders and the characteristics of the product. The company that had provided the delivery solutions was the Gurobi Optimization by the Walmart partnership with them.

Walmart also cooperates with IBM Food Trust and applies blockchain and supply chain to trace the origin and origin of each product, thereby creating customer trust and helping Walmart manage its goods more effectively. (Chapman 2020)

5.4 Chapter conclusion

Both Amazon and Walmart are at the spearhead of the industry 4.0. Both companies had adopted a number of technologies that allow for them to improve their operations. Amazon machine learning implementation shows that when a new technology is integrated with the company operations, it might take years before it will operate at its full efficiency. It is an issue for SMEs that want for the new technologies to immediately improve their operations: it took Amazon three years for the machine learning to achieve a level when the retail management could be automated, however, Amazon as a company has a much higher number of resources compared to the SMEs. The smaller companies have to utilize their resources more carefully and the three-year period might not be possible to wait.

The Walmart on the other hand shows how can a company that operates in one of the most competitive industries of retail, can enhance its supply chain by using the industry 4.0 technologies. The new technologies allow for Walmart to operate at a much higher efficiency levels than before and their implementation on all the levels of supply chain shows that this task is not as daunting as it seems.

6 Implementation

6.1 Main factors

Industry 4.0 technologies, as it was proven in the previous chapter, are changing the way how supply chains operate. While the value that those technologies provide still depends on the infrastructure that was created to support them, it still allows for any company to gain a competitive advantage.

However, the trial-and-error way of adapting to the fourth industrial revolution is only available to the large corporations. If the technology Return on Investment is small, a multinational corporations can recover quickly from the financial loss and move to another one. Smaller companies do not have such a freedom of choice and as such will be more careful when choosing which technology will benefit the most. SME´s are always under a much bigger pressure when it comes to the losses and because of that many of them would more than likely be slower in adaptation, thus falling behind in competition. This part of the research is dedicated to proving the information as to how to better prepare and then adapt to the new industrial evolution.

There are a number of conditions that any company that wants to invest in the adoption of new technologies, must meet.

6.1.1 Financial conditions

As it was mentioned previously, one of the major influencing factors on the company ability to quickly adapt to the new industrial revolution comes from their finances and how much is the company willing to spend on it. Bank loans is one of the most used options when it comes to the investment in the IT infrastructure and because of that it is possible for the companies of any size to take loans for this endeavour. Moreover, in the recent years SME across the industries had a much positive credit rating compared to the past as well as bank in general knowing much more about the investments in technology. (Zsifkovits & Woschank 2021.)

The only industry that has a trouble of acquiring funding for their business are the companies that work directly in development of applications for the technologies of the industry 4.0. The issue that they face is that usually in the beginning of the operations, they rely heavily on the investments and bank loans. However, even those companies had an improvement in their financing options: a example of that is the current situation in Germany were those companies are attracting more than 25% of the venture capital. (Minturn at al. 2021, 6.)

Overall, the main prerequisite for technology adaptation is the finances. In the most cases, bank is than enough to provide the funding needed, however, the entrepreneurs and smaller companies might face issues with getting credits with smaller interest and for larger sums thus making it harder to compete with corporations that have good and long credit history. In this case the government financial assistance would significantly boost the adoption rate of technologies within SME and allow for a faster modernization of a number of industries.

6.1.2 Workers

Another factor that influences the technology adoption, is the availability of the skilled workforce and in terms of Industry 4.0 there is a great need in AI, automation IT experts. For each new technology, a company would require more and more specialists in them in order to utilize them. The issue is that the number of graduates that specialize in the technologies mentioned. Even more SME will have an even harder position due to most of the graduates being taken by a much larger corporation. In order to correctly implement the technologies, it is needed to gain access to those specialists. In order to minimize the impact of labour shortage it is possible to train staff at the company to work with the new technologies but that comes at the cost of time and money.

The automation does minimize the amount of the uneducated labour required but the amount of skilled labour increases hence rapidly that the universities simply cannot satisfy them. (Wolter et al. 2015.) Large corporations have a better position compared to the SME due to them being able to cooperate with biggest universities in their region, which is much harder to do for smaller companies. In any case without the staff that is capable working with the technologies, the implementation is simply not possible.

6.1.3 Time pressure

Competition is another limiting factor that influences the implementation rate of the industry 4.0 technologies. While on one hand, the competition forces companies to adopt the technologies as quickly as possible to gain even a slight advantage in the industry where a company operates, on another hand, it makes the implementation process much harder.

Connection and automation are the key words when it comes to the industry 4.0 which makes the impression that in order to get the most value, all of the technologies need to implement at the same time. This way of thinking is especially dangerous for the SMEs that are limited in their finances. Moreover, such method of implementation also tends to

be much less effective and can cause significant disruptions to the supply chain. Even if the company infrastructure is prepared for it, the company resources will be extremely stretched in order to implement the technologies to every department and the supply chain, which in turn leads to higher rate of errors that tend to follow every new technology that is integrated into the supply chain.

It is very important for the company of any size to carefully implement any technology associated with Industry 4.0: while staying ahead of competition is always a priority, a careless approach might cause damage to the company operations far beyond anticipated risks.

6.1.4 Scale of operations

The technologies of the fourth industrial revolution can be divided into two categories: first group is the technologies that are actually generating value for the company and the second one is all of the technologies that are supporting the first group. From the simple point of view the most important are the ones that can immediately generate value, since they have a much more significant Return on Investments than the support ones. While true to some degree, support technologies allow for the main ones to work to its full potential. This idea is present in a large number of companies who are trying to cut corners by implementing new technologies on the old infrastructure.

Not all of the older equipment is compatible with the new technologies and can lower the efficiency of the company operations or to completely nullify their operating capabilities. Because of that if the companies want to lower the costs of implementation, they must check all of their current equipment and digital infrastructure to make sure that the new technologies of Industry 4.0 will be compatible. Moreover, negotiations with the technologies providers have to be more thorough and the compatibility have to be discussed before the signing of the contracts. (Minturn at al. 2021, 5.)

6.2 Implementation stage

Before starting this process, SMEs must work on implementing the support technologies such as Big Data, Cloud Computing and IoT. They provide a base for the other technologies to work, and their implementation can also be divided into simple steps. IoT relies on the sensors that are gathering data from a variety of machinery and as such a first step would be to start integrating sensors within the sectors of the company that are operating within physical space such as manufacturing and logistics, after that the sensors need to be connected to each other as well a company data storage. From there, it is

advised to enhance the existing IoT network by utilizing software kits from the IoT developers such as, but not limited to Bosch, Microsoft, Amazon and other smaller entrepreneur companies that are designing it for businesses. The choice will depend on the needs of the company and specifics of the software. As soon as the negotiations are finished then the next part of implementation can begin. (Minturn at al. 2021, 7-8.)

Next step in the implementation process is about management creating a mind-map that consists off six steps. The purpose of the mind-map is to identify the issues or areas of improvement within the company and its supply chain that can be improved by the technologies of the fourth industrial era.

1. Identify any possible bottlenecks in the company operations and their Key Performance Indicators. During the first step, it is important to choose a specific operation or a set of operations that have similar bottlenecks. During this step, the technologies that the company wants to implement are not taken into account and the priority is taken by the company in its current state.

2. The most important step in creating a mind-map is to identify which one of the technologies of Industry 4.0 are the best option to tackle those bottlenecks. The technologies must provide a long-term solution to the issues found as well as to show the improvements of the identified KPIs. Additionally, a budget for the possible implementation has to be made: it needs to be clear how much does the company is willing and able to spend on them.

3. Once the second step is complete, it is possible to start testing the technology identified in the second step. Test should be performed on the smaller scale to ensure that if something goes wrong during the process, it can be isolated to the testing area. Moreover, the smaller scale will allow for the KPIs measurements to be more precise and easier to get, however, the measurements need to be gathered within a specific time period for a better comparison with the usual performance.

4. If the management is satisfied with the results from the third step, it is time for a limited implementation that has to follow the training of the employees on how to handle new technologies as well as discussions with the suppliers on the better integration of them to the supply chain.

5. After the initial tests, a completely new way of measuring the performance must be created that would take into account the changes made to the supply chain. On

this stage it is important to make sure that the support technologies such as Big Data and Cloud Network are operating and are capable of handling all of the data that will be generated by the new technologies.

6. The final step is the implementation of the chosen technologies across the whole company: during this step it is vital to continue monitoring the performance of the technology as well as how it operates in the different environments and how prepared the different company facilities are. (Cotrino et al. 2020, 5-14.)

By adopting the idea of starting the process of implementation from identifying the company weaknesses, it is easier to understand which technology will be the most fitting. It is especially useful for SMEs that are usually are limited with their resources and are unable to implement all of them at once. SMEs can identify the bottlenecks within their supply chain at faster than larger corporations and as such the time saved can be applied for a more thorough implementation process. By cutting corners and trying to reduce the time of implementation, it is possible that the new technologies will either do not improve the KPIs or even cause disruptions within the supply chain. (Haricha et al. 2020, 640-644.)

In conclusion, due to financial, and workforce limitations SMEs are at disadvantage when it comes to adapting to the fourth industrial revolution. Therefore, careful planning and selective implementations are perfect way to get access to the new technologies without risking their market position by dedicating too many resources. The key idea is for companies to understand the weaker points of the supply chain before trying to implement the technologies thus preserving the resources for technologies that will generate the most value in the KPIs that were lacking before.

6.3 Barriers to implementation

6.3.1 Cyber-security

In order to understand the process of implementation of the technologies of the fourth industrial revolution, it is wise to understand at first what are the barriers that are keeping the companies from adopting the new technologies.

One of the first obstacles that was mentioned previously in this research is the issue of cybersecurity. According to CIPS (2018), in 2016 around 28% of the companies had reported an annual loss of 14% of revenue with 46% of the same companies making no investments to the cybersecurity for over two years. This data shows that while the risk of cyberattacks is high, the majority of companies are still not convinced that the cybersecurity is worth the investments. The issue lies in the general lack of understanding

of the importance of digital data protection: before the arrival of industry 4.0, the data did not have as much value as it does now, and the transition process was too sudden. Now with Industry 4.0 on the horizon, many companies are eager to use the new technologies but once they get access to them their business operations become extremely vulnerable. With the current rate of Industry 4.0 adoption, the industries will not be prepared for the increasing risks of data breaches. The more the supply chains will rely on the data that is transferred digitally, the higher the risks of supply chain disruptions.

This obstacle will become more and more daunting as the time goes on and the companies need to start investing more into cybersecurity as a part of preparing for the new technologies. While cybersecurity in the short run have close to none Return on Investment, in the long run it would allow to protect the company data from ransom and SC from disruptions saving.

6.3.2 Partner relationships

The reliable partners are a key component of the autonomous and data driven supply chain due to the reliance on the data sharing between the parties. It is especially important for the logistical and manufacturing operations that rely heavily on the suppliers to provide real-time data in order for the technologies such as AI to operate at full capacity. If the partner relationships are not at the level where such data share is possible, the supply chains could not be automated to perform at a reliable level due to the constant uncertainty from the suppliers. According to CIPS (2018), 79% of the surveyed suppliers provide their data to their partner companies. This obstacle is a critical point for many companies that wish to automate and improve their supply chain by using new technologies. To overcome this obstacle, it is crucial for companies to make sure that either the existing suppliers are ready to share data willingly or that during the discussions with the new suppliers this would be a part of the contract.

6.3.3 Uncertainty over Industry 4.0

While the research done on the topic of the fourth industrial revolution shows that the potential of the new technologies and the companies that are already using them have reported increase in their efficiency across the supply chain, the is not enough data that would provide a clear understanding of how those technologies work. An example of such case could be found in the previously used case of Amazon: machine learning algorithms had to fed with data over the span of three years in order for them to fully automate the manual work done within the retail department. Not knowing this case can rise the expectation of the machine learning and create a false understanding of its value creation

process. This is a dangerous thinking that can cause the expectation to be ruined by the under-performance as well as high maintenance cost of the technologies of the industry 4.0 in the short run compared to the manual labour and more common used technologies.

In order to overcome this obstacle, the companies need to conduct preliminary technology analysis as well as extensive cooperation with the providers and manufacturers in order to know how the new technology will perform for a task it was chosen for.

7 Market analysis and futures of SCM

7.1 SWOT analysis

As analysed in previous chapters, Industry 4.0 has had a significant impact on supply chain management. To develop the application of 4.0 technologies, businesses should consider the SWOT diagram for a comprehensive analysis.

Strengths: Technology 4.0 creates a new supply chain with transparency, agility, flexibility, and is constantly being upgraded and improved. Sharing information between customers or suppliers also becomes easier and more consistent, helping to improve customer satisfaction as well as enhance competitive advantage. With remote monitoring devices will ensure the preservation of product quality and inventory will always be well managed. Moreover, the electronic supply management system with intelligent marketing will always react quickly to the changing needs of customers, thereby making accurate predictions. Increased efficiency is a primary driver of the cost reduction as well as increasing company profits, however, the impact extends just simply having impact on companies, the GDP of countries that are willing to invest in the development of the technologies of Industry 4.0 and regulations. Industry 4.0 allowing for a complete change of the supply chain on all its levels from the supply and inventory management to time to market and environmental impact.

Weakness: The application of advanced technology to production requires high investment costs, complex infrastructure, and specialized human resources. Larger corporations have a larger pool of resources, but their supply chains are complex in their structure and as such require higher level of commitment to modify their supply chains using the new technologies, while SMEs have smaller supply chains but do not have access to as many resources. With that in mind, the process of technology implementation is difficult to complete to the full extent, especially due to Industry 4.0 technologies being interconnected. AI and machine learning are an example of technologies that require a large quantity of data no matter the part of the supply chain they are integrated into. The support technologies such as Big Data, Cloud Computing and IoT are required for the technologies such as AI, machine learning and others to properly operate. The case example of Amazon and Walmart prove that the automation of operations is possible but for many other companies this task is hard to achieve. Additionally, the continuous development and improvement of existing and new technologies of the industry 4.0 relies heavily on the data share on the current performance of technologies by companies that are using them in their operations, without

it the update process of technologies can slow down significantly. The issue of the trained workforce is also a problem that is hindering the process of the fourth industrial revolution, as the companies are simply unable to maintain new technologies and the training process of the current employees can take years and the resources needed for it can increase the cost of the implementations significantly. The larger enterprises have a higher chance of obtaining university graduates that have Information Technologies degree, while the SMEs has a much harder time to obtain them.

Opportunities: Industry 4.0 opens many development opportunities for businesses. Manufacturers can expand production while saving labour costs and shortening production times. Moreover, with analysed data, businesses can easily make more accurate decisions as well as improve the responsiveness and create sustainable development. (Hansen et al. 2017.) The future improvements of technologies can allow for a significant reduction in terms of price as well as making them more available of the market due to a higher number of the industry 4.0 technology developers and suppliers.

Moreover, the support technologies are starting to get more available on the market and the ability to use public technologies such as public cloud. The public technologies are ready to use and come with the installation process that would consider the current digital infrastructure of the company. They are available for as long as the contract with the technology manufacturer stays in place and solve the issue of companies having to spend extra to prepare their infrastructure for the new technologies. This means that in the future this type of technologies will be more widely available and the implementation process could be completely outsourced to a third party.

The new government programs that are focused on the increased benefits for the IT and data science students as well as the ever-increasing focus on the internalization of the universities is possible to resolve the issue with the lack of the workforce. This is not a quick process but in the long run it can completely solve the issue.

Threats: As technology develops, it also creates certain threats to humans. The first is information security. All data and business information are stored in the computer, so it is difficult to avoid theft or information leakage. The industrial espionage and the cyber-attacks will only increase as the time goes on and if the companies will not invest in the security, there is a threat of Industry 4.0 being stalled. The process of automation has been debated regarding the amount of damage that its capable of producing. On one hand robots and AI are indeed replacing the menial jobs, on another hand the need for the maintenance workers for those technologies is growing faster than the loss of menial work. The issue lies in the fact that not every company is ready to invest in the training of

the employees that will lose their jobs due to automation even though the example of Amazon shows the potential in it. This while not entirely an issue for businesses can lead to serious social problems within the developed countries in the following years and depending on the involvement of the local government to limit the amount of automation job replacement, this might increase in its complexity.

7.2 Industry 4.0 in the covid pandemic sustainable chain

The current COVID-19 pandemic has caused many negative impacts on the global supply chain. Many companies had to stop the production of goods because of a severe shortage of labour resources. However, many companies have quickly changed their production strategies to overcome difficulties in mass production by applying 4.0 technology and moving towards building smart factories. Technologies like AI, Big Data, and IoT help connect and help automate every manufacturing process. Managers or employees can work remotely using only a computer with an internet connection, and customers can also shop online and receive goods at home. That shows that with the impact of covid 19, there has been a strong impetus to change production to a new trend - the industry 4.0 trend. Industry 4.0 is helping to open new advanced technologies to save labour, reduce dependence on low-skilled labour, and lower production costs. Before the start of the pandemic, companies across the globe had already used the technologies of Industry 4.0 such as robotics, 3D printing, smart factories to reduce risks from the supply chain, Increased flexibility, improved product standards. However, the pandemic put a new emphasis on the importance of such advancements in automation and data analysis not only for companies but also for the civilian use.

Promoting automation solutions is the goal that 4.0 technology is aiming for during the pandemic. Providing automation solutions for several manufacturing industries and many other related fields to collect, transfer, store, analyse, and track information systems appropriately, accelerate the production process. export. Digital technology creates clinics on the internet through the application of remote consultation forms, helping to reduce patient load in hospitals and monitor patients' medical records more conveniently. Thus, the Fourth Industrial Revolution has brought many important breakthroughs to help minimize the impact of the Covid-19 pandemic, creating new solutions for businesses as well as boosting the development of technologies that could be used to improve the issues brought by the pandemic.

7.3 The future of SCM under the impact of industry 4.0

The future of the SCM completely depends on how the companies will be able to tackle threats that were mentioned previously, as of now the industry 4.0 will continue to change the way how the supply chains operate. The increasing levels of automation allow for a much quicker time to the marker for the products as well as increase in the online retail industry due to a much cheaper return logistics. (Shah et al. 2019.) The manufacturing companies rely heavily on the supplier and logistics provider relationships for the new technologies to actually optimize the logistics. For the manufacturing process itself, the reduction in the price of manufacturing robots does help their adoption rate but it is still not as low as the price of the workforce in the less developed countries or countries with a large population hence it is more likely that the manufacturing lines would adopt robots in the manufacturing facilities that do not have access to a cheaper workforce while the ones that are operating in the countries such as India, China, Vietnam would prioritize human workers. However, the additive manufacturing, robots and AI can make it possible for companies to operate better in the developed countries and limit the distance from the factory to the consumer as well as for SMEs being able to start their manufacturing process much faster and for a lower price since they will not be working at first on the international level.

AI development can lead to the new advancements of the SCM. As of now AI works perfectly for the operations that are based on the fast decision making and data analysis such as for the marketing operations or the handling of inventory which is an issue for a larger enterprise. For the IoT the development will go the direction of the cost reduction and expansion to every part of supply chain: the data gathering is as important as the technology that using it needs an up-to-date stream of large quantities of data over a long period of time. The idea of a complete manufacturing automation is still in its infancy but as the technologies of the fourth industrial revolution will continue to expand their presence on the market the automation will become more available for more companies.

8 Summary and discussion

The industry 4.0 is changing how the supply chains are operated: new technologies allow for the companies to operate with a higher efficiency as well as gaining a significant competitive advantage. This begun a race for adopting the industry 4.0 technologies and the results are mixed: while some companies report successful implementation, others had failed. The true impact of the industry 4.0 on the Supply chains is hard to fully grasp as with the first industrial revolution, it takes decades for the technologies to become mainstream and be used across all of the industries. As of now, it is possible to only see the separate cases of success and analysing them showed how every part of the supply chain can be transformed using the new technologies.

The key words for the fourth industrial revolution are automation and connection. Both describe well what is the final goal of all of the industry 4.0 and allow to reply on the main question of this study: what is the impact of the Industry 4.0 on the supply chains. The industry 4.0 allows for the supply chains to be much more flexible as well as being more predictable: with the new ways of gathering data, it is now possible to get real time data and plan in advance in order to predict possible disruptions within the supply chains. The manufacturing part of the supply chain can now perform at much higher efficiency than ever before: by utilizing robots and additive manufacturing the human workforce can now be shifted to either maintenance and control of production or the product development. The new industrial robots can be connected to the IoT system in order to able to conduct predictive maintenance making sure that the machinery can work nonstop maximizing the efficiency of the production process. While the additive manufacturing is a new potential replacement for the traditional forms of manufacturing that uses digital blueprints for manufacturing parts for complex goods. While the logistics and transportation can get benefit from real-time data analysis by making it possible for the delivery drivers to utilize updated routes that use real-time data.

The issue is, however, is that due to the technologies being new and not widely adopted, the cost of adoption is much higher compared to commonly used technologies within industries. This makes it less attractive for companies to adapt them as soon as possible, furthermore, the are additional obstacles to adoption such as lack of workers that can work with the industry 4.0 technologies as well as IT specialist and data scientists. Moreover, the new technologies require a prepared digital environment that is capable of handling large quantities of data as well as ability to gather it by utilizing sensors that are connected by using IoT system. With that in mind, SMEs are at a clear disadvantage due

to having a much more limited pool of resources compared to the larger enterprises. Because of that the SMEs need to rely more on careful planning as well as analysis of the strength and weaknesses of their supply chain.

The results of this research show that the supply chains will change significantly, however, this is a long process that had only begun. The rate of adoption of new technologies is still quite low but in the future the supply chains can completely transform automation and data usage are already changing the traditional outlook on the way the supply chains operate. The data that is generated by consumers and during the product creation process is now more valuable than ever and its value will continue to increase as the different segments of supply chain would use it to enhance their efficiency. The common phrase "works like a clock" is possibly the best description of the supply chain of the future: where every segment would be connected to another and the whole chain would work in unison to deliver a final product to the consumer, free from the human error.

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