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The Benefits and Challenges with Implementation of Internet of Things (IoT) in Manufacturing Industry

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Abstract

This thesis investigates the impact of IoT, with focus on manufacturing industry. The study is of qualitative nature where the empirical results were obtained by using a questionnaire as a data collection tool. The participants in the questionnaire are all employees of IBM and are experts in the fields of IoT or Industry 4.0. A primary objective of this thesis was to identify the key benefits as well as the challenges that a manufacturing firm might encounter, if it decides to invest in an IoT system. The obtained results indicate that there is a general belief IoT will increase the productivity of the factories by making the equipment more "smart" and interconnected. A more agile production process will be created and a much deeper insight into factory data will be possible. Equipment efficiency will improve which will directly decrease the maintenance costs. However, companies are still in the process of evaluating these benefits and are analysing the implementation challenges their organisations might face. These include, cyber-attacks, cultural resistance to technological changes and infrastructural issues.

Key Words: Internet of Things, IoT, Manufacturing Industry, Smart Factories, Disruptive Technology

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Finally, I would like to thank my closest family and friends who have been supporting, encouraging and inspiring me to move forward when it got tough.

"It is not the strongest of the species that survive, nor the most intelligent, but the one that is most responsive to change."
Charles Darwin

Abbreviations

IoT	Internet of Things
RFID	Radio Frequency Identification Tags
IoE	Internet of Everything
IIoT	Industrial Internet of Things
R&D	Research and Development
GHG	Greenhouse Gas
IBM	International Business Machines
ROI	Return on Investment

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1. INTRODUCTION

1.1 Background

Throughout history people have witnessed dramatic economic and social changes, which were in one way or another triggered by the technological progress and innovations. Schumpeter referrers to these changes as disruptions, which temporarily push the economy out of its stable equilibrium and stimulate growth (Schumpeter, 1934). Each Industrial Revolution carried certain technological disruptions which fundamentally changed the manufacturing industry (Coleman, 1956).

During the 1st Industrial Revolution manufacturing production went from basic tools to specialized machines, which in turn enabled mass production. Inventions, such as the James Watt's steam engine, have made this revolution recognizable for advancements in the field of mechanization. The 2nd Industrial Revolution which took place between the late 19th century and the early 20th century was riddled by technological advancements enabled by the electricity. Factories have, for the first time, started using electricity in the production, leading to more efficient production lines and mass-production. According to many researchers, the 3rd Industrial Revolution was initiated in the 1970s with the appearance of Intel's 4004 microprocessor (the main part of a personal computer) (Jovanovic and Rousseau, 2005). This revolution is still ongoing and it is often described as the *digital revolution*, because the PC, Internet and ICT (three main inventions of this period) are today being widely used by both households and the industry. Interestingly, out of these three, Internet is considered the most disruptive technology yet (Ashton 2010).

Today, close to 90% of US population and around 3,6 billion people worldwide are connected to Internet (ITU, 2017). These statistics suggest that the Internet has the power to transform and change our economic and social lives. Apart from that, according to some predictions, the overall number of connected devices will reach 50 billion by the year 2020, which indicates that the market reach for this technology is growing and developing at an extraordinary pace (Chase, 2013). With that in mind, it does not come as a surprise that the two most mentioned business notions in the recent years were Industry 4.0 and the Internet of Things (IoT) (Gilchrist, 2016).

"Industrie 4.0", as the term was originally introduced, was a directive by the German government aiming to fully digitalize German industry, but primarily the manufacturing factories (Balasingham, 2016). However, this paper will not focus solely on German firms but rather on manufacturing industry in general. It will investigate the potential for growth and productivity increases in the manufacturing industry, enabled by the IoT technology of the Industry 4.0.

Internet of Things is more a concept than a technology per se, it is a virtual network that enables various sensors, devices, objects or even people to be interconnected through internet (Gubbi, et al., 2013). These connected objects can then, in turn, autonomously generate and transfer enormous amounts of data (usually referred to as the Big Data), which, in turn, offers numerous opportunities to increase efficiency and productivity through data analysis (Jeschke et al., 2017). Due to those characteristics, the IoT technology has a great potential to disrupt and transform many industries, which is why IoT needs more attention from scientists and researchers. Manufacturing industry is the one that could face the biggest transformation, where, in the near future, factories and production lines could evolve into self-controlling "smart factories", with close to zero human labour needed. Many industry leaders believe that IoT will create extraordinary increases in growth and productivity (Gilchrist, 2016). This implies unprecedented opportunities for the industrial world, but with new opportunities comes a new type of risk which is often a key parameter for making new investments. And as the Internet was during the 1990s, the Internet of Things is still it its early stage, indicating that numerous questions remain to be answered (World Economic Forum, 2015).

For that reason, it is necessary to fully understand the technology behind the IoT. What are the main benefits one can expect with implementation of IoT and more importantly what are the biggest obstacles to implementation?

Focus of this thesis is on IoT because this field is still in the early stage of the life cycle, but even at this point, researchers are predicting that this new technology will be the main source of the coming large scale transformation and digitalization (World Economic Forum, 2015; Deakin et al., 2015). This digitalization will affect both household and industries and with that, our everyday lives. Apart from dramatically affecting the manufacturing, agriculture, energy and transportation, IoT will also transform the relationship between humans and machines (World Economic Forum, 2015). This opens a window of opportunity where humans would be able to utilize the machines and work together to increase the productivity. Brynjolfsson and McAfee (2011) argue that instead of racing to compete against machines, we should try to compete with machines, because computers are weak where humans are strong and this opens a chance for a mutually beneficial partnership. Particularly, in manufacturing, IoT will be the link between the industrial production and operations on one side and the IT on the other side (Balasingham, 2016).

1.2 Purpose

History has taught us that it is crucial to realize the benefits of new inventions early in their life cycle and to speed up the rate of diffusion on innovation as much as possible (Rogers, 1995). Meaning that, being an early adopter of a new technology may secure a stable and more competitive market position in the future. As the IoT is expected to drastically increase the productivity, prior understanding of the benefits as well as the barriers, is necessary for any firm deciding to invest in this new technology. This is highly essential for the manufacturing industry, where productivity and efficiency are the two most important benchmarks for creating value added and wealth (Sahar, 2002).

In regards to the above mentioned, the purpose of this paper will be to close this knowledge gap and hopefully, identify both the benefits and the barriers for implementing IoT in production. Consequently, two research questions were formulated:

I. **What are the benefits of implementing IoT in manufacturing production?**
II. **What are the barriers to implementing IoT in manufacturing production? How can firms overcome them?**

1.3 IoT as a Sustainability Driver

Sustainability is a policy concept, which has been, with time divided into three dimensions: social, economic and environmental (Kuhlman and Farrington, 2010).
Environmental dimension refers to the creation of an ecological balance for the future generations, by minimizing the depletion of irreplaceable natural resources (ibid). Economical dimension of sustainability is about giving the people what they desire while at the same time trying to maintain a fair distribution of limited resources, financial and other (Baumgärtner and Quaas, 2010). Finally, social dimension of sustainability is associated with the inclusion of all the social groups, creation of equality and abolition of world poverty (Kuhlman and Farrington, 2010).

In 2015, Zebra Technologies Corporation conducted a research with 600 manufacturing firms participating. Out of these 600 firms, staggering 97% said that the Internet of Things is the most important technological breakthrough of the last decade (Bond, 2015). One of the fundamental impacts of the IoT mentioned in the research was its influence on sustainability. When it comes to manufacturing, this impact will be realized through improvements in the supply chain. To be precise it is the warehousing and supply management that will transform, as the ever -increasing number of interconnected devices will enable a more precise tracking of products, from production line to the customer. Furthermore, the United Nations Environment Program states that: “Buildings use about 40% of global energy, 25% of global water, 40% of global resources, and they emit approximately 1/3 of GHG emissions”, indicating that there is room for optimizing the building energy consumption (UNEP). Apart from being able to optimize the logistical part of the production, manufacturers will be able to decrease energy usage and to reduce the level of waste created, if they decided to implement IoT (Schneider Electric). All these benefits and improvements would have a positive impact on the environment, as the energy consumptions of factories would go down, CO2 footprint would shrink and the level of waste would be minimized. On the other hand, IoT could be criticized as a technology which will increase the pollution, as the energy consumption will increase and the overall number of products in the market will increase, which is not in line with sustainability definition (Lewis, 2016). However, this paper will try to focus on the positive aspects of this new technology, but, will not be ignoring the possible hazardous effects.

1.4 Outline of the Thesis

Chapter 1 of this thesis is focusing on a thorough introduction of the topic, research question and the purpose. It is also supposed to get the reader familiar with the subject before reading the Chapter 2, where a more technical and detailed introduction to IoT and the Industry 4.0 will be presented.

Chapter 3 will discuss the three relevant theories, which this thesis will use as a backbone for analysing the results. In Chapter 4 the scarce literature on the IoT in manufacturing will be presented and discussed. Followed by the Chapter 5, where the methodology used to collect and generate the necessary data is presented and outlined.

Chapter 6 is presenting the most relevant and interesting results to the reader. Both text and graphs are used to present the empirical findings. Naturally, next chapter, Chapter 7 will discuss the empirical findings in an attempt to associate these results with the underlying theories. Finally, Chapter 8, will summarize the results of this thesis and propose ideas for future research.

2. TECHNICAL SPECIFICATIONS

2.1 Industry 4.0

The most recent industrial revolution has enabled a cross-linking between people, objects and software systems for the first time ever (Roboyo.de). This cross-linking ability is giving rise to broad spectrum of opportunities to increase productivity, quality, efficiency and flexibility of manufacturing processes. In simple words, Industry 4.0 is supposed to firstly bridge the industrial production with the information technology and then with the help of advanced data analytics achieve the above-mentioned opportunities. When it comes to the structure of Industry 4.0, it is often described as a four-layer one, where the base and the crucial part is the Internet of Things.

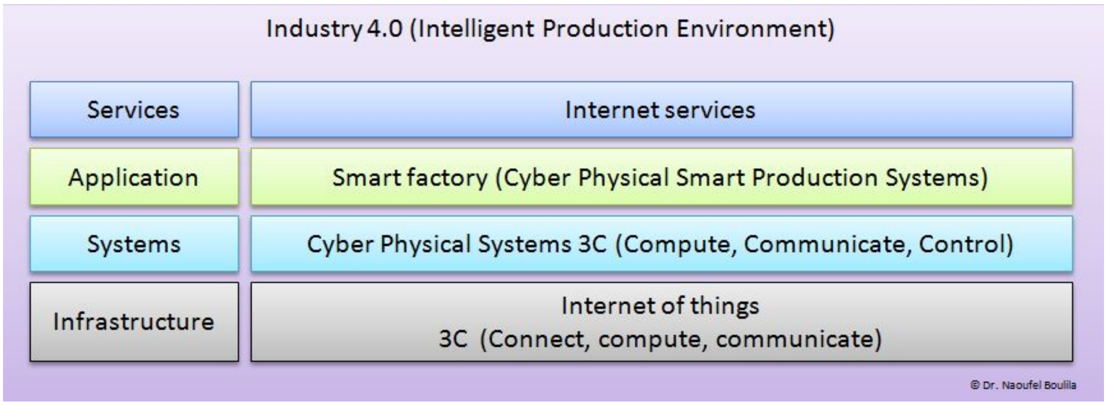

Figure 1-Industry 4.0 core layers. Source: ResearchGate.net (check the reference list for a direct web link)

As seen in the *Figure 2,* Dr. Boulila has depicted IoT as the backbone or the infrastructure of the Industry 4.0. This indicates that a strong IoT architecture is a required in order to exploit the benefits of the whole Industry 4.0 concept. In their online article, Van Thienen et al., (2016) argue that:" Industry *4.0 combines the connected technologies inherent in the Internet of Things (IoT) with relevant IT and OT, including analytics, additive manufacturing, robotics, high-performance computing, artificial intelligence, cognitive technologies, advanced materials, and augmented reality, to drive the physical act of manufacturing"* (p.1). Similarly, to Dr. Boulila's 4-layer structure, Van Thienen et at., (2016) describe the Industry 4.0 as a layered pyramid with IoT serving as a base for the whole structure (see Figure 2).

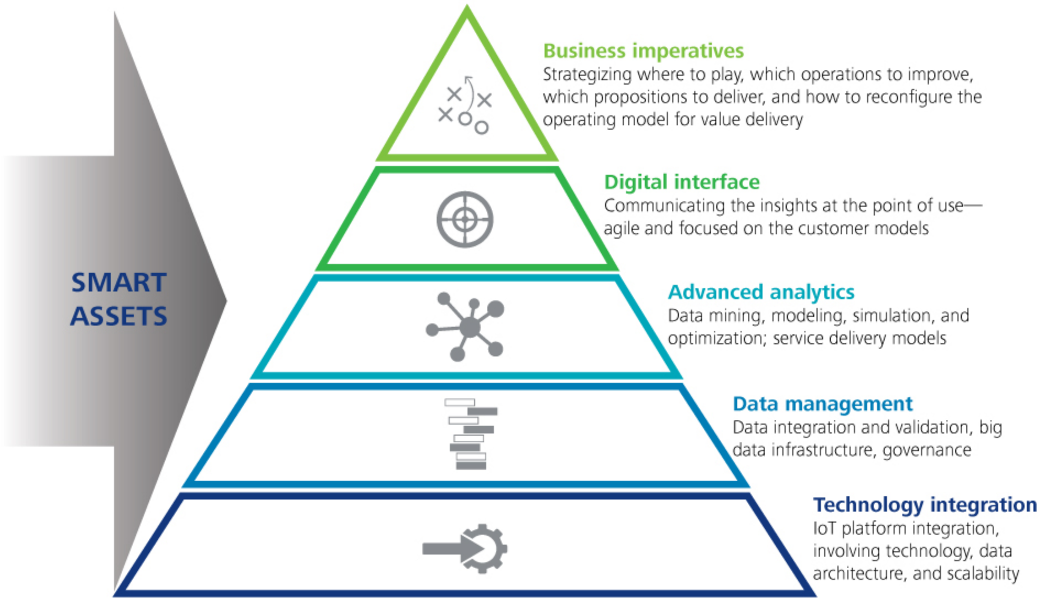

Figure 2 -Industry 4.0 - layer structure. Source: (Van Thienen et al., 2016, p.1)

Following this structure, Industry 4.0 will merge the physical actions with the digital world, where the outcome will be a more advanced manufacturing process leading to the creation of smarter factories, or the "smactories" (Waslo el al., 2017). If built correctly, these Cyber-Physical Systems, will enable the smactories to disrupt the manufacturing industry, lead to faster production processes and a safer environment for the workers. According to, Lee, Bagheri and Kao, (2015) the Industry 4.0 factories will differ from exiting one in many ways. Among other attributes they will possess self-awareness, self-predictiveness, self-configurability and self-organising. This will allow a thorough knowledge and understanding of the monitored factory (ibid).

2.2 Internet of Things – The name

The expression "Internet of Things" was firstly used by an MIT executive director, Kevin Ashton, back in 1999. At the time, the sensors were becoming cheaper and more digitalized, which made Ashton to start thinking about the next logical step for the ICT era: connecting the things via Internet (Ashton, 2009). The very basic idea was to utilize on the existing Radio-Frequency Identification (RFID) technology by equipping all the objects in with identifiers and wireless connectivity, enabling them to communicate with each other via Internet. From that point onwards, the term IoT has been expanding and definitions was modified in various ways. Internet of Everything (IOE) is a term that Cisco uses to explain an interconnected network of not just objects, but also people, places and things (Cisco, 2013). Then there is Industrial Internet of Thing (IIoT) which, as the name suggests, refers to the IoT in the industrial sense, where the primary focus is on connecting the machines involved in the manufacturing process (World Economic Forum, 2015). Bearing in mind that the term IIoT is considered as part or a subcategory of IoT, in order to avoid any confusion, this paper will use the basic term, IoT, as it encompasses all the other terms.

2.3 Internet of Things – The Architecture

The adjective that is commonly used to depict IoT is "smart"; smart objects, smart sensors, smart technology and smart network. Indeed, Internet of Things is a multilayer network of smart objects which when interconnected can increase their individual smartness by being able to share the information and react upon them in a matter of second. For this level of intelligent monitoring to be achieved and fully functioning, a specific structure of the IoT network needs to be constructed. To understand the architecture of IoT system and the data flow inside of it, it is important to discuss the general structure of most of the existing IoT solutions. The original architecture of an IoT systems was usually divided into three parts: *perception, network and application layer* (Zhang and Tao, 2016). However, Industry 4.0 has two more pillars, cloud computing and cyber-physical systems; and both have become crucial parts of the new IoT solutions on the market. An additional component that has been pinpointed as a prerequisite for a functioning IoT solution is Big Data Analytics (Columbus, 2017). Being able to just collect the data via IoT is not enough to drive the revenue, which is where the Data Analytics solutions come in hand and provide an ability to interpret, understand and act upon the data collected. Following these technological changes, the IoT architecture has changed as well, so today we generally divide an IoT solution into four parts: *perception layer, transmission/cloud layer, analytics layer* and finally the *application layer* (Zhang and Tao, 2016).

Figure 4 is a simplified representation of the IoT architecture and the flow of the data, from sensors to decision making.

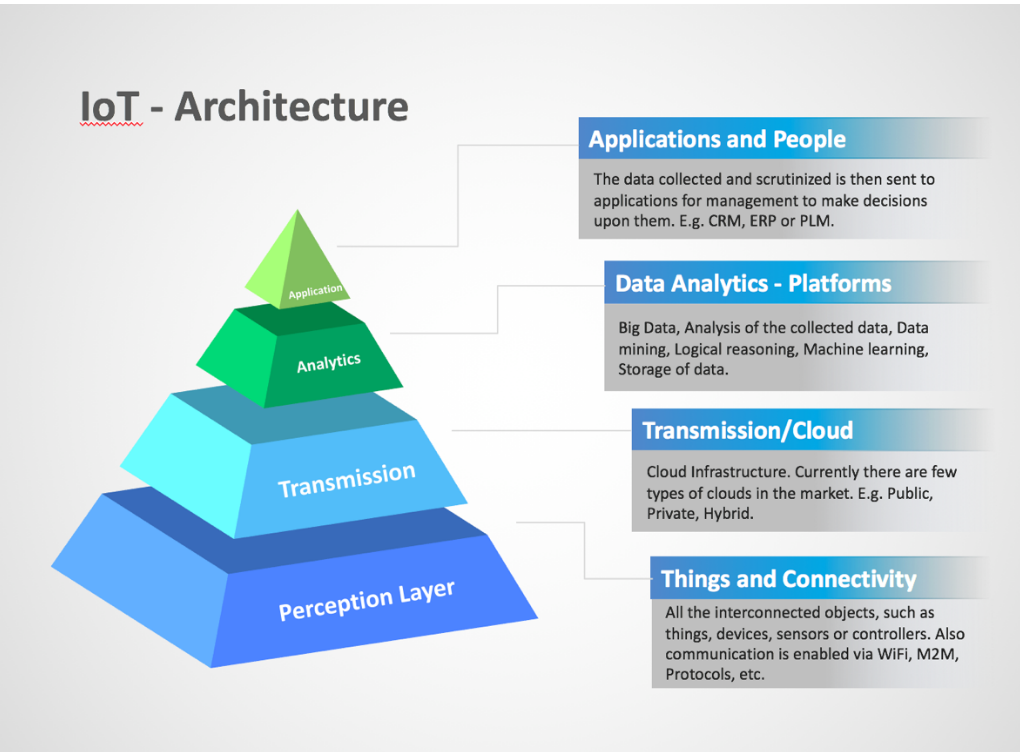

Figure 3 -Architecture of an IoT solution. Adapted from (Zhang and Tao, 2016, p.12)

2.4 Internet of Things – The Value Creation

The goal of implementing an IoT solution in manufacturing production is to create some type of value for the company. The key product that generates this value is *information*. Referring to the *Figure 4,* we can observe that the data collected in the perception layer is gradually formed into usable information which is presented as a final product in the application layer. At the first stage, the unstructured data is collected from various objects (e.g. sensors) and we can refer to this data as "inputs". These raw inputs then undergo an early transformation into usable information, by collecting and linking all the relevant data in one place (e.g. cloud). Third stage is the crucial one, because at this point, all the collected data and inputs are mixed together to generate structure, logical and useful information. That being said, it is understandable that powerful data analytics capabilities are crucial component of a quality IoT solution. Final stage is sometimes also referred to as the packaging stage, because here, the previously generated information is presented to the user, in a visually enhancing way (Höller et al., 2014). The-end user is then able to analyse these charts, graphs and numbers, after which he can make managerial decisions or conclusions. Some companies, such as IBM, are going even a step further and are offering analytics solutions with cognitive capabilities. These are the solutions that can understand human language, that can analyse large amounts of data in a matter of seconds and offer clarifications to a potential problem. IBM has a comparative advantage in this field because it can rely on the technology of their trademark product "Watson". For example, apart from predicting a failure in the production line, Watson IoT can advise the user on how exactly to prevent or fix that failure (IBM Internet of Things, 2016). However, not all solution providers are currently able to make such solutions, because they have not developed technology that would mimic human-like cognitive capabilities.

3. THEORETICAL FRAMEWORK

3.1 Disruptive technology and Innovator's Dilemma

When discussing disruptive innovation and the impact of technology on economic growth, a first author that most researchers think of is probably Joseph Schumpeter. To be precise, it is his theory of creative destruction that comes to our mind. According to creator of the term, the process of creative destruction is a: “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one” (Schumpeter, 2013, p83). What he refers to is that the economy’s stable equilibria are often challenged and destabilized by technological progress and innovation. On a firm level, this means adopting a new product, a new production technique, new and more sustainable energy sources, or in some cases, even adopting a whole new model of business organisation. It is logical to assume that majority of these transformation decisions are made by the firm’s managers. However, Schumpeter’s manger is more than that, he is also an entrepreneur. In contrast to some classical economists, Schumpeter theory clearly incorporates the role of entrepreneur as someone who is an innovator or someone who puts novel ideas operation (Baumol, 1996).

Following the above depiction of a manager, it seems reasonable to assume that survival of incumbent firms, during the disruptive periods, depends largely on the decisions, innovativeness and organisational skills of their managers. This assumption can be supported by the theories of Disruptive Technology and the Innovator’s Dilemma by Christensen (1997). He claims that new technology which has potential to become disruptive is often cheaper in the early stages of its life cycle, it is underperforming and it’s not so demanded by the high-end customers (Christensen, 1997). As such, it is not attractive to the management of the incumbent firms, who are seeking opportunities that are attractive solely to their most profitable customers. However, if the new technology improves with time, it attracts the mainstream customers and users, consequently pushing the early adopters of this technology to the forefront of the market. At that point the managers are facing a critical trade-off decision. On one side, they can continue to invest in their already established products and production systems, or decide to respond to disruptive innovation trends (Habtay and Holemen, 2012). Thus, the risk the incumbent firms face is, not reacting promptly to the technological changes in the market. Underestimating the impact of a disruptive technology may cost the incumbent firms their market share and customer satisfaction rate (Christensen et al., 2015).

3.2 Dynamic capability and Ambidexterity

When breaking down the impact of a disruptive technology, it is necessary to evaluate why some firms react and adapt better while other fail to do so. Most of this can be explained by the internal dynamics of the firm, that is how efficient and flexible firm’s organisational structure of a firm is, when adaptation to a new technology or a business model is needed.

A common ability of firms which are able to thrive in the established market but also to adapt to sudden changes, is to balance between exploitation and exploration (O’Reilly and

Tushman, 2008). Exploitation is referred to the firm's ability to increase efficiency and productivity of the current operations and to exploit the existing opportunities, while the exploration is more about embracing innovation and new more risky opportunities. Combination or balancing of these two is called *ambidexterity* and it is a major challenge for any firm striving for a long-term growth (Ibid). Most of the large incumbent firms find this balancing to be too risky and just too difficult to achieve, making the exploitation a more attractive path. However, while this path might provide a short-term advantage, it simply is not enough for a long-term dominance (March, 2003). Exploration is necessary as well, but due to its risky nature and the fact that it might impose a treat to exiting parts of a firm's organization, incumbents are typically vulnerable to technological and market changes (Siggelkow, 2001). So, to realize a long-term success it is not enough that firms compete in the well-known markets by improving their operational efficiency or minimizing costs. They also, should be capable to reorganize their assets, resources and organizational structure to meet the challenges triggered by a new technological disruption.

This is where the firm's dynamic capabilities play a decisive role. Teece (2007) sees dynamic capabilities of a firm as skills, structures, processes and competences which allow the firm to promptly react to new opportunities by simply redesign the existing assets and resources. Such firms will be able to emerge as the industry and market winners, as they have the unique capability to function in the current state but also to quickly adapt to the disruptive changes, technological or other. Unfortunately, many large incumbent firms have already long-established routines and processes which, even though are a vital component of dynamic capabilities, can present a problem if they are inflexible or slow to change. Apart from routines, the firms internal culture, knowledge and values are an important part of the puzzle, which can either make the dynamic capabilities more rigid or more flexible (Teece et al., 2016). Teece et al., (2016) further argue that the solution lies in the way the firm is managed, as it is the manager who engineers how the enterprise creates, shapes, and deploys capabilities. If this is done correctly, the end- result will be an agile organization of a firm, prepared to combine the knowledge, resources and the new technologies to generate an even higher value.

Some large companies have lost their dominance or even disappeared, because in the light of a big disruption, their core capabilities became their core rigidities. A suitable example of such company would be Kodak, a company that was for years a leader in film bases imaging market, a company that has even manged to foresee the digital revolution but was organisationally unable to adapt a new transformational technology. The largest barriers, that caused the decline of such a large company, were the unskilful middle management, culture and its rigid organisational structure (Lucas and Goh, 2009).

3.3 Innovation diffusion theory

According to Rogers (1995), *"Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system."* (p. 34). Rogers is a sociologist who developed the theory of innovation diffusion, by which he makes a clear distinction between early and late adopters of innovation. Focus of his research was on the speed of diffusion process, the timing and the reasons behind a decision to innovate. He claimed that innovation adoption process is most accurately represented by an S curve, where the cumulative number of adopters is defined by their openness to accept new ideas (See Figure 4).

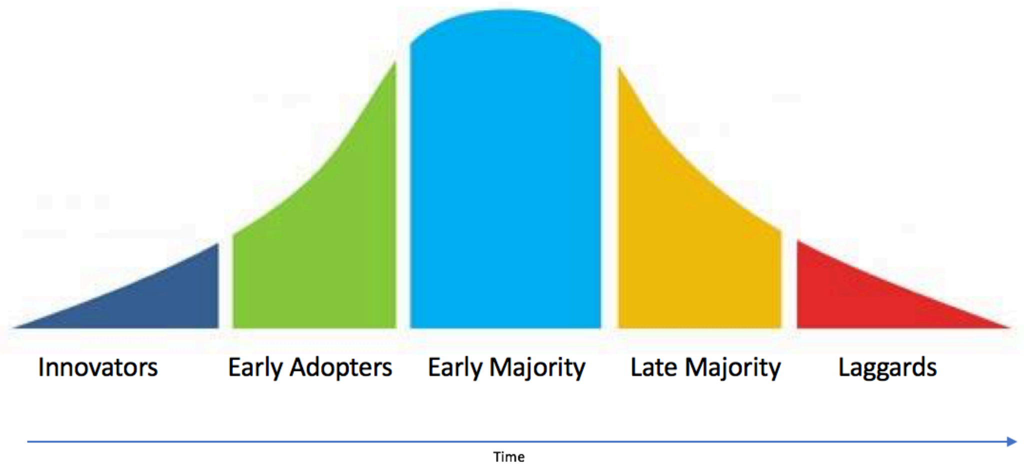

Figure 4 - Diffusion of Innovation Curve; adapted from (Rogers, 1995, p.62)

When a new idea or technology is presented it usually goes through a process of gradual adoption. Even when the benefits of this innovation are clear it can take many years for it to become widely adopted (Rogers, 1995). What Rogers, tried to point out here is that trying to make masses adopt a new and unexplored idea is a waste of time. Instead, one should focus on the innovators and the early adopters as they are more likely to embrace a new risky idea – which innovation in most cases is.

The uncertainty is the key reason to why just a few people dare to invest in a new and still unfamiliar technology (Brancheau and Wetherbe, 1990). It exists because the potential adopters lack the understanding of how this innovation functions and what are the potential consequences for themselves and the social system. To minimize the uncertainty, potential adopters will engage in information seeking usually through interpersonal peer networks (Agarwal el al., 1998). Only after they have collected sufficiently enough information, will the individuals start to accept and adopt innovations. As seen in the Figure 4, some individuals are more likely to adopt a new idea or technology, much sooner than the rest of their social system. The reason for such a behaviour can be explained by certain personal characteristics of the five categories of adopters, where the crucial one is their level of risk tolerance. Innovators, for example, are usually the individuals who are able to cope with great levels of uncertainty and are most exposed to mass-media, making them the category who needs the least time to adopt a new technology. Furthermore, their information reach is not focused solely on their own local social system, but it extends to other areas as well. Indicating that their decision to innovate cannot depend just on the subjective evaluation of innovation of their peers (Rogers, 1995).

Due to their personal characteristics, innovators can be seen as the opinion leaders, who can persuade others to adopt the innovation. Understanding these personal characteristics can help managers to target a new technology implementation more efficiently and precisely (Agarwal et al., 1998). Apart from the opinion of the innovators and early adopters, the rate of adoption could be also influenced by the other social messages and influences (Ibid). Additionally, it has been suggested that negative messages about certain innovation can have stronger social impact than the positive ones (Galletta, et. al., 1995). Hence, minimizing the negative messages about the innovation and focusing on the positive ones, could considerably help the managers in persuading the organisations or companies to adopt a new technology.

4. LITERETURE REVIEW

This section will present and outline the benefits and challenges of IoT implementation, according to the scarce existing literature. These finding will later be compared to the empirical findings of this thesis.

4.1 Benefits of IoT implementation

Firms are reluctant to invest in something they do not understand, something they cannot estimate the value of or when the return on investment is, more, or less unknown. All of this increases the level of risk of the investment and, in most cases, decreases the speed at which a new technology is adapted. However, there are always players in the economy who invest in early R&D of the new technologies. Some do it for personal profit (private or consulting firms) and some for overall society benefits (governmental agencies), but all with a common goal to make the economy growing. IoT is not an exception to this rule.

The IoT sensors would enable the factory to accumulate all sorts of data, from virtually any physical object in the production. From the temperature of the machines to the speed of assembly line. The key advantage of this system is that all this data would be collected and available for analysis in real-time. (Haight and Park, 2015). This opens a large window of opportunities for businesses to improve their operational efficiency by converting the raw IoT data into meaningful business decisions.

A research study done by Blue Hill Research analysed and interviewed three large organisations in the US, which have been using an IoT solutions for some time. This research found that all these organisations were able to transform their operational part of business, to reduce costs and improve the customer experience. However, a key factor, highlighted in this study was the ability of an IoT system to perform data analytics in real-time (Haight and Park, 2015). Once such system is in place and fully functioning advanced analytics are running, the system would be able to predict equipment failures and product defects, even before they occur, something a human operator could not do. A research by Davies (2015) provides evidence that the digitalization of the factories could significantly decrease the number of errors and defects but also increase the product quality. He argues that if the top 100 European manufacturers were able to bring down the level of defects to zero, they would automatically decrease the costs by 160 billion. Another study by World Economic Forum (2015), had a similar conclusion, where it was found that a most widely cited application of the IoT is the predictive maintenance. Apart from being more efficient than a human worker, the system could also decrease the rate of accidents caused by the human workers. An example of how IoT can improve both operational efficiency and decrease safety hazards are smart forklifts. A common operational issue arises with the usage of old-fashioned forklifts when the driver needs significant amount of time to locate the stock or the correct product. This causes a direct decrease in productivity. Additionally, forklifts are causing around 100 000 accidents in US, every year, where the majority are involving other pedestrians (Gilchrist, 2016). A solution for both problems could be found in an IoT interconnected system of sensors, RFID tags, cameras and warning signs. Sensors indicating a location of each aisle and each product on it, to the driver, could significantly improve the productivity. At the same time, cameras and sensors installed on the forklifts could warn the driver of an upcoming obstacle or in this case another worker. An even higher level of interconnectivity would ideally allow the forklifts to communicate with each other and enable the drivers to know who is closer to the demanded product, hence maximizing the productivity of the workers.

Robots are used in today's manufacturing processes, but these machines could soon become a thing of the past, since the advanced IoT systems will enable robots to be far more autonomous, interconnected and cooperative. Ultimately, these robots will able to interact with both each other and us humans, in a more safe and productive way. These types of robots are already available on the market and few firms are already offering advanced solutions. Kuka, a supplier of robotic equipment is offering a range of autonomous robots, which are fully interconnected, aware of the surroundings and can successfully cooperate with factory workers. Similarly, ABB is presenting a new type of a two-armed robot called YuMi which will be able to assemble products on the assembly line, together with other workers. It will be able to "see" and "know" which parts are supposed to be assembled next (Rüßmann et at., 2015). Bosch Rexroth, a supplier of smart drive and control technologies has realized the potential of the Industry 4.0 and started offering a range of smart-factory solutions. Their production facilities are described as decentralized, automated, autonomous, represented in real-time and above all are built to increase productivity by assisting the factory workers in their everyday work (Boschrexroth.com, 2017).

With time the IoT will become a building block of every industry, which will cause a shift to a pull-based economy, where the production will be driven by a real-time demand and products that are tailor-made according to the individual consumer (World Economic Forum, 2015). This flexibility in production is currently unimaginable, but the IoT based production will allow for much higher level of agility and adjustability that will ultimately shift the manufacturing industry from product-oriented to customer-oriented. This is something that was already seen during the Third Industrial revolution (see Allen, 2004), however, back then products were still produced after a common standard and not as a tailor-made product. Nowadays, the Industry 4.0 and IoT are associated with a real-time mechanism of feedback and monitoring, which if implemented in both production and logistics can help companies deliver a more efficient customer service (Gilchrist, 2016).

All of these improvements that Industry 4.0 and IoT will bring are still, in most cases, a prediction. It is still early to be able to statistically test the productivity and efficiency improvements as the digital transformation is yet to fully unroll. However, there are predictions and estimations which argue that the IoT is a profitable investment as the benefits it brings will lead to a better resource efficiency, shorter time to market, close to zero waste, shorter production times and a higher labour productivity (Jeschke et al., 2017). Eventually, this level of digitalization and interconnectivity between products, workers, machines and customers will ensure a higher competitiveness, a more sustainable production and will increase the overall profits. In Europe alone and with focus on its industry, these revenues will amount to €110 billion euro per year (Koch et al., 2014).

4.2 Challenges with IoT implementation

As mentioned in the beginning of this thesis, every disruptive technology (e.g. electricity) took some time to become widely adopted and used. The main reason is the rigidity of the existing infrastructure, which, in most cases, needs to suffer large-scale transformations for the new technology to work (World Economic Forum, 2015). The same scenario could be expected for the IoT. In order to enjoy the benefits of a fully functioning IoT system you would first need to install several sensors, cameras, motion detectors, RFID tags, robots, computers and employ skilful labour. The problem is that the existing infrastructure in factories is not designed to be interconnected and autonomous, meaning that a redesign might be necessary in many cases. Apart from investing in the networking infrastructure, the adopters of IoT will be required to invest in other areas, such as sensor technology development or the energy efficiency infrastructure (OECD, 2016). Such a redesign and new equipment, requires a large direct investment, which would be easier to make if the ROI on IoT was clear and easy to calculate. For that reason, many manufacturing firms are still reluctant to making such a risky move and investing in digitalization. A research based on a survey with 235 German industrial companies found that close to 50% of the participants indicated the high investment and unclear economic benefits as the main barrier to implementing IoT (Koch et al., 2014).

Similarly, a report by World Economic Forum (2015) apart from discussing the benefits, has pin pointed the major challenges of Internet of Things. What they found is that uncertain return on investment and immature technology present a notable barrier for potential adopters. The same report states that data security and cyber-attacks are an additional burden brought by increased connectivity and data sharing. In a paper by OECD (2016) it is argued that the data privacy challenges created by IoT are not largely different than those created by the existing digital technologies, but that it must be addressed differently. IoT is connecting the physical with the digital operations, where the data is controlling the physical parts of the system (pumps, lightning, ventilation, production line, etc.), indicating that a security breach could cause damage to both digital data and the physical production. For example, back in 2005, an internet worm infection stopped 13 Daimler Chrysler manufacturing plants for almost an hour, causing a total halt of production (Cisco, 2015).

Existing labour skills and knowledge are an additional problem that adopters might encounter. Having the most efficient IoT systems would not be enough if there are no employees who understand it, can monitor it and are able to develop it further. In the future, we might see a decline of traditional jobs and instead, there will be an increasing demand for skilful labour, that can program and design new digital systems (OECD, 2016). Brynjolfsson and McAffee (2011) found that the increasing level of digital innovation is causing many manufacturing jobs to become obsolete. More efficient production caused by a new technology will cause rationalization of input factors. Some workers will get laid off as a higher output can now be generated with less labour and with the help of smart machines. A model by Frey and Osborne (2013) suggests that workers who are most at risk of losing a job, are those working in production, logistics and transportation. Focusing on manufacturing industry, which still relies heavily on labour input in production, we might see a wave of cultural resistance to IoT implementation (Vodafone, 2016).

Participants believe that the IoT will stimulate growth in many other industries, where the suppliers of both hardware and software would have to be produce according to a new standard. This is the next obstacle for IoT to reach its potential. It is the institution and organisations which create legislatives and industry standards that need to focus of shaping the IoT policy frames. As IoT products will be sold across borders, it is an imperative to close the gap between different approaches and practices (OECD, 2016).

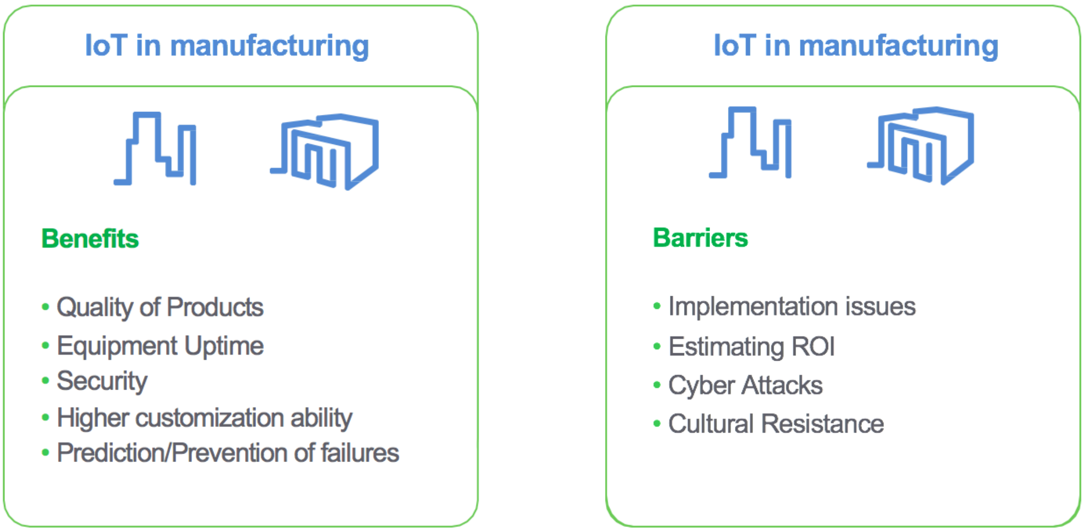

Figure 5 - Summary of the potential benefits and challenges

Figure 5, is a summary of the benefits and challenges which, according to the previous findings, have been associated with the implementation of IoT in manufacturing production. These will be discussed more closely in the following chapter.

5. METHODOLOGY

5.1 Research approach

The technology investigated by this paper is rather new and still under-researched, indicating a lack of statistical data and previous empirical. Because of that, this paper had to take the form of an explorative research. The goal with this type of a research approach is to unveil and understand the views, knowledge and trends in the opinions on a certain matter (Maxwell, 2012). That way the researcher is able to examine a problem and get sufficient level of understanding needed to shape the hypothesis or the research question. Furthermore, the questionnaire created for the purpose of this research paper, included both close-ended questions (there is a fixed number of possible answers) and open-ended questions (the participants provide the answer). This type of a mixed method approach, where the open and close ended question are combine in a single questionnaire is often referred to as inter method mixing (Tashakkori and Teddlie, 2010). Such an approach is expected to produce the most accurate and complete understanding of the issue investigated by the questionnaire Johnson and Christensen, 2010).

5.2 Data Collection and Survey

To gain knowledge and a clear perspective of such a young technology as IoT, author has firstly conducted a thorough investigation of existing material. Diverse commercial white papers, news articles, books and other academic papers were studied in detail. It was only after a significant knowledge and understanding, of the Industry 4.0 movement and IoT role in it, was achieved, that the author proceeded to formulation of the questions for the digital questionnaire. The questionnaire is aiming to gain answers which would highlight the biggest benefits and challenges with implementation IoT. IBM, is a company who is currently ranked the fifth biggest player in the IoT market (Buntz, 2016), indicating that they have extensive expertise and experience in the matter. Author was given, a unique opportunity to interview the IBMs experts in the field of IoT and find out what are the biggest concerns their customers face and complain about when it comes to implementing IoT, but also what are the biggest advantages of such a technology.

The questionnaire was designed to generate as much information as possible about the Industry 4.0 and the IoT. The backbone idea of this survey was to gain understanding of the issues such as: The current state of the Industry 4.0, the future of IoT adoption in manufacturing industry and how can the incumbent firms embrace this new transformation. The survey was fully digital, hence no live interview with the participants was established. Questions were of various form and design: open question, multiple choice questions and questions where participants were asked to estimate likelihood of a certain scenario occurring. Original idea was to send one survey (Type 1) to the IBM experts who would be answering from a solution provider point of view. At the same time a mirror image of that survey (Type 2) would be sent to the IT experts working at various manufacturing firms, who would be answering from the potential/current user of IoT solutions point of view. However, the IBM clients and firms who were contacted for Type 2 survey were not willing to participate in this study. Contacted firms differ in size, time spent as an IBM client and the industry segment. On the other hand, reasons for not participating were rather similar and usually concerned internal confidentiality policies as well as risk of losing competitive advantage. So, the focus was shifted to the Type 1 survey instead, and a totally of 12 (out of 45 contacted) responses was received and analysed. Nevertheless, it is important to highlight the response rate, as a different rate could have possibly led to different conclusions. So perhaps, if the author had a longer timeframe for this project and if he was to collect as many Type 2 answers, as he did for Type 1, he would have made considerably different conclusions.

After the survey was conducted and the necessary answers were acquired, the author has analysed the data by relying on the theoretical framework and existing literature. Following, the previous similar studies regarding the Internet of Things and the key points that were addressed in those studies, as well as the data generated from the above-mentioned questionnaire, the author had decided to focus his analysis on two focal points:

- Identifying the benefits and problems with implementation of IoT in manufacturing production
- Suggesting the ways in which the rate of adoption of innovation (in this case of IoT) can be increased

It is important to mention the fact, that even though structurally divided, these points have a common aim, which is to clarify how can a manufacturing industry and its incumbent firms benefit from IoT, as well as, what steps need to be done in order to utilize on this new technology. Also, a critical stand point was taken throughout the paper in an attempt to avoid generating biased or false conclusions.

5.3 Validity and Limitations

Validity is an indicator showing how reliable your research method and instruments are. It is also described as the level of accuracy of the measurement used in the research. When tools such as survey, questionnaire or face-to-face interviews are used, validity denotes the precision of these tools, which are used to measure the underlying outcome of interest (Sullivan, 2011).

Validity is a concept which is usually mentioned in regards to quantitative studies, where it is much easier to test the validity through different statistical tests. However, it is as important for a qualitative study to, at least, try achieving a higher validity (Noble and Smith, 2015).

The author of this thesis has been working at IBM, but not as a master thesis student. Meaning that all the work regarding this these was not commissioned, and was conducted outside the regular working hours. The questionnaire, however, took place at IBM and an online survey has been conducted with various experts. To be more specific, all 12 participants in the survey are the experts in the IoT/Industry 4.0 field and are working at IBM. They have been chosen according to their expertise and have not been offered any type of incentives. However, since the results of this research paper might highlight the benefits of IoT technology and since IBM has in its product portfolio a range of IoT solutions, the participants might have a tendency to provide more optimistic answers on the benefits or the future of IoT technology. Apart from that, there is a risk of selection bias, as the individuals deciding to participate have somewhat similar characteristics and knowledge, which would directly decrease the randomization of the sample. It is important to underline this fact since according to Noble and Smith (2015), one strategy to ensure the credibility of a qualitative study is to account for personal biases which can influence the overall results. However, the participants are aware that their individual answers will be presented as one aggregate result, so they might not be as inclined to be biased, because the impact of a single answer is lower. A second technique to ensure a higher validity is critically reflecting upon the research method throughout the paper.

A potential limitation with this study is a lack of empirical data. This is mostly because Internet of Things is still a young and not widely applied technology, making it hard to collect any other type of data than the one acquired through the survey. Quality of such data can be somewhat problematic, since the opinions and knowledge of participants are not fixed parameters and the interpretation of those opinions is likely to vary (Miles, 1979). Finally, it is important to mention, that the survey (data collection method) and the analysis used, are designed to focus on the impact of IoT on manufacturing industry only. To follow the exact same methodology and same question, for other fields of study could be problematic, so a prior and substantial remodelling is advised.

6. EMPIRICAL FINDINGS

6.1 The Results regarding the Industry 4.0

When asked, which industry would be the most impacted by the Industry 4.0 changes, majority of participants stated that the manufacturing industry will experience the biggest transformation (See Appendix – Q3). Other industries mentioned were automotive industry, energy, food and medical technology. However, the overall opinion was that any industry that includes a moving product or a factory floor will be affected by the Industry 4.0. The biggest reason for such a scenario is the need for improvement and transformation in these industries as there is a growing trend for customer centralization, predictive maintenance and automation. To be precise, 16.67% of the participants indicated that Industry 4.0 will have a large impact on the way in which products or production systems are designed and operated (See Appendix- Q10). The remaining 75% and 8.33%, stated that we can expect a significant and limited impact, respectively. Such results suggest that there is a general belief that Industry 4.0 will indeed, have a transformation and disruptive effect on many industries, but primarily on the manufacturing industry, where there is a need for a higher level of automation.

Furthermore, most of the questionnaire respondents agree that there will be a shift from engineering and product oriented culture in firms to more customer-centric organisations (See Figure 6). As the new connected systems, will provide an immediate customer feedback, this will force the companies to become more customer oriented and to beginning testing the pay-per-use strategy. Engineers will still be needed to run the production, but the customers will be able to influence the future roadmap of the product.

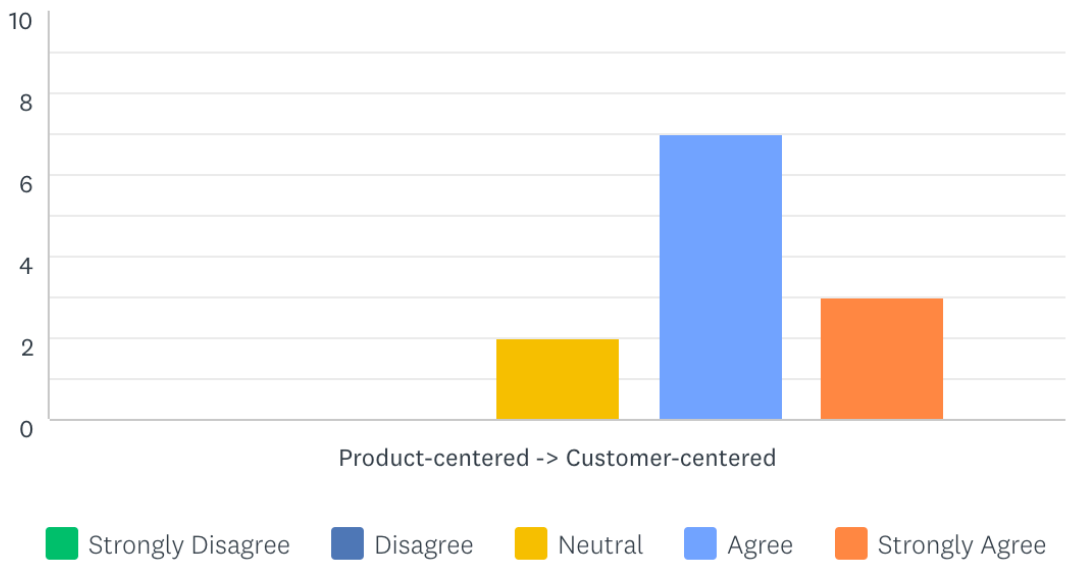

Figure 6 - Industry 4.0 will shift the product-oriented culture to a more customer-centric culture in organizations

6.2 The Results regarding the Internet of Things

Benefits

As discussed earlier in this thesis, there are couple of elements of the Industry 4.0 which are relevant and important for the next stage of digitalization. In Question 9 (See Appendix) the participants were asked to estimate the level of transformational impact of IoT, Data Analytics, CPS and Cloud Computing on the manufacturing industry. According to the results, all four elements are expected to have a large or significant impact on the manufacturing industry. However, 91.7% experts believed that IoT will be the technology which will the driver of large transformational changes in the industry. It was also highlighted that all the four elements need to be in order and in place to generate the full value from the system. Structured data generated from the connected devices is not viable without a Cloud and even when transferred to the Cloud, this data will not provide value without Data Analytics layer. The IoT systems, if successfully implemented are expected to enable the creation of the so called "smactories", where the greatest improvements will be seen in productivity and effectiveness of production. All the participants estimated a specific percentage increase in productivity and effectiveness, ranging from 15% to 72% and with an aggregate average of 36% (See Appendix – Q12). Apart from an increase in productivity of factories, IoT is expected to significantly improve: the customer satisfaction, the quality of products and safety of the factory workers. IoT will serve as a platform for further innovation and will enable a higher degree of process automation. It will also considerably increase the equipment uptime by the process of predictive maintenance, where equipment failures can be discovered even before they occur. All 12 participants agreed on this subject (See Figure 7).

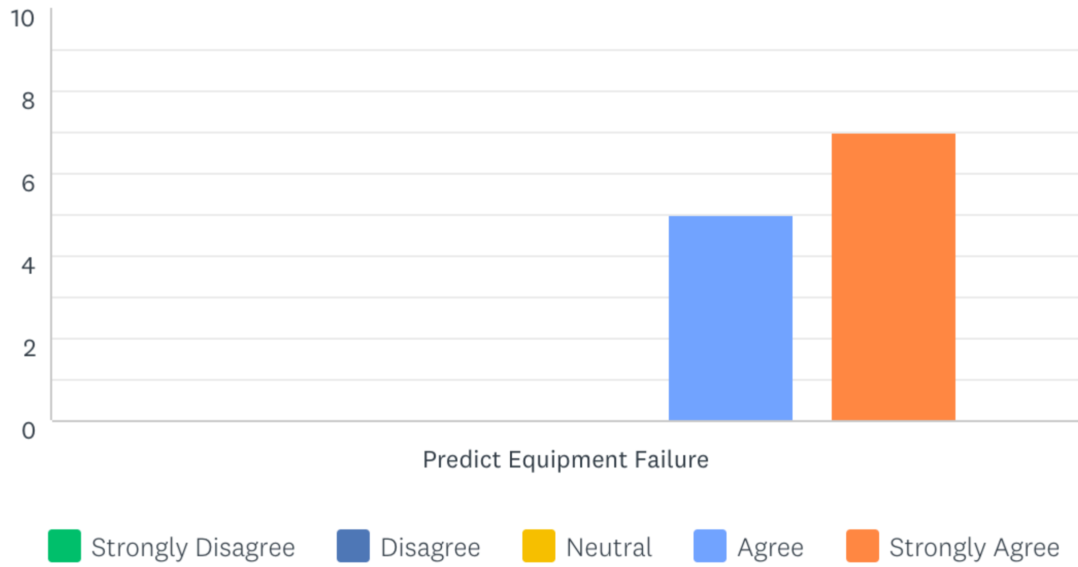

Figure 7 - IoT will help manufacturers predict equipment and product failures

A successfully implemented IoT system, will be generating large amounts of data, which can be used in two ways: (1) cutting cost through decreases in equipment downtime and automation; (2) adding value by understanding the usage of the factory machines. But then again, simply generating data cannot have a tangible impact. Advanced data analytical tools are essential for any IoT system, as they are the key for converting the raw data into meaningful insights. 83.33% participants classified the data analytics as a very important feature of any IoT system and other 16.67% classified it as important. When it comes to the shift from product-oriented to customer-oriented production, 10/12 participants believe that IoT will help preventing the out of stock problems and will also enable manufacturers to produce according to the real-time demand (See Figure 8). Furthermore, 10/12 experts stated that this new technology will give an ability to manufacturer, to provide more tailor-made products than what it is possible today.

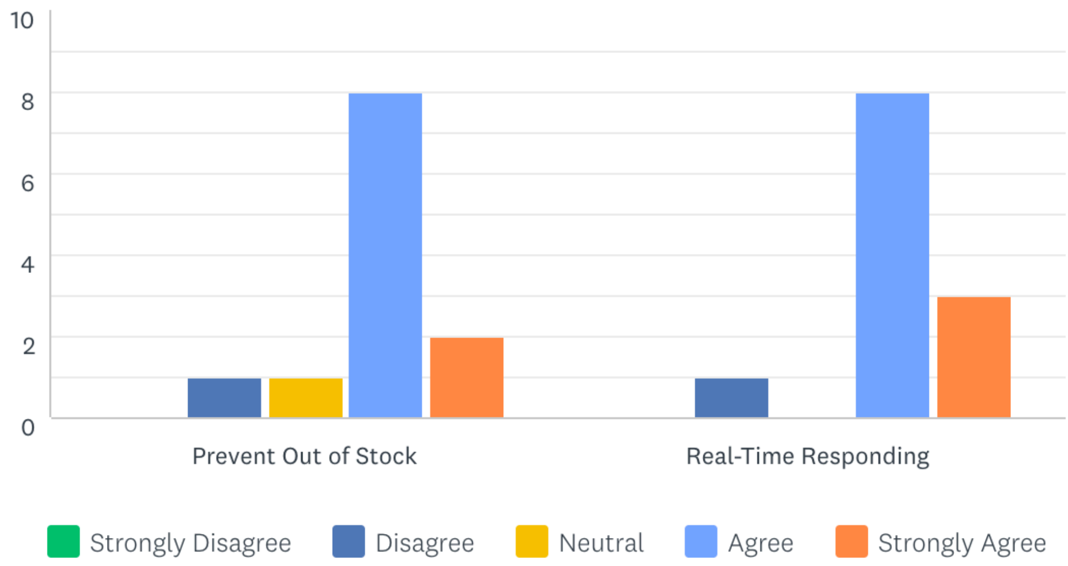

Figure 8 - IoT will help prevent out of stock problems and enable production by real-time demand

On an industry level, achieving a first-mover advantage by implementing IoT early on, seemed to be a smart strategy (See Appendix – Q14). To be precise, the expert votes as follows: somewhat important (2 votes), important (7 votes), neutral (1 vote) and very important (2 votes). The results also indicate that there is 63% chance that the early adopter of the IoT technology in their manufacturing production will become the industry leaders (See Figure 9). Similarly, the three previously mentioned benefits (predictive maintenance, out-of-stock prevention and product tailoring) were all classified as important or very important for manufacturers who wish to stay competitive in the future (See Appendix – Q27).

As for the IoT solution providers market, the results were slightly less optimistic and, on average, the participants approximated that there is a 42% chance that the new entrants will become the industry leaders (See Figure 9).

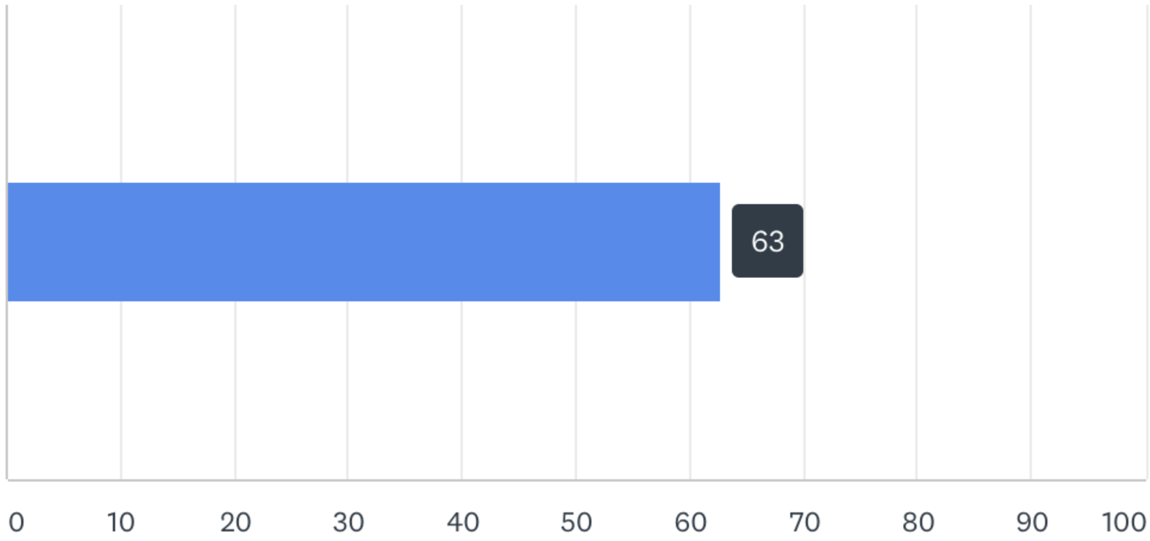

Figure 9 - A chance that early adopters of IoT will become manufacturing industry leaders (in %)

Challenges

As any other large scale investment, IoT requires planning, understating and careful implementing process. A firm deciding to invest in this technology needs to be aware of the fact that he or she is making a medium to long term investment (See Appendix – Q15). They need to have a clear strategy and vision, which requires a detailed analysis of the production painpoints and a process of continuous engineering. In addition to that, an investor could look at the data his factory is producing and then follow it to find its source. That way, he could identify if the data needed for analysis is being produced, which would also pinpoint the exact parts of the production which need to be connected into IoT system. Lastly, the investor, should understand his/her business model and how this new technology can have an impact on it. Other specific challenges related to IoT: cultural resistance, infrastructural problems with implementation, estimating ROI and cyber security. According to the answers to question 29 (See Appendix), the ROI is presenting the greatest obstacle for the manufacturing firms to decide to implement IoT. On a scale from 1 to 10 (1 - presenting no problems to clients; and 10 – causing great problems to clients) 9/12 experts responded with 5 or higher when asked to rank the ROI as a potential barrier. A mentioned explanation for such results is that manufacturers want wired sensors installed in their factories, which directly increases their device cost implementation efforts, thus making the ROI more risky and harder to determine. Additionally, as the IoT is a new and undertested technology, it is hard to predict how many years exactly will it take until the investment pays off.

In some cases, companies, would need to transform and integrate the whole supply chain in this new system, which, for many, might be a to large investment to make. A heavy work on system integration is required, because the data sharing and transparency is only possible if the sub-systems in the supply chain communicate with each other. Integration should also include the office IT and not just the factory floor. Size of the factory is an additional obstacle, as the IoT investment cost increases proportionally with the size and the units which need to be integrated or marked with sensors. Participants, further state, that both the current and the potential clients have company-wide knowledge about IoT and are aware of the its benefits, however, the current clients seem to understand the IoT a bit better (See Figure 10). Unfortunately, this knowledge is described as immature and shallow.

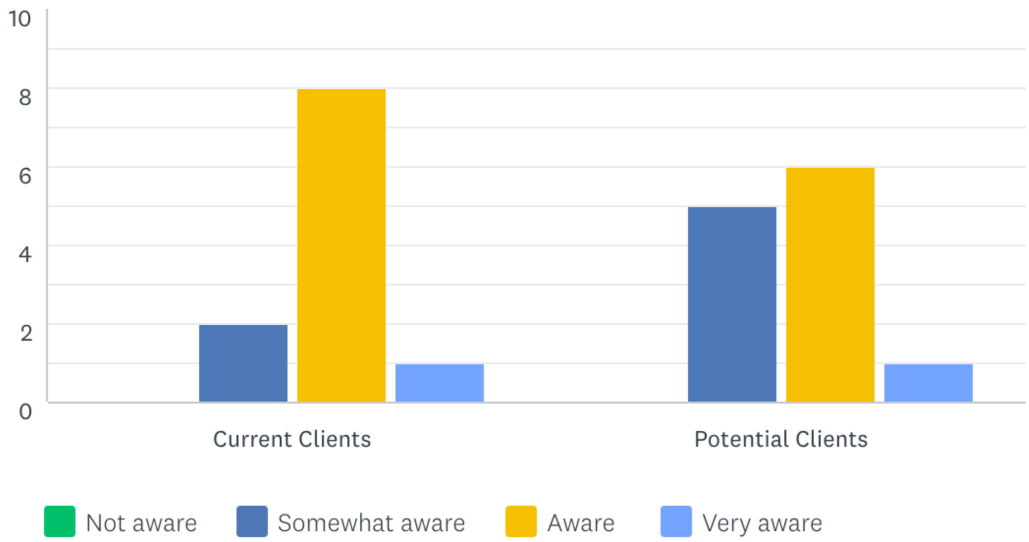

Figure 10 - How aware are the clients of the benefits of IoT?

This indicates that another great barrier to implementation are the skills and knowledge of the existing labor and management. All 12 participants said that new competences are required and that new operating business models need to be developed (See Appendix – Q8). Technical expert will be in demand and the skill premium for these experts will increase (12/12). Overall, Industry 4.0 will very disruptive, in terms of the traditional jobs lost. Perhaps therefore the cultural resistance inside the organization was also ranked high as a significant problem to IoT implementation (8/12 responded 5 or higher).

The large amount of data generated by IoT and a fully interconnected system of devices will create a security painpoint. On a scale from 1 to 10 (1 - presenting no problems to clients; and 10 – causing great problems to clients), most experts (8/12) ranked the cyber-attacks 5 or higher. Additionally, all the contributors classified the data security capability of an IoT system as either important or very important (See Figure 11).

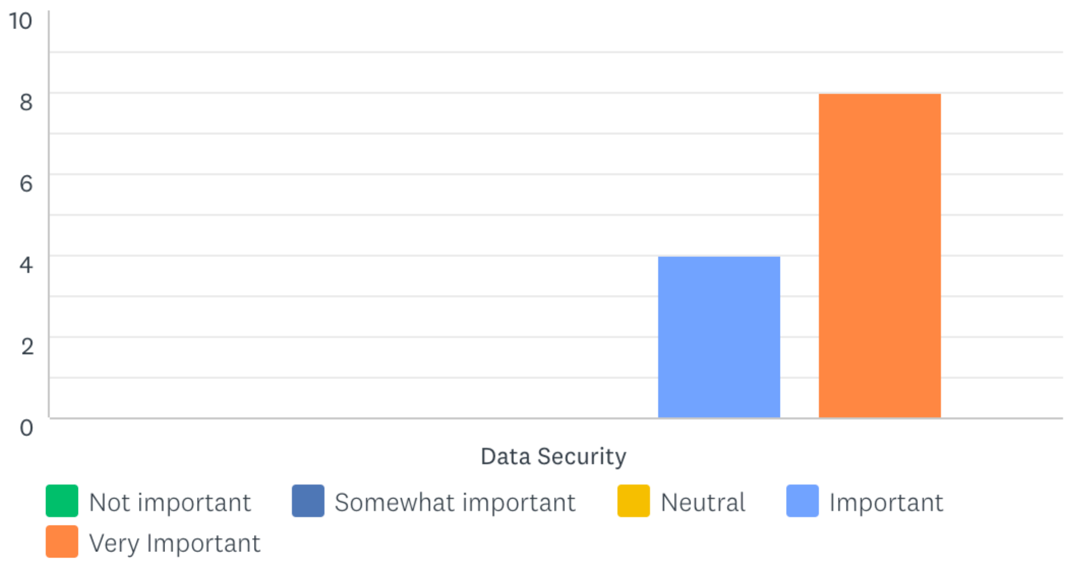

Figure 11 - How important is the data security feature on an IoT system

Overall the adoption rate is rather slow at this point, as the potential adopters are reluctant to invest in a risky technology. Experts in this survey, believe, however, that these obstacles can be tackled if approached differently. A better-defined business cases are a potential solution, which would help get a more clearly articulated ROI. Lower entry price and a package solution (including data analytics and platforms) are another way to tackle the above-mentioned challenges (See Appendix – Q31).

7. DISCUSSION

In recent years IoT, Industry 4.0 and smart systems have been widely discussed and mentioned concepts, both in media and in manufacturing industry. The underlying explanation for such a behaviour, could be the increased competition and price pressure created by the entrance of either foreign firms or domestic firms, who have offshored their production to the low-cost countries (Schlötzer, 2015). Prior to the digital revolution, the manufacturing depended largely on labour input, so from a financial stand point it made sense to move the production to the low-wage economies. However, the Internet of Things and the smart factories might just turn the tables around. In theory, IoT, mass-customization and automation of manufacturing production, will, in the long-run, enable the EU manufacturers to bring back the production to their home countries, because these new technologies are making the benefits of offshoring obsolete (Soldatos et al., 2016). However, both the previous literature and the empirical findings of this paper are suggesting that manufacturing companies are still in the process of learning and understanding of how the IoT can optimize their own production.

In line with the Schumpeter's theory of disruptive technology, the results imply that IoT will disrupt the manufacturing industry, with supply chain and production process, being affected the most. Traditional production process will be replaced by a new, fully automated system of devices, that will increase the productivity and decrease the down-time of the factories. The empirical results indicate that adopters of IoT systems, need to consider this a long-term investment, where the benefits will be visible only when the large majority of adopters joins in and starts using the IoT. Implementing IoT now, will ensure a strong position in the market later and will make the company remain or become competitive. When asked to rate the importance of the first-mover advantage, in the case of IoT, 9/12 participants ranked it as either important or very important. Following the innovation diffusion theory logic, early in the adoption process, the attractiveness of innovation is decreased by the level of risk it comes with a new technology. Since the survey result indicate that a small number of firms is understanding and implementing IoT, we can assume that the diffusion of IoT is still in the early phase. Hence, we can see only the innovators embracing the new technology and risking now in order to become industry leaders in the future.

If a firm considers to invest in such a new technology as IoT, there are two key elements that play a role in decision making. It is the firm's dynamic capabilities and management ability to make entrepreneurial decisions. The larger companies have harder time implementing the IoT technology as they need to invest substantially more capital into redesign of their existing infrastructures. These companies have already well-establish internal routines, culture, and large labour pool, which might pose a problem when trying to introduce a technology that might make some human jobs obsolete. Moreover, unclear return on investment and cyber-security were the two general challenges for all the firms deciding to invest in IoT, regardless of the size. With all these barriers, IoT is still, for many, a too risky investment to make and only a few firms have started the transformation process. Such behaviour is explained by the Christensen's (1997) depiction of firm's mangers who are seeking the opportunities which are attractive solely to their mainstream customers. The questionnaire pointed out that, if a firm wished to successfully implement IoT it needs to include the employees early in the process. Reason for that is that IoT is a complex technology, which should be built step-by-step, allowing the other system to integrate and the employees to get used to a new working environment. According to Teece et al. (2016) apart from routines, it is the employees internal culture and the knowledge that are building blocks of dynamic capabilities. If the firm' s dynamic capabilities are not sufficiently agile, any new technology will be hard to implement. This is supported by the questionnaire, where it is claimed that to successfully implement IoT manufacturer needs to have a clear strategy, include the staff early on and to implement the technology stepwise using an agile and iterative approach.

Furthermore, the results suggest that there will be a shift from product to customer oriented organisations. This means that new organisations will require new employee skills in managing the customers. As the production will shift towards more flexible model, where customers will be able to influence the production and demand tailor-made products, the employees will have to attain a new set of skills, essential to satisficing customer preferences. By some prediction there will be a shortage of 825 000 ICT professionals by the year 2020 and that, overall, the skills mismatch is the key obstacle for implementing Industry 4.0 technologies (Davies, 2015). As the demand for skilful workers will drastically increase, the skills premium will also increase. Where the skills premium is usually defined as a ration of the wages of the skilled workers to wages of unskilled workers (Roser and Nagby,2016). During both the first and second industrial revolution, the technological changes have created a disruption in the labour market and the skilful workers were payed much more than the unskilled ones (ibid). According to the questionnaire, all the participants believe that the skills premium will increase as the newest technological disruption unfolds, indicating that a similar scenario can be expected for the Industry 4.0 as with the previous industrial revolutions.

As for the technical features of the IoT system, both data analytics and data security were rated as important or very important. Considering the conceptual idea of IoT, which revolves around creating and then analysing large amounts of data, this makes perfect sense. An IoT system that solely generates data, without an ability to analyse it, is simply an expensive data tool and unnecessary cost. Similarly, data security is what worries the manufacturers the most, because we are moving towards an era, where digital and physical words will merge. This might make the cyber-attacks much more frequent, since the hackers could at that point, control the whole factory by simply hacking a single employee device. In some more extreme cases, a competitor could hack into the surveillance system of the factory and steal information and ideas, that are, perhaps, crucial for achieving a comparative advantage.

Overall, the collected answers, indicate that there is a positive belief among the IoT experts regarding the potential benefits of the IoT system, when implemented into the manufacturing production. However, as mentioned in the begging of the paper, they are perhaps bias and motivated to amplify the benefits, as that is their own best interest. On the other side, potential adopters of this new technology are still rather sceptic and unsure of how to understand and implement the IoT. In theory, the IoT has an enormous potential but its functionality and benefits still remain to be empirically tested.

8. CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The major goal of this thesis was to identify the key benefits, as well as the challenges, a manufacturing firm can expect, if it decides to invest in Internet of Things. Achieving this would help closing the knowledge gap which exist between the IoT solution providers and the potential adopters of the technology. The results have highlighted certain benefits but also some critical barriers which manufacturers might experience. Both research questions were answered to some degree, however, more accurate results would have been achieved if the questionnaire was extended to the current/future IoT users, as was originally planned.

The summary of the questionnaire results can be seen bellow:

I. What are the benefits of implementing IoT in manufacturing production?

- **Predictive maintenance** – IoT will maximize the equipment uptime and minimize the equipment failure by, predicating the failures even before they occur. Such capability, would decrease the cost of production, increase the productivity and increase overall revenue.

- **Data analysis** – A deeper insight into factory data will be possible. What were previously unstructured pieces of data, will be transformed into useful information, which could then be transformed into smarter business decisions. Perhaps therefore the capability to perform data analysis was ranked as a very important feature of an IoT solution.

- **Higher customer satisfaction** – With the new digital factories, both supply chain and production will become much more agile. Out-of-stock problems will be minimized and real-time responding to demand will be possible. This will enable the customers to request more tailor-made products, which would significantly improve the customer satisfaction rate.

- **Securing a competitive advantage** – The above-mentioned benefits, will have a considerable impact on the firm’s competitive advantage. Being an early-adopter might secure an industry leading position in the future.

II. What are the barriers to implementing IoT in manufacturing production? How to overcome them?

- **Estimating ROI**– Estimating the Return on Investment (ROI) of IoT is presenting a major obstacle for potential adopters. As IoT is a new and conceptual technology, the manufacturer need to invest in both IoT and its integration into existing systems. In many cases, large-scale redesign of production facilities is necessary, which changes the functionality of the existing systems. All this makes ROI estimation of IoT very difficult and unclear.

- **Cyber-Security** – When in place, the IoT system would be generating large amounts of data, often referred to as the Big Data. This data would be transferred through the Cloud, where the data analytics would be performed and the useful information is generated. However, this system would imply, that the whole factory, with all its equipment and machines, would be interconnected, monitored and controlled wirelessly. Problem is that this creates, an increasing number of possible entry points for cyber-attacks. Cyber security is one of the most important and most demanded features of an IoT system.

- **Cultural Resistance** – Many incumbent firms will have difficulties persuading the existing employees that IoT should be adopted. The biggest reason for this is that people are afraid that they will be replaced by intelligent machines and that they will become a liability, rather than a useful resource. This barrier could be surpassed if the firm includes the staff early in the process of implementation and offers education or trainings, so that the employees can gain the skills required for the new smart systems.

- **Structural Problems** – Firm's internal infrastructure can, in some, cases present an obstacle to implementation of new technologies. If the firm's internal dynamics are not flexible and agile, adopting any kind of new ideas will be almost impossible or extremely risky. Management play a key role here, and should be focusing on building an agile environment, both when it comes to labor resources and the physical assets. The size of the production facilities is one specific characteristic, that could make the implementation of IoT much more complex, hard and expensive.

IoT is a technology that has a potential to become disrupting factor in the manufacturing industry. Companies are starting to realize this and have slowly started to analyse and prepare for the inevitable transformations that they might need to endure. These transformations will include the firm internal dynamics, production process and customer relations. New business models will also emerge since the IoT will serve as an innovation platform, on which firms will be able to develop their own systems. Ultimately, a full digital interconnectivity of manufacturing production will be realised, at which point, the companies will have a much more agile production facility, ready to please the new customer preferences.

8.1 Future Research

The results obtained in this thesis are somewhat limited and perhaps too focused on a single industry. Indicating, that one should not assume comparable results can be achieved if the same research method was applied to a different industry or for a different technology. Hence, a prior redesign of the research approach is advised. As it was mentioned, earlier in the text, a biggest drawback was the fact that IoT users were not willing to participate in this research.

This could have changed the empirical results and led to considerably different conclusions. So, for the future research it would be interesting obtain the opinions and beliefs of the potential IoT adopters and then to cross-check those results with the ones produced by this thesis. Only then it would be possible, to comprehend why do the IoT solution providers firmly believe in the industry changes triggered by Internet of Things, while the potential users are somewhat more sceptic and unsure.

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APPENDIX

Questionnaire (*the link to the digital questionnaire: https://www.surveymonkey.com/r/W6D3HCC)*

1) What is your role/job at IBM?
2) What is your expertise (which IBM solution are you specialized in)?
3) In your opinion, which industries will experience most disruption/change by Industry 4.0? Why do you believe so?
4) When it comes to market for IoT solution providers, how likely is a scenario where the new entrants will become the market leaders? (from 0% - highly unlikely; to 100% - highly likely)
5) When it comes to manufacturing producers, how likely is a scenario where the early adopters of the IoT technology (in their production) will become the new industry leaders? (from 0% - highly unlikely; to 100% - highly likely)
6) How disruptive will the Industry 4.0 (primarily IoT) be in terms of the jobs lost, due to an increasing percentage of traditional jobs being managed by the intelligent machines?
7) Some research indicates we should race with the machines not against them. Do you believe that these IoT-generated disruptions in the manufacturing industry will require new competences in managing the relations with the customers? Will the manufacturing (operating) business models be forced to transform, in order to adapt to the newly developed changes?
8) As in every previous Industrial revolution, with the appearance of a new technology, the highly skilled workers were in demand, which caused their earning to increase. Do you believe that this so called "skill premium" will rise in the future, due to emergence of IoT technology?
9) In the past, revolutionary technologies have stimulated dramatic economic changes, usually in four (bellow mentioned) ways. Will the IoT technology effect the economy in all four ways? Try to rank these four ways from 1 - the most important; to 4 - the least important.
10) How big of an impact do you believe, Industry 4.0. will have on the way in which products or production systems are designed and operated? Give a grade and please elaborate on your answer, if possible.

11) Manufacturing industry, in particular, is expected to “suffer” a great deal of transformation in the coming years, due to Industry 4.0. Rank the four pillars, by the level of transformation they will cause in the manufacturing industry. Please elaborate on your answers if possible.
12) IoT, in particular, is expected to increase the productivity and effectiveness of manufacturing factories (eventually creating “smactories”)? Assuming a factory has successfully implemented the IoT technology, estimate the increase in productivity.
13) It is expected that IoT will also lead to other types of improvements in manufacturing. Give your own estimates of the level of impact IoT will have on these different parameters.
14) How important is the first-mover advantage, when it comes to the implementation of the IoT systems, in the manufacturing industry? Why?
15) If a manufacturer decides to invest in an IoT system, should he/she consider this a long or short term investment? When could the manufacturer expect to see the benefits of this investment? Relying on your knowledge and expertise, please provide an answer bellow.
16) An IoT system is not something that can be implemented over the night. Relying on your own knowledge and expertise where should a manufacturer start, if he wishes to digitally transform his factory?
17) Industry 4.0 is expected to shift the traditional engineering and product-centered culture in firms, towards a more customer - centered organisations. Do you agree with this statement?
18) How important is it for a manufacturer to achieve a customer - centered organisation before he/she decided to implement the IoT solutions in his/her production? Please elaborate on your answer if possible.
19) For the production factory to generate data, the manufacturer should install the cyber-physical systems (e.g. sensors). How will this generated data create new business value or increase productivity?
20) However, this generated data can be endless and most often unstructured. Data analytics software is a logical solution. How important is the data analytics capability of an IoT system when deciding which solution to implement in a factory?
21) MPI Group’s Internet of Things study has found that 24% of 360 manufacturers in the study has no company-wide knowledge of the IoT and its possible benefits.

Relying on your own knowledge and experience, how aware are the current/possible clients of the benefits of the IoT technology?

22) Relying on your own answer above, how could this “awareness” be increased?

23) How important are the data security features, when deciding which IoT solution to implement in your factory?

24) According to the current literature the IoT technology will help the manufacturers to produce a more “tailor made” products for each customer. How strongly do you agree with this statement?

25) According to the current literature the IoT technology will help prevent the out of stock problems and it will enable manufacturers to respond in real-time to changes in demand. How strongly do you agree with this statement?

26) According to the current literature the IoT technology will help the manufacturers to predict and prevent equipment and product failures, before they occur. How strongly do you agree with this statement?

27) In regards to the competitiveness, how important will these abilities (Q:23,24,25) be in the future?

28) Apart from integrating the IoT system in the production, are there any other prerequisite for a manufacturer to successfully achieve such a high level of mass customisation and real-time responsiveness? (e.g. High level of technological integration, size of the factory, transformation of the whole supply chain infrastructure…)

29) When discussing the IoT implementation, 4 barriers are usually mentioned: (1) problems with implementing the new technology in the factories, (2) possibility of cyber-attacks, (3) problems with evaluating the return on investment and a (4) “cultural resistance” against implementation of IoT due to possibility of jobs being lost. As an IoT solution provider, rank these barriers from 1 – are causing no problems to clients; to 10 – are causing great problems to clients.

30) Relying on your own answer above, what could be the possible solutions for overcoming these barriers? (Advice to a potential client)

31) What could accelerate the adoption rate of the IoT technology in manufacturing industry? (e.g. Lower price of IoT solutions, more customer-friendly platforms and applications, IoT package solutions which also include cloud storage and analytics etc.)