Industry 4.0, transforming incomplete systems into complete networks through collaboration

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ABSTRACT,
Originally the interest in Industry 4.0 started in Germany, but now Industry 4.0 has reached international interest and acknowledgement as a field of research. There are many areas to be explored and because of the high potential economic benefits of Industry 4.0 this has become a more popular topic. As of yet, many applications or systems are incomplete and this research will conclude what is needed to make complete Industry 4.0 networks. This research takes into account existing literature as well as views by companies involved in Industry 4.0. This research also looks at how markets will shift towards information-oriented markets due to the implementation of Industry 4.0 networks and how companies may adapt to market changes. Furthermore, due to the high level of automated processes which require less human interaction, technology could take over human's tasks in the manufacturing industry. This will create opportunities to save cost and increase efficiency, but might cause the destruction of jobs. This research concludes that businesses can collaborate to make Industry 4.0 systems complete and as such establish Industry 4.0 networks. This collaboration will be realised in financial aspects, as well as organisational aspects.

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1. INTRODUCTION

Note that Industry 4.0 may be substituted for just "4.0" during this thesis for reading purposes. Furthermore to avoid confusion: 4.0 processes are generally incomplete. They can be ideas, small applications or bigger systems with characteristics of Industry 4.0, but they are incomplete and as such will be called '4.0 systems'. This does not mean that these systems do not work, but they are technically not qualified as Industry 4.0 as long as they are incomplete. When there is a complete 4.0 process it will be referred to as a '4.0 Network'. This is to create the distinction between complete and incomplete Industry 4.0 processes or applications. More importantly, this is to better conclude how to transform an incomplete 4.0 process (system) into a complete 4.0 process (network).

Industry 4.0 is also known as the fourth industrial revolution. A quick overview of the industrial revolutions: The first industrial revolution used water and steam power to mechanize production. The second used electric power to create mass production. The third uses electronics and information technology to automate production (Schwab, 2016). We are now in the early stages of the fourth industrial revolution which uses a combination of machine-to-machine communication and Cyber-Physical Systems (CPS). "CPS refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities" (Baheti & Gill, 2011, p1). Building on CPS as well as machine-to-machine communication, the goal of Industry 4.0 is to strongly reduce or even completely remove the need for human intervention to achieve a high level of efficiency and autonomous production.

Guo et al. (2015) have shown how recent developments have increased the availability and affordability of sensors, data- and acquisition systems and computer networks. This resulted in an increase in the generation of high volume data which is also known as 'Big Data'. CPS can be utilized for Big Data as well as for enabling machine-to-machine communication to create independent and self-learning machines. Research by Lee, Bahgeri & Kao (2015) concludes that If CPS is integrated into industrial practices it could transform the current manufacturing industry into a 4.0 manufacturing industry.

According to Heng (2014) 4.0 networks are being developed, because the economic potential is extremely positive. Therefore the exploration of Industry 4.0 is becoming more and more popular among researchers (Lee et. Al., 2013). There is relatively little literature available regarding Industry 4.0, since many aspects have yet to be researched (Krogh, 2008). For example: if 4.0 systems become world-wide used, how will these different systems be combined? As companies aspire to connect their systems into a network, will there be one single network? And who will operate that network? These are perhaps questions to be answered in future research, because for now there are no complete 4.0 network in existence. Lee (2013) states that a problem regarding Industry 4.0 is that there are currently no industry standards defined and agreed upon. There are different reasons why the complete implementation of 4.0 networks is not yet realised, the most obvious reason being that it is simply a very intense and expensive investment. To successfully implement 4.0 systems, companies may need to change their entire organisational setting to adapt to the new standards (Lee, Lapira, Yang & Kao, 2013). Once the road to 4.0 networks has been paved, surely many companies will soon try to adapt to these standards when the financial and organisational risks are significantly less, but the potential benefits still being large. This road to standards for Industry 4.0 is where current literature seems to be stuck, as different opinions have been raised on what kind of rules should be incorporated into these standards. Another challenge is that 4.0 systems can be very different from each other depending on what they are used for, which makes it extra difficult to align those different systems into one network (Shi, Wan, Yan & Suo, 2011). See Figure 1.7 & 1.8 in the Appendix for a visualisation of components of Industry 4.0

2. RESEARCH DESIGN

The purpose of this research will be to present a way that allows different 4.0 systems to be interconnected to create a 4.0 network. As mentioned before many 4.0 processes are incomplete, they are systems with characteristics of Industry 4.0, but they are not yet qualified as such. To create 4.0 networks and therefore complete the systems that are currently incomplete, this research also looks at the needs and interests of companies who are pursuing 4.0 processes. These interests and needs are compared to research on how markets will change due to the implementation of 4.0 processes. The aim of this research is then to answer the main research question: ***How can multiple companies and their 4.0 systems be interconnected to create a 4.0 network?***

When companies are not capable of producing or acquiring certain resources, materials or products they generally tend to acquire it somewhere else, this can be called: outsourcing. By this same logic this research applies outsourcing to 4.0 processes. If for example "Company A" is not able to complete their 4.0 system, because they lack a certain technology, material, or lack specific know-how, they could try to find "Company B" who have exactly what they need. This usually results in a win-win situation where both parties gain from the "trade". However, Industry 4.0 is more complex than a simple trade, so therefore there are different things to be researched to see whether this kind of "outsourcing" is applicable to Industry 4.0 as well. The bottom line of this research is whether companies can try to collaborate their efforts to create complete 4.0 networks.

To answer the main question there needs to be a theoretical framework. Leading to the first sub question: ***How can existing literature provide a framework for 4.0 networks and the interconnectivity of different 4.0 systems.***

The purpose of this question is mainly to point out where the challenges lie in creating complete 4.0 networks. Also this will show possible gaps in the literature which could be researched in the future. When this framework is done it is important to see how this actually would affect business in practice. To create a realistic view of Industry 4.0 this research will aim to research companies who are currently pursuing Industry 4.0. Theory sometimes discusses the "perfect situation" which can be unrealistic in practice. Apart from researching how companies view Industry 4.0, this research will also investigate how markets will change due to the implementation of 4.0 networks. As mentioned before, Industry 4.0 may pressure companies to change their entire organizational setting, which can result in major changes in markets. Therefore the second sub question will investigate how the theory will actually affect business in practice: ***How will markets respond and adjust to the implementation of complete 4.0 networks?***

It is important to have theories be tested in practice to see whether and how these theories can be realised. This will be investigated by an anonymous survey among companies that are pursuing Industry 4.0. These companies will be chosen by the researcher based on whether they have a project regarding Industry 4.0 or are thinking about implementing Industry 4.0. This research will be limited to companies who are active in Germany and The Netherlands due to limited time and resources of the researcher and due to the fact that this is where currently most Industry 4.0 research topics are discussed (in the future this should be

expanded internationally). This leads to the last sub question: ***Why do companies pursue 4.0 systems and what are the needs and interests of these companies to make the implementation of 4.0 networks a reality?***

After answering the three sub questions this research compares theory to the needs and interests of the companies involved in Industry 4.0. The results of the survey will clarify whether and how incomplete 4.0 systems can be transformed into complete 4.0 networks. This will answer the main research question mentioned before.

3. THEORETICAL FRAMEWORK

This chapter will answer the following question by analysing and reviewing existing literature on Industry 4.0: "*How can existing literature provide a framework for 4.0 networks and the interconnectivity of different 4.0 systems"*

As mentioned before, there is currently no agreement on how 4.0 networks could be established as there are no standards formulated. There are arguments for different approaches, but there has not been research that combines those arguments to find a clear answer. Additionally. to answer the question this research tries to find where existing literature agrees and disagrees. This can be used as a starting point to analyse exactly what it takes to realise a 4.0 network.

3.1 Benefits of Industry 4.0

When Industry 4.0 was just recently introduced in literature, many things were uncertain. However, the potential benefits were rather clear: 4.0 processes would lead to large savings due to strong increases in efficiency. At that time many researchers spoke of the benefits, but could not specify exact numbers (Krogh 2008) (Lee et.al. (2013). It was in 2014 that a joint report by the Fraunhofer Institute and the industry association Bitkom stated that German gross value can be boosted by a cumulative 267 billion euros by 2025 after introducing Industry 4.0 (Heng, 2014). This was the first time that someone had researched exact numbers to prove that the benefits of Industry 4.0 were indeed as large as speculated. Research in "Big Data" and "Internet of Things" (IOT) amplified the research on Industry 4.0. Both these topics are closely related to Industry 4.0. "In an Industry 4.0 factory, machines are connected as a collaborative community. Such evolution requires the utilization of advance- prediction tools, so that data can be systematically processed into information to explain uncertainties, and thereby make more "informed" decisions" (Lee, Kao, Yang, 2014, pp1). These prediction tools are derived from Big Data- and IOT research. Also, by interacting with different systems that have a direct impact to machine performance improved intelligence will be achieved. Then regular machines can be turned into self-learning and self-aware machines which improves overall performance and maintenance management. In short: it improves the efficiency of the machines while making them easier to maintain.

3.2 Industry 4.0 will cover the entire value-chain

Industry 4.0 is greater than just the purchasing function, even though the purchasing function should co-design Industry 4.0. "Considering that in a typical industrial firm about two thirds of its turnover directly go to its suppliers, and that the share of production cost rarely exceeds 10%, it becomes clear that industry 4.0 will not only decide in the production hall, but particularly along the whole value chain" (Schiele, 2016, pp15). To interconnect all parts of the value chain there will need to be an exchange of sensible data. Furthermore, Schiele (2016) states that this will rarely happen via the open internet, but via secure connections. Industry 4.0 will interconnect devices and components with each other as well as with users, which should all optimize autonomously without human intervention.

3.2.1 E-procurement systems

As a starting point for purchasing in 4.0 networks existing e-procurement catalogue systems could be used. Barua et. Al. (2001) stated that e-procurement is the most important element of e-business' operational excellence for large corporations. Davila, Gupta and Palmer (2003) described the current state of e-procurement and after analyzing the economic benefits and risks concluded that it would be the most important part of supply chain management. They also mentioned that in the future E-procurement technologies would also need to 'talk' to suppliers' systems to automate the ordering process, and to customers' systems to ease the functioning of the supply chain. That future is now close as Industry 4.0 will take this to the next level by building upon these "older" catalogue systems. For example: Inventories can be maintained autonomously with the use of "smart bins", "smart assembly lines" self-manage to ensure fluid continuity and "cloud-based order management" allows customers' orders to be integrated into the process without the need of further human intervention .

3.3 Disagreement in existing literature

So far most literature seems to generally agree , however there are also areas in which different literature seems to disagree. Disagreement does not mean that one side is right and the other side is wrong, usually both sides are partly wrong and partly right. By looking at both sides this research tries to clarify why literature disagrees and, if possible, in what ways this can be solved.

3.3.1 Collaboration

While some argue that collaboration is the key to achieving a complete 4.0 network, others, like Bouncken and Kraus (2013) state that companies will have to compete and "protect themselves" against competitors. One argument for collaboration is that Industry 4.0 will lean towards mass-customisation. Which is a combination of mass-production and customization. This requires flexibility, while taking advantage of economies of scale. In the future there would be less agility/flexibility or mass-production focused companies, but instead hybrid strategies would be appropriate. " Agility is needed in less predictable environments where demand is volatile and the requirement for variety is high. 'Lean' works best in high volume, low variety and predictable environments" (Christopher, 2000, pp38). Brettel et.al. (2014) state that companies have to focus on their core competencies and create a network of collaboration to outsource other activities. Rogers et.al. (2011) say that collaboration is only necessary when compentences and capabilities are not sufficient. Generally speaking it is agreed that the question to collaborate or not should be answered by how well a company can implement flexibility and mass-production into their manufacturing process. For almost everything that is lacking, a collaborator should be sought.

3.3.2 Large companies vs small companies

Large companies generally have the advantage of mass production and economies of scale, while smaller companies tend to be more flexible and have more customised production. Industry 4.0 is characterized by both these features, mass production while still being able to diversify and customize products accordingly. Large companies may find it not too difficult to implement flexibility into their manufacturing processes using 4.0 systems. However, small companies may find it challenging to implement mass production into their manufacturing process due to their size. Some argue that small companies are not necessarily at a disadvantage (Motohashi,

2005). Small companies tend to have incorporated a flexible strategy and that would outweigh the lack of mass production. A large company who has been mass producing but suddenly has to adapt a flexible strategy may not have the managerial or organizational capabilities to adapt to a 4.0 network. Large companies may need these smaller companies who have specific technological know-how and are experienced with a flexible production process. It seems that companies with high technological capabilities will dominate the markets in Industry 4.0, but that may not be the case either.

3.3.3 Dominating the market in Industry 4.0.

To define exactly what kind of companies will dominate the markets, or are expected to outperform their competition, requires a very complex and in-depth research. However, for now a preliminary answer can be made by taking into account the previous paragraphs. The characteristics that have been mentioned that would improve a company's performance in Industry 4.0 may be contradicting in general sense (large companies being capable of mass production but consequently having less flexibility). This is where the strong separate themselves from the weak and one could argue that 'survival of the fittest' applies here. Theory tends to speak 'generally' and the companies that will likely outperform their competitors are those who free themselves of these 'generalistic' ideas. Those companies who, for example, manage to implement mass production ánd flexibility (mass customization) are those who will dominate the markets and outperform the competition (Qu et.al. 2011).

4. MARKETS RESPOND TO IMPLEMENTATION OF INDUSTRY 4.0

This chapter will aim to answer the sub question: *How will markets respond and adjust to the implementation of complete 4.0 networks?*

First of all it must be noted that this question implies that markets will respond and adjust to the implementation of Industry 4.0, however it could also be that companies will have to respond and adjust to changing markets. By answering the sub question above this research will try to make clear whether and how Industry 4.0 will affect markets as well as the companies pursuing Industry 4.0.

4.1 Smart factories will change the value chain and information becomes key

As mentioned before Industry 4.0 will cover the entire value chain. This means that many aspects are subject to change when 4.0 networks are implemented. One of those changes will be a result of a concept called 'smart factories'. Smart factories are established by "The vertical integration of various components inside a factory to implement a flexible and reconfigurable manufacturing system" (Wang et.al. (2016), pp158). This flexible and reconfigurable manufacturing system will allow the manufacturing process to be significantly more efficient. "The vision of future production contains modular and efficient manufacturing systems and characterizes scenarios in which products control their own manufacturing process" (Lasi et.al. 2014, pp239). Generally, products are a result of the manufacturing process, so how can they control their own manufacturing process? This is one of the most characteristic aspects of Industry 4.0: Communication between machines and combining that with Cyber-Physical systems. The single most important factor is information. As mentioned before the use of 'Big Data' and 'Internet of Things' can help create prediction tools so that systematic processes can make more informed decisions, but machines that are self-aware and self-learning can only be created if the supply of information is constant, reliable and correct. Apart from that the initiation of this process needs to be done by human intervention, but after a while the system should become stable and then autonomous. Because of this markets will tend to be more information- and technology oriented. Companies will actively search for and create prediction tools and technological applications to improve their flow of information while competing for the most flexible and efficient systematic manufacturing processes. Jazdi (2014) stated that data protection will become even more important than it already is as data and information flow will be used between machines as well. This means that digital breaches or hacks could shut down entire manufacturing processes, with possibly large scale consequences.

4.2 Humans vs machines

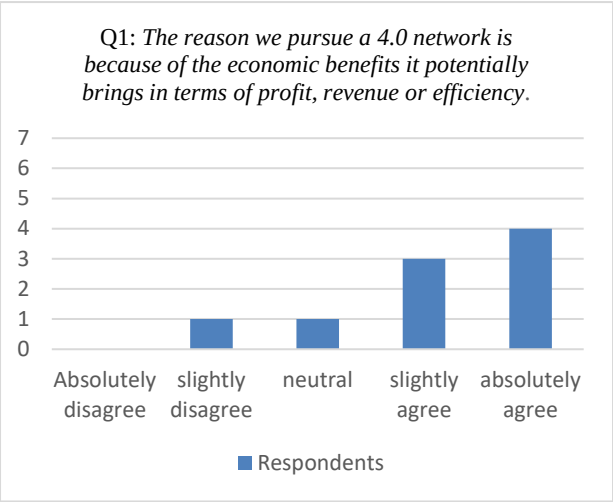
With the introduction of self-aware and self-learning machines, it seems that many employees will be out of jobs soon as machines will take over tasks that were assigned to employees in the manufacturing industry. Arntz et.al. (2016) showed that the largest automation potential lies with the low educated, low income workers. However, the age of digitalisation has begun years ago and, instead of the destruction of jobs, a shift in jobs has been the case (Frey, Osborn, 2013). Frey and Osborn also state that new technologies create new jobs. Humans are significantly more flexible in their capabilities than machines. "As the most flexible entity in cyber-physical production systems, workers will be faced with a large variety of jobs ranging from specification and monitoring to verification of production strategies" (Gorecky et.al. (2014) pp1). Gorecky et.al. also state that machines will only take over specific tasks and not entire occupations. Still there is no guarantee that some jobs might be automated and those jobs tend to be low educated, low income jobs. Employees who fulfill such jobs will want to - and can- prepare themselves from the automation process. It is important to train those employees in specific tasks, that are hard to automate. Focus on tasks at the individual level and ensure that workers attain the skill requirements of tomorrow's world of work.

5. RESULTS

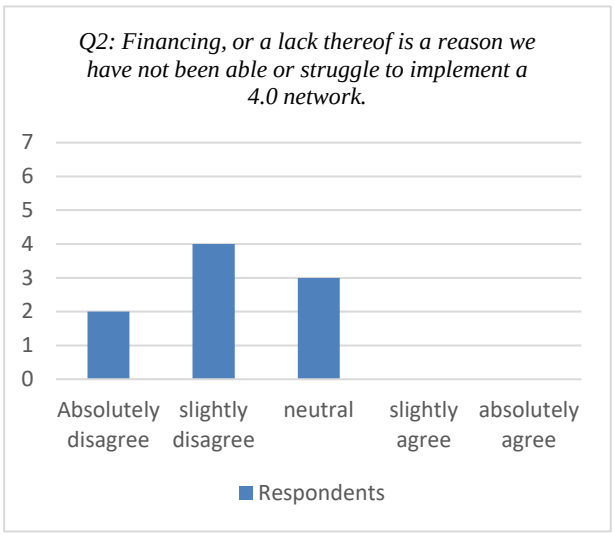
This chapter will discuss the results of the survey. Additionally, the results will also add to the previous chapter by showing companies' perspectives on Industry 4.0, market changes and companies' changes within their organisational settings related to the implementation of 4.0 networks. There are 9 respondents in total and every question was scored by all 9 respondents. The 9 respondents are representatives of the following companies: Picnic, Wehkamp, Zalando, Kasto, Philips, Samsung, Bosch Rexroth, KPN and Siemens. These companies have publicly indicated that they are working on implementing Industry 4.0 or are thinking of implementing Industry 4.0. The respondents were asked to "score" 1-5 on a Likert scale on several statements where 1 means 'absolutely disagree', 2 means 'slightly disagree', 3 means 'neutral', 4 means 'slightly agree' and 5 means 'absolutely agree'. The results are shown in graphs below. The x-axis shows the scores 1-5 and the y-axis shows the amount of respondents that entered that score.

5.1 Companies that pursue Industry 4.0

This chapter will discuss companies' views regarding the pursuit of Industry 4.0. As mentioned before the economic benefits have proven to be high, but there is more to Industry 4.0 than just that. By means of a survey this research aims to find an answer to the following question: *Why do companies pursue 4.0 networks and what are the needs and interests of these companies to make the implementation of 4.0 networks a reality?*



(figure 1.1, Q1)



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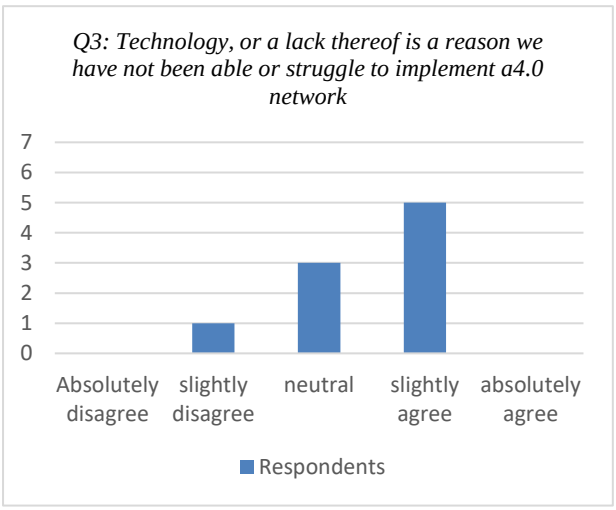
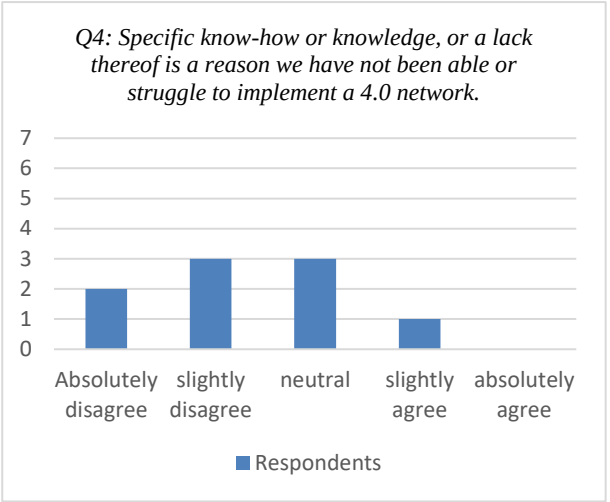


(figure 1.3, Q3)



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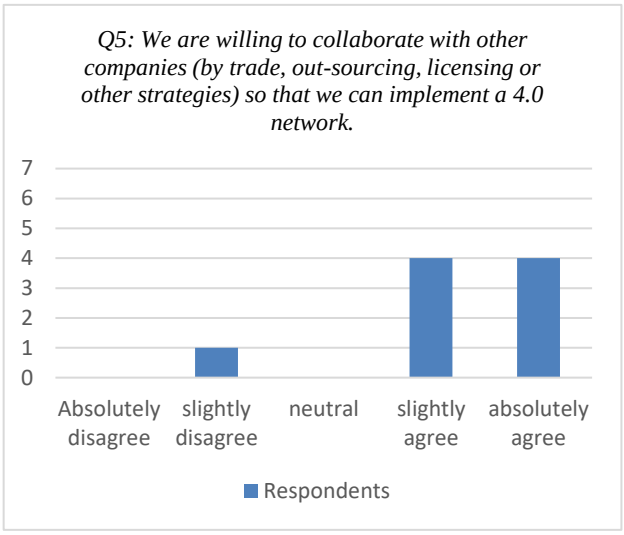
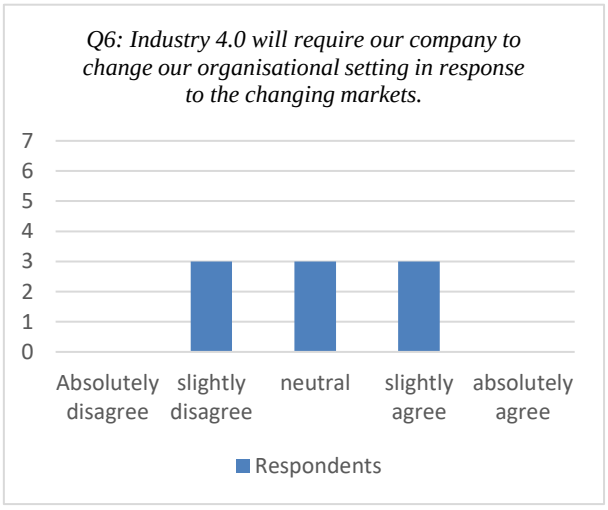


(figure 1.5, Q5)



(figure 1.6, Q6)

Figure 1.1 shows that sSimply put, most respondents agreed that the economic benefits of Industry 4.0 is reason enough to pursue a 4.0 network. Despite the costs of implementing a 4.0 network, most companies see it as a profitable opportunity. 1 Respondent slightly disagrees and might have different reasons for pursuing Industry 4.0. Perhaps this company wants to keep up or stay ahead of the competition by implementing Industry 4.0. Or it sees its benefits purely in the increased efficiency that Industry 4.0 can bring.

Figure 1.2 shows that financing or a lack of financing is found to not be a significant factor in whether a 4.0 network can be implemented. Figure 1.2 also shows that 3 of the respondents were neutral regarding this question. Which could mean they are not certain of the costs of a 4.0 network or that they are not yet certain what they need to implement a 4.0 network.

Figure 1.3 shows that technology plays a significant role in whether companies are able to implement a 4.0 network. The required technology for 4.0 networks is high-end, new and expensive. Therefore it can be hard to obtain for certain companies. Furthermore this could explain why some respondents scored 'neutral' on Q2: financing could be a problem if the required technology is rare or hard to obtain. When/if the technology becomes more available, financing may be an even less important factor.

Figure 1.4 shows that the respondents generally do not see specific know-how or knowledge as a significant factor in implementing 4.0 networks, but the results are not too convincing. Again this could mean that companies are not certain about what is needed to implement 4.0 networks, but it could also imply that they know where to find it, but not how to obtain it.

Figure 1.5 shows that companies are willing to collaborate to complete their 4.0 systems and transform them into 4.0 networks, although 1 of the respondents seems to have a negative attitude towards collaborating for a 4.0 network. Due to the anonymity there is no hint as to why this is so, but it is interesting to see that this company might deem collaboration unnecessary. Perhaps it is close to completing a 4.0 network without the need of others, but this is only speculation. The majority is willing to collaborate and it is likely that this is connected to Q3, the lack of technology. If companies can collaborate and share their technology amongst each other, then a 4.0 network might be established.

Figure 1.6 shows that the respondents evenly scored 'slightly disagree', 'neutral' and 'slightly agree' in Q6. This makes it hard to assess the results of this question as there is no information available yet as to why some companies think they do not require change, while others think they do require change. It is possible to see the results as though companies are uncertain about the future and how markets would establish after implementing 4.0 networks. Or perhaps they think that it could depend on finding the right companies to collaborate with or that it could depend on how negotiations with those collaborators go. Perhaps the results should be interpreted as: "If there is need to change our organisational setting we will and if there is no need to change our organisational setting we will not". Perhaps future research may shed more light on this particular question.

6. LIMITATIONS AND FUTURE RESEARCH

Before addressing and answering the research questions it is important to address flaws in this research. First of all, some arguments are based on new literature. New literature can take into account older literature and correct mistakes if needed, however it can turn out to be wrong in the future when more information is available. Since industry 4.0 is a relatively new field of research and many things are uncertain, argumentation can be incorrect or misinterpreted from other research. Another issue is that some key literature is still in German language and not always available in English, which makes it possible for translation errors or misinterpretations to cause incorrect arguments.

The results of the survey had to be anonymous. It is understandable that innovative companies cannot always share their ideas and innovations with the world, however this has made it difficult to make certain conclusions. Perhaps in future research similar companies can be compared to each other in terms of, for example: organisational background, size and technological capabilities to conclude whether statements based on literature in Chapter 3.3 also apply to actual companies who pursue Industry 4.0. Also then it would be possible to compare a respondent's answers to different question to find whether some of these questions are correlated to each other, which is likely. However the results still provided the means to answer the main research question.

Furthermore a survey among 9 respondents is generally not very representative, however there are currently not many companies who pursue 4.0 networks. Perhaps better and more convincing results can be obtained by including companies worldwide who pursue 4.0. These companies will likely face different challenges, but those companies could add a significant amount of useful information to existing research.

7. CONCLUSION

First the sub questions will be answered and then the main question will be answered which will be the conclusion of this research.

"*How can existing literature provide a framework for 4.0 networks and the interconnectivity of different 4.0 systems"*

German gross value can be boosted by a cumulative267 billion euros by 2025 after introducing Industry 4.0. 4.0 Networks would lead to large savings due to strong increases in efficiency. Big Data and IOT will be used to create prediction tools and by interacting with different systems that directly impact machine performance a higher level of intelligence can be achieved, i.e. self-learning and self-aware machines. Also by interacting with different systems that have a direct impact to machine performance improved intelligence will be achieved. Then regular machines can be turned into self-learning and self-aware machines which improves overall performance and maintenance management. In short: it improves the efficiency of the machines while it makes it easier to maintain. Industry 4.0 will cover the entire value-chain. 4.0 networks will interconnect devices and components with each other and with users, which should optimize autonomously without human intervention. As a starting point for purchasing in 4.0 networks existing e-procurement catalogue systems could be used. Generally speaking it is agreed that the question to collaborate or not should be answered by how well a company can implement flexibility and mass-production into their manufacturing process. For almost everything that is lacking, a collaborator should be sought. Large companies may need smaller companies who have specific technological know-how and are experienced with a

flexible production process. Companies who, for example, manage to implement mass production ánd flexibility (mass customization) are those who will dominate the markets and outperform the competition.

How will markets respond and adjust to the implementation of complete 4.0 networks?

Many markets will become highly focused around technology and information and data protection will become even more important than it already is. Companies will actively search for and create prediction tools and technological applications to improve their flow of information while competing for the most flexible and efficient systematic manufacturing processes. Machines will take over employees' tasks. It is still likely that some jobs might be automated and those jobs tend to be low educated, low income jobs. Employees who fulfill such jobs will want to - and can- prepare themselves from the automation process. It is important to train those employees in specific tasks, that are hard to automate. Focus on tasks at the individual level and ensure that workers attain the skill requirements of tomorrow's world of work.

Why do companies pursue 4.0 systems and what are the needs and interests of these companies to make the implementation of 4.0 networks a reality?

The results of the survey show that companies pursue 4.0 for the economic benefits that 4.0 networks might bring. These companies have a strong need for technology, but are uncertain about how to obtain it. Financing industry 4.0 networks is not necessarily a problem, but the lack of technology makes it only available to those willing to pay the high price. Companies generally think that specific knowledge or know-how is not a significant factor in whether they can implement a 4.0 network, but there is uncertainty on what exactly is needed for a 4.0 network. Most importantly, companies are positive towards collaboration. Most of the respondents in the survey are willing to collaborate with other companies to implement a 4.0 network. This could solve, perhaps partly, the problem of lacking technology and this could speed up the process of Industry 4.0 becoming a reality.

Finally, the main research question will be answered: ***How can multiple companies and their 4.0 systems be interconnected to create an 4.0 network?***

Taking into account existing literature and the view of companies who are involved in Industry 4.0, this research found that collaboration is the key to successfully implementing 4.0 networks into the manufacturing industry. Even though literature may disagree on whether collaboration should only be used when it is absolutely necessary or whether it is generally beneficial. The ability to implement flexibility as well as mass-production is a key factor in deciding whether collaboration is required. This is supposed to realize the manufacturing of individual products in a batch size of one while maintaining the economic conditions of mass production. Therefore both large and small companies can struggle to implement "mass-customization". A complete 4.0 network is so complex that it is considered almost impossible for a single company to create, since a 4.0 network will cover the entire value chain. Therefore for everything that is lacking a collaboration should be sought.

The changing markets require companies to actively search for information as markets will shift towards being strongly information-oriented. These markets will be highly competitive, but companies will still want to find collaboration in some way. Finding information and then making sure that it is used correctly will be a deciding factor in successfully implementing a 4.0 network. "Smart-factories" and especially "smart-cities" will be based on huge amounts of information flowing from one place to another and then so forth. Figure 1.7 & 1.8 (Appendix) show that a complete 4.0 network is complex and has many components that should all be integrated into one network. This can only be done when all information is available at the right places. As a final conclusion: The only realistic way of Industry 4.0 being realized in the near future is through collaboration. 4.0 networks are very complex and require different companies to collaboratively create a successful implementation of Industry 4.0. In the far future however technology may finds its way to big organisations who create and monopolise large 4.0 networks and as such establish "smart-cities", which would be a very interesting research area.

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9. APPENDIX

Figure 1.7 (Industry 4.0)

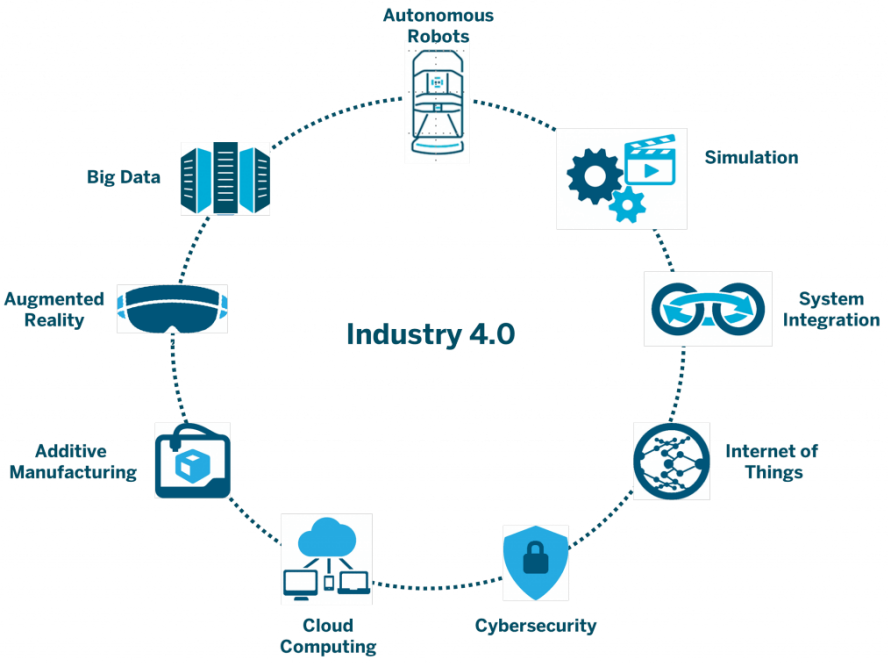

Figure 1.8 (Industry 4.0)