The Internet of Things (IoT) in Smart Industry – Chance and Challenge in Industrial Business Relationships

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ABSTRACT,

Industry 4.0 is disrupting many businesses, changing not only the way companies work internally, but also externally. Relationship building between firms proved to become increasingly important since the start of the globalization, but industry 4.0, with its possibilities for connectivity, takes this even further. Based on established literature, a model is proposed, describing how internal technology changes influence the way companies collaborate with each other. By interviewing several leading firms in the area of automation and connectivity, optimizations to this model are proposed. The main factors in relationship building prove to be cooperation, commitment, trust, transparency, communication quality, information sharing, participation, joint problem solving, and conflict resolution techniques. This paper helps in evaluating those factors in the context of industry 4.0, while at the same time showing how they connect to internal changes caused by the digitization.

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Keywords
Industry 4.0, Business Networks, IoT, Supply Chain Collaboration, Integrated Supply Chain, Individualized Production

11th IBA Bachelor Thesis Conference, July 10th, 2018, Enschede, The Netherlands.

1. INTRODUCTION

Industry 4.0, also commonly referred to as "the fourth industrial revolution" (Gerbert, Lorenz, Rüßmann, 2015), Enterprises(SME's), demanding different work requirements than in the past. (Gebhardt, Grimm, Neugebauer, 2015) It challenges "business as usual" and puts pressure on companies to adopt new technologies. The term "Industry 4.0", originally coming from Germany, involves the integration of sensors, middleware, software, and cloud computing into the operations of a firm to generate data from the various business processes. This data can then be analyzed and used to improve efficiency and finally also profits. (Kiel, Müller, Arnold, 2017)

Through automation and increased connectivity, companies can benefit from short lead times, lower costs, and enhanced product quality. (Kiel, Müller, Arnold, 2017) The data that is being generated through this paradigm shift leads to a greater understanding about machines, customers, and business processes. Results of this change are smarter products which increase the value for the customers, as well as an improved supply chain within the manufacturing firms. Even though benefits are plenty fold, companies in Germany have a low adoption rate and many do not fully comprehend the value of these technologies yet. They often do not realize, that becoming a "digital reinventor" leads to increased turnover and a better market position. (Bughin, Catlin, 2017)

As the number of these technologies increase, companies are generating more data within their supply chain. To get the most value out of this data, processes need to be changed and business models adjusted. This requires collaboration between companies along the entire value chain. (Lee, Bagheri, Kao, 2015) Therefore, companies should always be seen within the business network they are operating in. Previous research has shown that collaboration with other companies within the value chain can improve efficiency, effectiveness, and the market positions of the contributing companies. (Min et. al., 2005) The business network a firm is embedded in often influences the level of cooperation between 2 firms. Trust and Relationship commitment are crucial factors when collaborating in Industry 4.0, making data sharing and the implementation of an integrated supply chain significantly easier. (Holm, Eriksson, Johanson, 1996)

The effects this collaboration has on the supply chain can be seen in the changed manufacturing landscape. Individualized production, horizontal integration, and end-to-end integration become increasingly important in this context. (Brettel, Friederichsen, Keller, Rosenberg, 2014) As these trends continue, new forms of coordination are needed, including logistics synchronization, information sharing, incentive alignment, and collective learning. (Simatuoang, Wright, Sridharan, 2002)

1.1 Purpose and RQ of study

The purpose of this study is to identify the important factors in relationship building, and to figure out how the current trends in industry 4.0 change how companies relate to each other. Hereby, the focus will be on collaboration between firms within a business network. How supply chain changes influence this collaboration will be subject of this work. Therefore, the research question will be:

How do the supply chain changes in Industry 4.0 influence the relationship building of companies within a business network and why do those changes occur?

This research starts with a literature review where all the technologies and supply chain changes in Industry 4.0 are being determined. Additionally, all the important aspects are being looked at from a business network perspective. After that, the "Methods" part makes clear how the data is being collected and analyzed. The "Results" part will then analyze the findings of the collected data and will present the main points of how business relationships are changed in industry 4.0. The conclusion will tie everything together and give propositions based on the findings, as well as show the limitations of this research. In the end, acknowledgements and references can be found.

2. LITERATURE REVIEW

2.1 Business Networks

When looking at business networks, Industry 4.0, and the paradigm shift it caused, firms are forced to change the way they see their own company in relation to partners outside of its own walls. One such example is for example the changing big data environment many companies find themselves in. Manufacturing firms are generating an increasing amount of data, and its usage can have an impact on outside entities, like customers or suppliers for example. This data needs to be managed to get the most value out of it. (Lee, Kao, Yang, 2014) The emphasis the literature places in this regard is often connected to the possibilities that data-generating cyber-physical systems can create, and to the new supply chain configurations they often bring with them. One of the biggest factors is the role of collaboration in these new supply chain configurations. Integrated supply chains demand new modes of coordination, cooperation, and communication. (Lee, Bagheri, Kao, 2015)

Established Research has shown in the past that partnership success has its foundation in collaboration between firms. The external components of firm relations should not be forgotten in this new Industry 4.0-context. Jakki Mohr and Robert Spekman (1994) give us predictors of success that help us in assessing the success of a business partnership. These predictors are:

1. Coordination
2. Commitment
3. Trust
4. Communication quality
5. Information sharing
6. Participation
7. Joint problem solving
8. Conflict resolution techniques

Despite the age of the model, these 8 factors can still give a starting point in discerning the meaning of business networks under industry 4.0. The model makes a distinction between relationship attributes, communication, and conflict resolution in partnerships.

The first category, relationship attributes, shows that the interpersonal relationship between companies plays a significant role in collaboration success. It consists of the first 3 factors: Coordination, commitment, and trust. The model describes coordination as the formation of boundaries for the collaborating companies. This includes for example the tasks assignment for each party. In the context of industry 4.0, research has shown that new supply chain trends allow for improved coordination along the entire value chain. (Stock, Seliger, 2016) A prerequisite for this is commitment which is the attempt to continuously work towards common goals without the occurrence of opportunistic behaviour. To reach these goals, trust should be present between the partners. Companies should be able to belief that the involving firms are reliable and hold their word. Ik-Whan G. Kwon and Taewon Shu proved the positive impact of commitment and trust on business relationships already in 2005.

Beside those factors, Mohr and Spekman also researched communication between companies, which is an important predictor of success in business relationships. This category

consists of communication quality, information sharing, and participation. Communication quality is important for the transmission of information. Useful information possesses the attributes of timeliness, reliability, accuracy, and adequacy. Especially in Industry 4.0, companies must be able to make sense of the data they are generating. (McAfee, Brynjolfsson, 2012) Of course, the willingness for information sharing should be present in the first place. Zhenxin Yu, Hong Yan, and T.C. Edwin Chan (2001) highlight the importance of information sharing to reduce the bullwhip effect, and to improve the performance of the entire supply chain. Nonetheless, to get the most value out of the information all parties need to actively participate in planning and goal setting. This might for example effect production planning along the value chain. (Lee, Bagheri, Kao, 2014)

To enhance the probability of partnership success even more, companies must implement conflict resolution mechanisms, like for example joint problem solving. Through this, mutually satisfactory solution can be found to benefit all involving companies. What should be avoided in conflict resolution is the smoothing over problem, so the deliberate act to ignore any major issues. Furthermore, other severe conflict resolution techniques like domination or confrontation should also generally be avoided. (Mohr, Spekman, 1994)

While all these factors certainly play a role in business networks, industry 4.0 demands more from companies than to just improve relationship building to outside partners. To get the full picture of how industry 4.0 changes business networks, a look needs to be taken into the technology this revolution brought with it. Even though its stays highly important for companies to work on an external relationship level, the internal changes that enable changes in these relationships are equally important. Almada-Lobo (2015) recognizes this, and prompts firms to adjust their technology to the new needs that are created through industrial changes.

2.2 Technology in Industry 4.0

To better understand the technology in industry 4.0 and the changes that are required within companies to realize a successful implementation, it becomes useful to split up the technical side of industry 4.0 into its single components. Lee, Bagheri, and Kao (2014) recognize the importance of cyber-physical systems in this context, and illustrate the architecture necessary for their implementation by describing 3 essential parts of industry 4.0 technology:

- Components
- Production Systems
- Machines

2.2.1 Components

Components in Industry 4.0 consist of sensors, that act not only as a data source, but give also a way of networking that was not possible in the past. These sensors facilitate information exchange and communication. Wollschlaeger, Sauter, and Jasperneite (2017) explain that there is a trend towards a distributed organization of production and recognize the importance of Wireless Sensor Networks (WNS) for this sake. While the sensor technology was mainly responsible for fault detection in the past, Industry 4.0 elevates its importance to degradation monitoring and remaining useful life prediction, while at the same time gaining the ability to self-predict, and to be self-aware. (Lee, Bagheri, Kao, 2014) Those attributes make this technology to one of the enablers of distributed production.

Aside from production, sensors in cyber-physical systems have plentiful uses that can bring value for organizations not only in isolation, but in cooperation with other companies. One such example is the use of sensors in the Internet of Things (IoT). IoT technology enables supply chains to fuse the data from the digital and physical world. This leads to increased information transparency, leading to improved collaboration, as well as the need to analyse and manage all this data. The forms of communication IoT can enable are machine-to-machine, human-to-human, and human-machine communication. (Hermann, Pentek, Otto, 2016) Aside from this, other examples are the integration of RFID technology into WSN networks (Zhang, Wang, 2006) or predictive maintenance that becomes enabled using sensors. (Wang, 2016)

2.2.2 Machines

Machines in Industry 4.0 have controller as a data source that help in terms of health monitoring and diagnostics of the physical parts in the operations. While they used condition-based monitoring in the past, Industry 4.0 enables machines to predict its condition. (Lee, Bagheri, Kao, 2014). The connectivity that is created through the components in cyber-physical systems allow companies to get more information about their machines that they can use to implement optimizations. (Monostori, 2014) These optimizations depend on quality and efficiency requirements and are complemented by self-optimizable algorithms that respond to the parameters fed into the system. (Lee, Ardakani, Yang, Bagheri, 2015)

2.2.3 Production Systems

Through the interplay of components and machines, the production systems they are embedded in can benefit from leaner operations, productivity increases, and less errors in production. (Lee, Bagheri, Kao, 2014) Self organization of operations becomes possible, with intelligent machines communicating with each other. Through data and algorithms, machines can prevent deadlocks by themselves with minimal human intervention. (Wang, Wan, Zhang, Zhang, 2016)

Furthermore, the use of flexible manufacturing systems(FMS), as well as reconfigurable machining systems(RMS) within operations leads to a more flexible and adjustable manufacturing process. The FMS has loosely defined production requirements, allowing to produce a wide variety of capabilities. Unfortunately, this often leads to excess capabilities, leaving the customers to pay for unwanted functions and features. To solve this, companies introduced the RMS. An RMS consists of modular machine parts that can be changed quickly and at a low cost. This leads to the ability to produce a wide variety of capabilities, while at the same time being able to remove machine parts that produce unwanted capabilities. (Xing, Eganza, Bright, Potgieter, 2006)

While the use of those production systems can lead to internal optimizations and cost savings, big opportunities also emerge for the cooperation with outside companies. The technology that was analysed acts as an enabler in this regard and can embedded into the supply chains of companies to improve the total value generated by the collaborating companies.

2.3 Supply Chains in Industry 4.0

New developments in Industry 4.0 require a change in how manufacturing firms operate their supply chain. The increased data generation, from the technologies discussed in the last section, lead to the possibility of improved collaboration between firms. New supply chain trends increasingly emerged in the last couple of years due to these developments. These changes consist of:

1. Individualized production
2. Horizontal integration of supply chains
3. End-to-end digital Integration (Brettel, Friederichsen, Keller, Rosenberg, 2014)

Research has shown that the improved collaboration of these trends leads to increased productivity. Nonetheless, to achieve the desired benefits, firms must properly communicate, coordinate, and cooperate. Examples for this are information sharing, resource pooling, cross-functional activities, as well as sense-making, goal-congruence, and empowerment. (Schuh, Potente, Varandani, Hausberg, Fränken, 2014)

2.3.1 Individualized Production

The degree of customization within the supply chain is a direct indicator for the progress a company has made in terms of Industry 4.0. Next to the individualization of products, other factors for assessing Industry 4.0 maturity are strategy, leadership, customers, operations, culture, people, governance, and technology. This paper specifically focuses on strategy, operations, products, people, and technology. Individualized production specifically belongs to the category operation and products. (Schuhmacher, Erol, Sihn, 2016)

To be able to realize effective mass customization, companies have to solve the challenge of flexibility and automation. Supply chains must be able to respond quickly to changes in customer demand and requirements. 3 techniques that help in achieving this outcome are:

1. Smart product design
2. Hybrid prototyping
3. Smart production control (Zawadzki, Żywicki, 2016)

The reason many companies adopt a differentiation strategy is the increased competition on factors like production costs, product quality, and innovation. A flexible supply chain helps to keep the costs of mass manufacturing low and to fulfil specific customer demands. (Brettel, Friederichsen, Keller, Rosenberg, 2014)

The goal of smart product design is to get the design right the first time. This becomes possible through KBE-based designs. These designs allow for a reusable project structure. Additionally, it helps in completing all the standardized task, that can take up to 80% of the time during a design process. These tasks include identification of knowledge sources, acquisition of knowledge, representation of knowledge, analysis of identified knowledge, the creation of bases and repositories of knowledge, and the searching accessing and sharing of knowledge. The reduction of the time spent on these activities can significantly contribute to costs savings in this area. (Zawadzki, Żywicki, 2016)

The second element, leading to improved individualization of the supply chain, is hybrid prototyping. Hybrid prototyping helps in fulfilling the customers' demands in the products design process. A digital prototype is not always enough to meet these expectations and companies must build physical prototypes. The downside of these physical prototypes is the costly production and the time it consumes. Hybrid prototyping introduces the use of Virtual Reality (VR) technology to combine the two approaches. Through this, firms gain the advantages of a physical prototype, while keeping the costs down. (Zawadzki, Żywicki, 2016)

Research has shown that the maturity of VR technology is high and that it can also be used for other application during the production process. Aside from design and prototyping, it can also be used in operations management, leading to better planning, simulation, and training. Additionally, it can be of use directly in the manufacturing process. VR can help in machining, assembly and in the inspection of products, leading to easier maintenance. (Choi, Jung, Noh, 2015)

Aside from smart design and hybrid prototyping, smart production control can be used to achieve a higher individualization of products. (Zawadzki, Żywicki, 2016)

To be able to reach this goal, production needs to be able to make fast responses to changes in customer demand. The most effective material flow needs to be selected to ensure that no time is wasted when machine parts in RMS are changed for example. To ensure this, intelligent systems must be able to make decisions based on data that deliver information on the interactions during the production flow. This information is gathered by technologies coming from the Internet of Things(IoT), namely sensors. (Zawadzki, Żywicki, 2016)

Complementary to IoT for the individualization of the supply chain are cloud computing and the modularity of products. Cloud computing is usually offered as a service in form of Infrastructure-as-a-Service(IaaS), Platform-as-a-Service(PaaS), or Software-as-a-Service(SaaS). IaaS provides the necessary hardware a company may need for processing, PaaS consists of modular software, program languages, and hardware, and SaaS can provide computational hardware. Aside from this, the modularity of a product can help a company to keep the costs of production and R&D low. Old parts, or modules, can be used in new products to save costs and time. (Mehrsai, Karimi, Thoben, 2013)

2.3.2 Horizontal Integration

Another way industry 4.0 impacts supply chains is through the horizontal integration of companies within a collaborative network. This is desirable due to the benefits it can provide. Research has shown that the linking and integrations of supply chains can lead to increased innovation of firms. Resources and knowledge are shared, and a solution where everyone benefits is the result of such a collaboration. Nonetheless, this form of connectivity requires management and good communication between the parties. (Soosay, Hyland, Ferrer, 2008)

To get the most out of a collaboration, managers should decide together on:

1. Performance measures
2. Integrated policies
3. Information sharing
4. Incentive alignment

Performance measures are used to provide information about the outcome of the collaboration, helping in assessing if it was a success. Companies should have their focus on the end customer in this regard. Integrated policies require the change from outdated policies to new ones that enable the cooperation between the collaborating companies. This can be done on a strategic level, as well as on a tactical level, like deciding on procedural guidelines for example. Information sharing is important for the visibility of important function within, as well as between companies. Commonly shared data include the availability of resources, the status of performance, the status of processes, and the status of contract. Finally, incentive alignment should ensure that the collaborating companies have the same goals in mind, making it a priority that mutual goals lead to an overall better performance of the whole supply chain. Overall, these four measures should target the minimization of conflict while collaborating, while also ensuring a smooth transition into new processes that are created through the collaboration. (Simatuoang, Sridharan, 2002)

Now, the role of visibility of supply chain has already been proven to be vital for the collaboration between firms within a network. Nonetheless, the question remains what role this visibility plays and for what purposes the members of the value chain can use the shared information. Hsiao-Lan Wei and Eric

T.G. Wang have identified 4 different constructs of supply chain visibility to help us better understand why information should be shared within a business network. These 4 constructs are:

1. Visibility for sensing
2. Visibility for learning
3. Visibility for coordinating
4. Visibility for integrating

Visibility for sensing describes the extent to which a company can quickly react to changes in the external environment through real time data that is shared through the business network. Visibility for learning represents the extent to which a company can learn from the shared data. Visibility for coordinating includes the benefits a company can reap in terms of supply chain decision making when information is shared. This may include decisions for optimal product flow for example. Finally, visibility for integrating is the creation of a collective supply chain identity that is the result of the shared information between firms. (Wei, Wang, 2010)

While the uses of information sharing can be plentiful, there are also certain conditions for the collaboration between firms within the network. Research shows that collaboration requires strong engagement between firms, as well as extensive information exchange and higher levels of coordination. This too, confirms again the importance of information sharing between the collaborating parties. (Vereecke, Muylle, 2010) Other research has shown the importance of connectivity and willingness. (Fawett, Osterhaus, Magnan, Brau, 2007)

Even though the relationship aspects, that need to be considered when collaborating with other firms, are important, the technical implementation of an integrated supply chain should not be ignored. In this context, companies see increasingly the need for the introduction of multi-agent systems. A multi-agent system is a system in the supply chain, consisting of communicating agents. An agent is ‘‘An autonomous component that represents physical or logical objects in the system, capable to act to achieve its goals, and being able to interact with other agents, when it does not possess knowledge and skills to reach alone its objectives’’. Multiple agents within the supply chain exchange information and build a hierarchy to solve the tasks that were assigned to them. This helps to implement modularity within the production, as well as providing the decentralized nature a distributed manufacturing system needs. (Leitão, 2009)

2.3.3 End-to-End Integration

End-to-end integration is the third big supply chain trend analyzed in this paper. It is an attempt to integrate engineering along the entire value chain in the business network. This is done via virtualization of the supply chains, as well as through methods of communication between the firms. (Brettel, Friederichsen, Keller, Rosenberg, 2014) The need for such a virtualization can be comprehended when looking at the work of Martin Christopher and Denis R. Towill. They recognized that long end-to-end supply chains will not be able to respond in a timely manner to changes in customer demand. This could ultimately negatively affect the ability of a supply chain to exploit marketplace demand. This creates the need for a more agile and customizable supply chain which can be achieved through a virtualization of said supply chain. (Martin, Towill, 2000)

A major hurdle companies need to handle when working on this virtualization is the “Bullwhip Effect”. This phenomenon describes the distortion of information as it wanders upstream along the value chain. (Lee, Padmanabhan, Whang, 2015)

This “Bullwhip Effect” leads to a need for a synchronized supply chain. Due to outsourcing, every company takes on only a small part of the final product. The automotive industry is a good example for this. This makes the business network very large and ultimately more difficult to ensure a smooth information flow. Collaboration between the firms is needed to ensure that accurate information is passed down the value chain. An example of a company that solved the “Bullwhip Effect” is Philipps Electronics. They worked out 4 key requirements, namely

1. Intensive collaboration between partners is needed
2. Key supply chain information needs to be shared
3. Synchronization of decisions on capacities and material flow under high volatility
4. Very quick supply chain decisions

These requirements finally helped the company to overcome common conflicts in supply chain collaboration and ensure effective data sharing across the value chain. (de Kok, Janssen, Doremalen, Wachem, Clerkx, Peeters, 2005)

2.4 Framework

While the supply chain and the underlying technology were less supportive of collaboration in the past, industry 4.0 reduces the

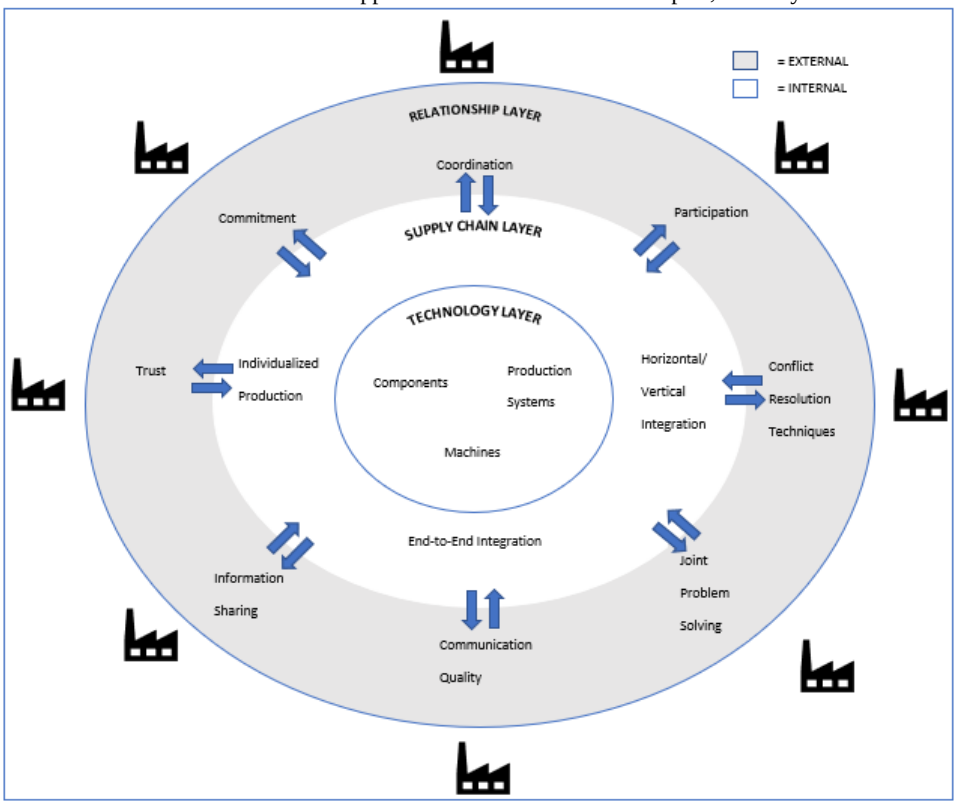

Figure 1

barriers that separated the internal operations from a more collaborative approach that was less likely to occur because of technical restrictions. To get the most value out of industry 4.0, companies must set up their supply chain in cooperation with their network. Through this, value can be unlocked, and new possibilities can be opened that were not feasible until recently. Relationship building is not something exclusively external anymore, it is instead involved across the entire value chain that becomes increasingly integrated. The framework and its visual representation can be found under figure 1.

2.5 Research Question

This study tries to fill the gap between research into business networks and research into industry 4.0. While there is plenty of work done in both fields already, the connection between relationship aspects within a network and internal organizational changes within industry 4.0 are only ever mentioned as a side note. While the theoretical model proposed in this literature review might help in bridging this gap, it still houses one severe limitation, Mohr and Spekmans' model of partnership success that was integrated into this framework. Because of its age, its implications on businesses might be different than what they would be in 1994. Since the work of Mohr and Spekman was written in a time before industry 4.0, so in a different context, the relevance of their factors become questionable. The goal of this research is to reevaluate the importance of those factors, to put them into the context of industry 4.0, and to check if they still hold relevance in today's industrial environment. Furthermore, this paper wants to check for new factors that might play a role nowadays but were not of great importance in 1994. Finally, the implications, so the chances and challenges for industrial relationships that can be concluded from the model will also be investigated. For this sake, the research question will be:

How do the supply chain changes in Industry 4.0 influence the relationship building of companies within a business network and why do those changes occur?

3. METHODS

The purpose this study serves is to uncover the changes that become important for relationship building in business networks due to supply chain changes in industry 4.0. These changes refer to the model proposed by Mohr and Spekman to figure out relevant factors that lead to partnership success. (1994) The changes under industry 4.0 refer to the supply chain trends analyzed by Brettel, Friederichsen, Keller, and Rosenberg. (2014) These trends include individualized production, horizontal integration, and end-to-end integration. The goal is therefore to not only explain the changes in relationship building, but to also check how different supply chain configurations differ in those changes.

3.1 Data collection

This paper is conducting an exploratory case study of several firms operating with industry 4.0 technology. The use of an exploratory case study indicates the heavy reliance on contributions and theoretical frameworks from other researchers. (Ogawa, Malen, 1991) This is also the case in this paper. To figure out the changes of the relationships within a business network, this research was making use the proposed framework in the literature review section.

Because of the lack of theoretical contributions combining areas of industry 4.0 with research about business networks, an inductive approach was being used. The reasoning is context-dependent in this regard and was implemented by using theoretical contextualization. Ketokivi and Mantere (2010) recommend using this type of inductive reasoning when underlying theory plays an important part in developing claims that can explain the research question. Since this research paper puts a heavy emphasis on the theory, that is represented by the proposed framework at the end of the theory section, and since this research is of exploratory nature, an inductive approach was deemed fitting for getting answers to this research question.

To extract the desired information, the interview method was being used. This means that interviewees can ask questions if something is not clear and that a dialogue can begin to emerge. Since it is the purpose of this study to examine the lived experience of firms and their experience with Industry 4.0, this methodology is fitting this goal. (Seidman, 2006)

The interviews were semi structured because of the nature of the studied research topic. This is because the goal of the interview is to involve the interviewee into a dialogue about his lived experience. Additionally, while the factors describing the relationship aspect of the business network are transfixed, the aim of this paper was also to figure out challenges and chances for these business relationships. Because these relationship situations can be very individual depending on the firm, an open dialogue may be suiting this purpose the best. (Barriball, While, 1994)

The interview question can be found in Appendix A. They were chosen based on the theory that was discussed in the "Theory"-section. To assess the changes that Industry 4.0 causes in business networks, this study is using the model proposed by Mohr and Spekman, describing important factors that lead to partnership success. (Mohr, Spekman, 1994) Based on this model, a comparison is being made between the relevant factors before Industry 4.0 influenced the supply chain and afterwards. This leads to further questions about the chances and challenges that Industry 4.0 poses for these relationships.

3.2 Research Setting & Subjects

Target of the research were companies in Germany and the Netherlands that have extensive knowledge about the topic Industry 4.0, as well as leaders in this field. The focus in this regard was laid on manufacturing firms and Small and Medium Sized companies. (SME's) Furthermore, companies in the automation industry were interviewed, too. Due to their intense contact to manufacturing firm, implementing industry 4.0-solutions, they had an interesting perspective on the internal workings of such firms and extensive experience in this regard. Research subjects were managers with knowledge about the strategic decisions made in terms of Industry 4.0, as well as supply chain and business network changes.

The interviewed firms were being chosen by using the webpage "Plattform Industrie 4.0" that was created by the German ministry for economy and energy. The webpage highlights companies that are practically living industry 4.0 in Germany and presents various projects of companies from all over the country. Companies were chosen by filtering out the ones with mentions of business networks within their industry 4.0 projects.

In total, 9 firms were being interviewed, and the data was analyzed together with 2 written answers that were given. (n = 11) All these firms had extensive knowledge in their fields, being ahead of competition in regard of industry 4.0. Additionally, the interviewed companies were doing business in a variety of fields, including the automotive industry, electrotechnical engineering industry, automation industry, machine engineering industry, and the logistics industry. The interviewees were also working in different job positions. Their job areas included marketing, IT, Innovation, Strategy, Communication, and some chief executives were also interviewed. The geographical locations of the chosen firms had a focal point in the south of Germany, since the automation has progressed the furthest in that place For the

sake making more accurate and reliable conclusions, a multiple case study approach was being used. To get informed and evidence-based findings, such an approach is necessary. The use of this methodology becomes justified because this research focuses on the 'why' and 'how' questions, the behaviour of the research subjects cannot be manipulated, and because contextual factors are important for the phenomenon studied in this paper. (Baxter, Jack, 2008) These contextual factors refer to the influence of business networks on the adoption of Industry 4.0. Because of the small sample size in this work, cases could not be selected randomly. For this paper, the influential method for case selection, proposed by Seawright and Gerring (2008), was used. Cases with influential configurations of the independent variable were the focus in this case.

In terms of validity, this paper does not aim to prove statistical validity but more external validity, since a generalization of the findings should be the conclusion. To reach such a conclusion, only companies with much experience in the field of Industry 4.0 were being interviewed. Because of the experience of these firms, the findings should be applicable to other firms which are not as far in terms of Industry 4.0 adoption yet. (Scandara, Williams, 2000)

Even though the interview method for conducting this research is obtrusive, the questions are designed to be open, so that the interviewee can tell about what concerns his company the most. The chosen managers are interviewed in a one-on-one fashion, with the goal to make the experience pleasurable, creating an open environment where the interviewees can speak freely about the topics on hand.

3.3 Data Measurement

For the supply chain configurations in industry 4.0, the trends described by Brettel, Friederichsen, Keller, and Rosenberg will be used. (Individualized production, horizontal integration, end-to-end integration) To measure them, the interviewed companies were assigned to each of the trends based on their individual solution. The assignment of each company can be found in table 1.

Interview → Supply chain ↓	1	2	3	4	5	6	7	8	9	10	11
Individualized Production	X					X					
Horizontal Integration				X			X				X
End-to-End Integration	X	X	X	X	X	X	X	X	X	X	X

Table 1

The factors described in Mohr's and Spekman's model give the possibility to compare them with the results that are found in the interviews. Gioia, Corley, and Hamilton created the Gioia methodology for this sake. According to them, the content of interviews should be first sorted into 1st order concepts. Afterwards, these concepts should lead to 2nd order themes that should finally lay the groundwork for creating dimensions that can answer the research question. Based on these dimensions, conclusions can be made about whether their supply chain configuration made any difference in their mode of relationship building.

3.4 Data Analysis

The transcripts, that were created for the sake of analyzing the interviews, were subject of a qualitative content analysis, as proposed by Mayring in 2009. To do this, a category system was being used, the categories being the factors researched by Mohr and Spekman. The content of the transcript was being summarized, and sorted into the right categories. Afterwards, the Gioia methodology helped in creating dimensions for the summaries in each category that would help in answering the research question. The goal was to create a theory-guided analysis, so to iterate between theory and data to get results that are associated with the findings from the literature review. (Eisenhardt, 1981) This is done by comparing the dimensions in each category with the original definitions of the categories proposed by Mohr and Spekman, and by comparing differences in answers based on the supply chain configuration of the firms. The rules for the coding, as to when data had to be put into which category, are as follows:

- Direct mention of the category leads to the assignment to said category
- Information chunks from the transcripts can be placed into multiple categories
- If information has direct or direct implications on the category, it is assigned to said category

Gläser and Laudel (1999; 2010) criticize Mayrings work and propose an improved version of the category system. Via a theory-based category system, the categories are not as rigid anymore and can be changed, modified, or some can even be added based on the findings. This is also used in this paper and excludes a common source of error in Mayrings model, which is the lack of differentiation between categories. (Krippendorf, 2004) When two categories are too close to each other in the findings, the combing information chunk from the transcripts associated with both can be taken and created into a new category. Finally, the results were being compared to the independent variable, the supply chain category of the firm, to check if there was any significant change because of a different application of the industry 4.0 technology.

4. RESULTS

4.1.1 Coordination

When it comes to coordination, the interviewed companies most commonly talked about 3 dimensions that would be most important for coordination in an industry 4.0 world:

- Connectivity
- Transparency
- Decentralization

Connectivity was mentioned by 5 interviewees, and referred mainly to internal connection between machines, systems, and sensors, but also to connectivity between companies within a supply chain, so end-to-end integration. The connectivity helps those companies to get information about their processes, like through-put time, and the statuses of machines. The latter helps for predictive maintenance, which even entails that machines have the possibility to act without human intervention. Another implication of the increased connectivity is the increased knowledge about the supply chain, including data of stock levels, and location of shipped products. This way, important tasks like procurement can be outsourced to the supplier for example.

The second factor mentioned by the interviewees was transparency, which again includes both internal and external implications and was mentioned by all firms that were interviewed. Internally, companies reported internal optimizations through the increase of information about products and processes. Benefits of transparency were for example

decreased stock levels, improved planning, and easier integration of all processes. Interesting enough, this did not only apply to companies which operated on a vertical level, but also for companies with horizontal partners.

The third factor mentioned in accordance to coordination was decentralization. Decentralization was talked about by 5 companies. Most often, decentralization was utilized to handle complexity, putting more decision making to the shop floor level. Especially companies with many production lines were highlighting the importance of decentralization. In some cases, their technology would help as a crutch in decision making, and in others, automatisms would even completely replace the need for decision making by humans. Another way decentralization came into play was over the cloud. By outsourcing processing to the cloud, companies could save costs by not having to handle servers by themselves.

In terms of supply chain configuration, companies with individualized production and with only end-to-end integration were mentioning all the dimensions defined during the coding process. Contrary to that, the companies that implemented horizontal integration were only mentioning connectivity as an important dimension, and not transparency or decentralization. A reason for this might be the reluctance of many companies to become transparent to other firms outside of their supply chain and to lose control via the decentralization.

Furthermore, Mohr and Spekman (1994) highlighted that high coordination would be necessary for production planning and just-in-time processes. The extend to which this was important to the interviewed firms depended largely on the complexity within the organization. Coordination between partners became less important the lower the number of members in the business network. One interviewee for example had only 2 suppliers, leading to a decreased importance of vertical and horizontal integration. Due to the networked nature of many firms in the industry, the majority of the interviewees had enough partners to deem coordination important for them.

Another interesting observation that could be made is that the category coordination had the most mentions during the coding process. A lot of the interviewees had much to tell about this category. This could be explained by the internal optimizations that many companies experienced through the implementation of industry 4.0. Even if they would not think of coordination between companies as important, industry 4.0 would still lead to an improved internal coordination that would be independent of the external network. In this case, coordination would be important for those firms, even though they do not put much focus on external coordination.

Overall, what the interviewees highlighted very often, was the technical challenge that industry 4.0 would impose on them. Nonetheless, the implementation of connected, transparent, and decentralized systems was ultimately important to handle the increased complexity within the firms, and to benefit from optimization through this implementation. It can be concluded that the changes in coordination between firms through industry 4.0 is caused by the higher complexity in today´s industrial world.

4.1.2 Commitment

For commitment in the data collection, the least amount of data could be recorded compared to all other researched factors. This might be due to industry 4.0 being relatively new. The companies which have implemented industry 4.0 did not have the systems long enough to provide any information about commitment with outside partners. This was the case for all companies, except the ones in the automation industry. Those firms did sell industry 4.0 solution long before the term was formed, and the answers for this section mainly came from these interviewees. Overall, 5 companies highlighted the importance for commitment, the main dimensions being:

- Product understanding
- Need for partners during implementation

Since the interviewees in the automation industry had the most experience with implementations of industry 4.0 solutions, the most important thing highlighted by them was the long-term involvement of their clients with them. Implementation could only work with partners, and it does not have a definite end-point, since these systems can be extended and further improved on to better fit the requirements of the implementing firms. The other dimension was product understanding. Through better understanding of the product, improvements can be made and the relationship with customers improved.

When it comes to differences in supply chain configurations, companies with different configurations highlighted the importance of commitment to different partners. The companies that implemented individualized production and horizontal integration highlighted the importance of commitment for product innovation, while the companies using only end-to-end integration were mainly highlighting the importance of commitment during the implementation phase. This may be the case because the companies using only end-to-end integration were mainly concerned with optimizations within their supply chain and not horizontally with other partners that are normally unrelated to the firm. Companies that think more horizontally can access knowledge not only from their supply chain partners but also from outside companies like competitors.

In Mohr and Spekmans' work (1994) they identify commitment as being the extend to which partners invest themselves into the business relationship to let it grow. While this definition did not change, the interviewees highlighted the importance of this commitment only for certain projects like product innovation or industry 4.0 implementation. Commitment was not mentioned in connection with higher integration that was present in a lot of the interviewed firms. This leads to the conclusion that commitment is considered to only be necessary when there are problems and obstacles, so in this case, when a project, like a new product development or system implementation, starts. Once the systems are implemented and running commitment must not be regarded as a goal in itself anymore, since the projects are finished. The need for commitment arises therefore only when challenges arise, which in tun leads to relationship growth.

4.1.3 Trust

Trust played an important role for 10 of the 11 interviewed firms. While industry 4.0 lead to mistrust before and during implementation, fears and worries about the effects could be dissolved soon after. Cause for the fear of employees and managers alike against the implementation arise because of the following points:

- Technology
- Data Security
- Transparency

Fear of the technology was mentioned as important, because of negative thoughts connotated to industry 4.0. This includes the possible job loss because of automation, as well as doubts of the usefulness in their firms. Data security created worries, because of a possible data loss or hacker attack, and finally, transparency plays a role in exposing people, showing the true worth a company is delivering, and providing information that make a company easier to compare. People are afraid because the technology exposes them.

Dimensions that dissolved this mistrust were, according to the interviewed firms:

- Traceability
- Reliability
- Real time information

The benefits of traceability would in the end always become apparent through optimizations in the entire value chain. Especially the firms in the automation industry must work with trust management to win their clients over to their side. This entails implementing a reliable system with less errors in production, and reliable delivery of data. The possibility to access the data in real time is possible because of this, and suppliers and customers alike can benefit from these changes.

Differences because of the supply chain configurations could be found in the companies with horizontal integration. While companies with only end-to-end integration mentioned all dimensions, and the ones with individualized production everything except real time information, there were little mention about the dimensions creating trust from the companies that implemented horizontal integration. Only reliability was mentioned in this context. On the other side, those companies mentioned all the dimensions identified that cause the mistrust in the beginning. The reason for this might be that collaboration within the horizontal network requires cooperation between 2 companies that would normally not cooperate with each other. One of the interviewees mentioned that many companies he was working with would be very far in terms of vertical collaboration but lacking behind in horizontal integration. The nature of those relationships requires more trust and traceability and real time information might therefore have a reduced effect on these firms.

The original definition of Mohr and Spekman highlight this even more. They describe trust as the ability of a firm to rely on the word of their partner. While traceability and real time information increase control within the relationship, they do not necessarily create trust in the underlying relationship. One of the interviewed companies said that trust had to be earned through technical solutions.

In total, the changes caused by the implementation of industry 4.0 solutions leads to opportunities internally, as well as externally. Internally, systems help employees to make better decisions, and externally, partners can have better access to information, leading in many cases to improved collaboration.

4.1.4 Communication Quality

Since all the 3-supply chain configuration researched in this paper (Individualized production, horizontal integration, end-to-end integration) lead to an increase in information flow, communication quality must be improved. In the interviews, all the firms reported the need for information of high quality. The dimensions that could be retrieved from the transcript entail that data has to be in real time, fast, simple, comparable, secure, and precise. This was implemented through a variety of solutions in the interviewed companies. To visualize the data and make it more accessible, some firms implemented cockpits, where all the parameters could be displayed. Furthermore, companies highlighted the need for the data to go to the right place, and to the right people, and for the critical data to be separated from the non-critical. Not all data is ever used, so the information that do need attention, need to be gathered in one place, where it is also secure. Additionally, companies gain the ability to display the data in real time through sensors. This helps to make the whole operations faster and smoother.

When it comes to supply chain configurations no differences could be observed between the companies. All the interviewed companies are generating a big amount of data and the need for high quality information is present for all of them. In the context of industry 4.0, this means that having quality information is not a competitive advantage anymore but a necessary step to not fall behind the competitors. When looking at the motivation theory of Herzberg, this kind of data can therefore be considered to be a hygiene factor. (1959)

According to Mohr and Spekman, information between partners needs to be accurate, timely, relevant, and credible. As could be seen through the examples shown above, information in this day and age needs to be much more than that. It also must be in real time, simpler, due to the increased complexity, accessible to the right people, secure and comparable.

4.1.5 Information Sharing

For information sharing, data could be collected from 9 of the 11 companies. The dimensions of most concern for the interviewed firms to facilitate information exchange were:

- Data security
- Transparency
- Separation of critical and non-critical data

Data security is important on different levels. For one, it needs to be established where data can be saved and how rules for access are decided. Internally, data security needs to be set up, so that the companies can benefit from it externally. Effective data security facilitates information exchange between companies and can help in boosting collaboration. The second factor that can contribute to increased collaboration is transparency. One example is data traceability from operations to end customer. This enables fast error detection and helps to correct mistakes, preventing them from occurring a second time. Additionally, transparency leads to higher comparability, so that customers can easily see what qualities and values a company creates. Furthermore, a separation between critical and uncritical data was deemed necessary by the firms. This makes life easier for the receivers of the information and helps collaborating firms to be more in line with each other.

The companies that only implemented end-to-end integration mentioned all these dimensions, while companies with the other configurations only mentioned transparency and data security once. This indicates that data sharing is more often used with vertical partners. The reason for this might be the increased need for coordination. The data gathered for the coordination category entails exactly that. Most companies with end-to-end integration in this category stressed the importance of coordination because of higher complexity. This complexity might lead to more information sharing between those companies. Like mentioned in the trust section, companies with the horizontal integration might lack the trust to share critical information with each other and individualized production might not even need much information sharing. The collaboration in this configuration does not consist of much integration, at least not as much as in the other ones, and therefore companies that focus on this might also not value information sharing as much as companies who integrate more intensely.

Overall, there is still much uncertainty going around about what data is allowed to be shared, and companies have still much room for expanded information exchange. Nonetheless, through the drastic increase in information, sharing of data becomes vital if two companies want to collaborate.

4.1.6 Participation

Participation was from the viewpoint of the interviewed companies important for several actors within and outside of the companies:

- Employees

- Customers/ Suppliers
- Horizontal Network

In total, data about participation could be collected from all companies. The first group of people companies must give the opportunity to participate more, were the employees. Changes in processes within and between companies require education and training for the employee. Especially automation is responsible for making many jobs unnecessary, and according to the interviewees, employees should be supported in this phase of change with possibilities to get a role in the company that suites their skills the best.

When looked at from a vertical perspective, customers and suppliers should also be integrated in changes due to industry 4.0. Changes like stock surveillance or individualized production were already mentioned in this paper. With the whole value chain involved, companies can benefit from each other's information.

Horizontal networks proved important for the companies, too. Not only did industry 4.0 facilitate collaboration with partners for system implementation, companies also reported working with academics, tech providers, start-ups, and OEM partners to provide innovation and product improvement.

Slight differences because of the supply chain configurations could also be observed. Companies with individualized production mentioned employees and customers as important dimensions, while leaving out horizontal integration completely. This indicates a preference towards working only within their own supply chain. Companies with the horizontal integration configuration mentioned all the factors, and companies with only end-to-end integration mentioned all of them, too. This is surprising, since those companies did not implement horizontal integration yet, while still recognizing the importance of the horizontal network. A reason for this might be that they consider collaboration with this network to be the desirable in the future and an extension to their already existing end-to-end integration. In fact, many of these companies even mentioned the importance of collaboration within horizontal networks for the future.

The fact that companies with the horizontal integration configuration mentioned all the factors is also supported by the theory discussed by Mohr and Spekman. They mention that when actions of companies influence the way their partner can effectively compete, the need for participation increases. Since horizontal integration includes cooperation with competitors, this was particularly important for those firms.

4.1.7 Joint Problem Solving

While there is collaboration possible with many new partners through industry 4.0, there is also a variety of dimensions this collaboration can have, in which joint problem solving plays a role:

- Joint Product Development
- Joint Product Improvement
- Joint Process Improvement

Not only are companies able to, as already mentioned before, work on new product development together, they can also collaborate on product or process improvement. Product improvement was mainly done with the customers using individualized production or the use of virtual reality. One company for example used virtual reality to help customers in visualizing preexisting solutions, and to plan out the desired product together with them. Solutions like this lead not necessarily to the development of new products, but to the improvement of already existing ones. The same could be applied to processes, even though the main target for process improvement were in most cases internal optimizations, while only having indirect effects on outside partners.

The differences in supply chain configurations show that companies with individualized production focus on product improvement. This also reflects the nature of the business collaborations within this type of supply chain. One interviewed company for example worked with their customers together via VR technology to customize the end product according to the customer`s wishes. The companies with horizontal integration on the other hand focused on joint process improvement and new product or innovation development. Because the cooperation with companies outside of their own vertical supply chain, the development of new product innovation makes gives creative and new input. Companies that solely concentrated on end-to-end integration focused on all three types of joint problem solving.

4.1.8 Conflict Resolution Techniques

For the interviewed companies, 3 sources of errors were mentioned that would most commonly lead to conflict:

- Production Errors
- Implementation Errors
- Human Resource Errors

Production errors most commonly entailed that faulty products were produced, and that they would be sent back for reclamation, or scraped during the production process. The solutions companies would use to prevent such mistakes are for one a zero-fault production. Many of the companies in the automation industries claimed this to be their goal. Through their systems, companies would often benefit from increased transparency and traceability, leading to a fast detection of errors. Additionally, data usage helps to take preventive measures in maintenance.

The second source of errors companies talked about were implementation errors. These errors mainly referred to mistakes done during the implementation stage of the industry 4.0 system. One such mistake for example is the lack of process optimization before the implementation. This would lead to errors, described best by the saying: "Garbage in, garbage out." To prevent such errors, communication proved to be vital, not only with the implementation partner, but also with the employees. Acceptance from within the company was required. Additionally, companies must decide how much their implementation partner should be involved during this phase. The planning, for example through a virtual implementation, was very important in this regard.

Human Resource errors are created when employees are not at the place where they can use their skills the most efficiently. Due to automation, many jobs are replaced, and employees need to be working elsewhere. To combat issues because of this, companies can offer training for new positions, or introduce automatisms that help companies in their tasks, even if they do not have all the knowledge necessary to perform the job. One company for example used the technology in a way to help employees getting material from the right boxes by highlighting them on a display.

Differences due to the supply chain configurations could not be observed. Conflict resolution techniques proved to be important for all supply chain configurations. This indicates that collaboration within industry 4.0 still produces errors. While the technical solutions aim at reducing those errors, there are still areas where human errors occur. This leads to the conclusion that technology can only fix a number of errors. Relationships between people on the other hand need to be improved by communication or proper planning for example, so very non-technical solutions. The focus in this regard was clearly placed on prevention, with solutions aiming at fixing potential mistakes before they even happen.

5. CONCLUSIONS & RECOMMENDATIONS

5.1.1 Contribution to Theory

Based on the comparison between the supply chain configuration of the interviewed companies and the findings from the interviews, several conclusions can be made that reflect these results. These conclusions can be formulated in claims as proposals for further research. Because of the exploratory nature of this paper, points for further research are created through those proposals. They are as follows:

1. **Coordination: The higher the complexity within a firm, the higher the need for internal and external coordination becomes.**
2. **Commitment: The need for commitment arises when challenges arise, for example through the development of a new project or a system implementation**
3. **Trust: Industry 4.0 technology leads to mistrust, that can be dissolved by using systems that produce reliable, traceable, and real time data.**
4. **Communication quality: High quality information is a hygiene factor in industry 4.0, and not a competitive advantage anymore.**
5. **Information sharing: The closer companies are to each other, the higher the information exchange. This leads to increased data sharing between companies within a supply chain and reduced sharing between horizontally collaborating ones.**
6. **Participation: The participation within a value chain depends on who is integrated within this value chain.**
7. **Joint problem solving: Vertically collaborating companies focus more on joint product and process improvement, and horizontally collaborating ones more on product and innovation development.**
8. **Conflict resolution techniques: Errors are made because of technical faults, but also because of human mistakes. Technology from industry 4.0 needs to be used together with management techniques to prevent them.**

As discussed in the results section, this paper was able to explain how industry 4.0 changed relationship building between companies based on different supply chain configurations. Possible reasons for why these changes occur were also given, and propositions were created to encourage future research into that area. Nonetheless, what is the effect of these results on the framework proposed in the theory section?

For one, as a control variable, the opinion of the managers about industry 4.0 were recorded and compared to the results. This was done to see if the changes in relationship building could also be attributed to the attitude of the companies about the topic. Since all the manager's opinions were positive, it can be assumed that their companies' leader positions in this field are related to that. To prove this quantitatively, further research must be done in this field.

While we now know that technology changes how relationships are handled, and not the supply chain, we must also have a look at possible changes in the relationship building factors themselves. As Gläser and Laudel (1999; 2010) propose, Mayring's model may be improved by allowing the possibility to modify categories or add new ones to the model. This paper proposes the inclusion of transparency as a factor in relationship building. While it was often mentioned during the interviews, it was often not described as a consequence of relationships, but as a descriptor. Transparency can then be explained as a describing factor of the relationship between two companies. It is therefore not only a result of industry 4.0 changes but can also be seen as part of the definition and nature of how business relationships work today. New technology enables transparency during this paradigm shift, and, on top of that, transparency also becomes a precondition in business relationships for a good competitive position.

5.1.2 Contribution to Practice

Now that the contribution to the theory is clarified, the practical managerial ones must still follow. Because the importance of chances and challenges that are created through this change in relationship building under industry 4.0, a question about this was also included in the interview form. The practical and managerial implications are as follows:

1.) The model that was created shows that there are much lower barriers nowadays between internal processes, and external relationship building. This means that setting up the internal processes together with partner companies, like suppliers or customers, can bring value to the whole value chain.

2.) Technology does not matter most. While it acts as an enabler of all the benefits created by industry 4.0, these changes bring an even bigger advantage when outside partners from the value chain are involved.

3.) Thinking about industrial relationships must change. Not only allows the new technology more integration between already existing partners within a value chain, it also helps in letting businesses collaborate from fields that were completely unrelated before. Horizontal integration can therefore become realized more easily.

4.) Internal requirements should not be underestimated. Processes need to be adjusted before industry 4.0 systems are implemented. Additionally, employees need to be prepared for changes and communication with them becomes significantly important at this point.

5.) Being open to transparency is important. While many companies are afraid of revealing too much data, other companies profit exactly because they do. Finding partners who are open to information exchange can therefore become a crucial competitive advantage in the digitized world.

6.) There is no complete solution in industry 4.0. Industry 4.0 is a very broad term that includes a wide range of solutions that need to be chosen based on the specific needs of every company. Digitization for the sake of digitization does not necessarily lead to improved performance.

6. ACKNOWLEDGMENTS

Some special thanks goes to my supervisor, who supported me and gave me feedback during the writing of this work. Additionally, this work would have not been possible, without the gracious cooperation of the interviewed firms.

7. REFERENCES

[1] Almada-Lobo, F. (2015). The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES). Retrieved from https://journals.fe.up.pt/index.php/IJMAI/article/view/249

[2] Batten, L. M., & Savage, R. (n.d.). Information Sharing in Supply Chain Systems. Global Integrated Supply Chain Systems. doi:10.4018/9781591406112.ch005

[3] Barriball, K. L., & While, A. (1994). Collecting data using a semi-structured interview: A discussion paper. Journal of Advanced Nursing,19(2), 328-335. doi:10.1111/j.1365-2648.1994.tb01088.x

[4] Baxter, P., & Jack, S. (2008, December 1). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. The Qualitative Report.

[5] Brettel M., Friederichsen N., Keller M., Rosenberg M. (2014). How Virtualization, Decentralization, and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. International Journal of Information and Communication Engineering, 8(1).

[6] Brynjolfsson, A. M. (2014, October 08). Big Data: The Management Revolution. Retrieved from https://hbr.org/2012/10/big-data-the-management-revolution

[7] Choi, S., Jung, K. and Noh, S. (2015). Virtual reality applications in manufacturing industries: Past research, present findings, and future directions. Concurrent Engineering, 23(1), pp.40-63.

[8] de Kok, T., Janssen, F., van Doremalen, J., van Wachem, E., Clerkx, M. and Peeters, W. (2005). Philips Electronics Synchronizes Its Supply Chain to End the Bullwhip Effect. Interfaces, 35(1), pp.37-48.

[9] Eisenhardt, K., & Eisenhardt, K. M. (1989). Building Theories from Case Study Research. Case Studies, 14(4), 532-550. doi:10.4135/9781473915480.n52

[10] Fawett S., Osterhaus P., Magnan G. M., Brau J. C., McCarter M. W. (2007). Information sharing and supply chain performance: the role of connectivity and willingness. Supply Chain Management: An International Journal, 12(5), pp.358-368.

[11] Gawel, JosephE. (1997). Herzberg's theory ofmotivation and maslow's hierarchy of needs. Practical Assessment, Research & Evaluation, 5(11). Available online: http://PAREonline.net/getvn.asp?v=5&n=11.

[12] Gebhardt J., Grimm A., Neugebauer L. M. (2015). Developments 4.0 – Prospects on future requirements and impacts on work and vocational training. Journal of Technical Education, 3(2).

[13] Gerbert P., Lorenz M., Rüßmann M. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. [online] Available at: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx [Accessed 1 May 2018].

[14] Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2012). Seeking Qualitative Rigor in Inductive Research. Organizational Research Methods, 16(1), 15-31. doi:10.1177/1094428112452151

[15] Gläser, J., & Laudel, G. (1999). Theoriegeleitete Textanalyse? Das Potential einer variablenorientierten qualitativen Inhaltsanalyse. Berlin: Wissenschaftszentrum Berlin für Sozialforschung.

[16] Gläser, J., & Laudel, G. (2010). Experteninterviews. Experteninterviews Und Qualitative Inhaltsanalyse, 111-196. doi:10.1007/978-3-531-91538-8_4

[17] Harvard Business Review. (2018). What Successful Digital Transformations Have in Common. [online] Available at: https://hbr.org/2017/12/what-successful-digital-transformations-have-in-common [Accessed 1 May 2018].

[18] Hermann M., Pentek T., Otto B. (2016). Design Principles for Industry 4.0 Scenarios. Hawaii International Conference on Systems Services (HICSS).

[19] Holm, D., Eriksson, K. and Johanson, J. (1996). Business Networks and Cooperation in International Business Relationships. Journal of International Business Studies, 27(5), pp.1033-1053.

[20] Ketokivi, M., & Mantere, S. (2010). Two Strategies For Inductive Reasoning In Organizational Research. Academy of Management Review, 35(2), 315-333. doi:10.5465/amr.2010.48463336

[21] Kiel, D., Müller, J., Arnold, C. and Voigt, K. (2017). Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0. International Journal of Innovation Management, 21(08), p.1740015.

[22] Krippendorff, K. (2004). Measuring the Reliability of Qualitative Text Analysis Data. Quality & Quantity, 38(6), 787-800. doi:10.1007/s11135-004-8107-7

[23] Kwon, I. G., & Suh, T. (2005). Trust, commitment and relationships in supply chain management: A path analysis. Supply Chain Management: An International Journal, 10(1), 26-33. doi:10.1108/13598540510578351

[24] Lee, H., Padmanabhan, V. and Whang, S. (2015). The bullwhip effect in supply chains. IEEE Engineering Management Review, 43(2), pp.108-117.

[25] Lee, J., Ardakani, H. D., Yang, S., & Bagheri, B. (2015). Industrial Big Data Analytics and Cyber-physical Systems for Future Maintenance & Service Innovation. Procedia CIRP, 38, 3-7. doi:10.1016/j.procir.2015.08.026

[26] Lee, J., Bagheri, B. and Kao, H. (2015). A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing system. Manufacturing Letters, 3, pp.18-23.

[27] Lee, J., Kao, H. and Yang, S. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. Procedia CIRP, 16, pp.3-8.

[28] Leitão, P. (2009). Agent-based distributed manufacturing control: A state-of-the-art survey. Engineering Applications of Artificial Intelligence, 22(7), pp.979-991.

[29] Martin, C. and Towill, D. (2000). Supply chain migration from lean and functional to agile and customised. Supply Chain Management: An International Journal, 5(4), pp.206-213.

[30] Mayring, P., & Brunner, E. (2009). Qualitative Inhaltsanalyse. Qualitative Marktforschung, 669-680. doi:10.1007/978-3-8349-9441-7_42

[31] Mehrsai, A., Karimi, H. and Thoben, K. (2013). Integration of supply networks for customization with modularity in cloud and make-to-upgrade strategy. Systems Science & Control Engineering, 1(1), pp.28-42.

[31] Min S. et. al. (2005). Supply chain collaboration: what's happening? The International Journal of Logistics, 16(2), pp.237-256.

[32] Mohr, J. and Spekman, R. (1994). Characteristics of partnership success: Partnership attributes, communication behaviour, and conflict resolution techniques. Strategic Management Journal, 15(2), pp.135-152.

[33] Monostori, L. (2014). Cyber-physical Production Systems: Roots, Expectations and R&D Challenges. Procedia CIRP, 17, 9-13. doi:10.1016/j.procir.2014.03.115

[34] Norta, A., Othman, A. B., & Taveter, K. (2015). Conflict-Resolution Lifecycles for Governed Decentralized Autonomous

[35] Organization Collaboration. Proceedings of the 2015 2nd International Conference on Electronic Governance and Open Society: Challenges in Eurasia - EGOSE 15. doi:10.1145/2846012.2846052

[36] Ogawa, R. T., & Malen, B. (1991). Towards Rigor in Reviews of Multivocal Literatures: Applying the Exploratory Case Study Method. Review of Educational Research, 61(3), 265-286. doi:10.3102/00346543061003265

[37] Scandura, T. A., & Williams, E. A. (2000). Research Methodology In Management: Current Practices, Trends, And Implications For Future Research. Academy of Management Journal, 43(6), 1248-1264. doi:10.2307/1556348

[38] Schmidt R. et. al. (2015). Industry 4.0 – Potential for Creating Smart Products: Empirical Research Results. International Conference on Business Information Systems, pp.16-27.

[39] Schuh, G., Potente, T., Varandani, R., Hausberg, C. and Fränken, B. (2014). Collaboration Moves Productivity to the Next Level. Procedia CIRP, 17, pp.3-8.

[40] Schumacher, A., Erol, S. and Sihn, W. (2016). A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. Procedia CIRP, 52, pp.161-166.

[41] Seawright, J., Gerring, J., Seawright, J., & Gerring, J. (n.d.). Case Selection Techniques in Case Study Research: A Menu of Qualitative and Quantitative Options. Case Studies. doi:10.4135/9781473915480.n31

[42] Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in education and the social sciences. New York: Teachers College Press.

[43] Simatupang T. M., Sridharan R. (2002). The Collaborative Supply Chain: A Scheme for Information Sharing and Incentive Alignment. The International Journal of Logistics Management, 13(1), pp.15-30

[44] Simatupang, T., Wright, A. and Sridharan, R. (2002). The knowledge of coordination for supply chain integration. Business Process Management Journal, 8(3), pp.289-308.

[45] Soosay, C., Hyland, P. and Ferrer, M. (2008). Supply chain collaboration: capabilities for continuous innovation. Supply Chain Management: An International Journal, 13(2), pp.160-169.

[46] Stock, T., & Seliger, G. (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. Procedia CIRP, 40, 536-541. doi:10.1016/j.procir.2016.01.129

[47] Vereecke, A. and Muylle, S. (2006). Performance improvement through supply chain collaboration in Europe. International Journal of Operations & Production Management, 26(11), pp.1176-1198.

[48] Wang, K. S. (2016). Intelligent Predictive Maintenance (IPdM) system – Industry 4.0 scenario. WIT Transactions on Engineering Sciences, 113. doi:doi:10.2495/IWAMA150301

[49] Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for industry 4.0: A self-organized multi-agent system with big data based feedback and coordination. Computer Networks, 101, 158-168. doi:10.1016/j.comnet.2015.12.017

[50] Wei, H. and Wang, E. (2010). The strategic value of supply chain visibility: increasing the ability to reconfigure. European Journal of Information Systems, 19(2), pp.238-249.

[51] Wollschlaeger, M., Sauter, T., & Jasperneite, J. (2017, March). The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0 - IEEE Journals & Magazine. Retrieved from http://ieeexplore.ieee.org/document/7883994/

[52] Xing, B., Eganza, J., Bright, G. and Potgieter, J. (2006). Reconfigurable Manufacturing System for Agile Manufacturing. IFAC Proceedings Volumes, 39(3), pp.509-516.

[53] Yu, Z., Yan, H., & Cheng, T. E. (2001). Benefits of information sharing with supply chain partnerships. Industrial Management & Data Systems, 101(3), 114-121. doi:10.1108/02635570110386625

[54] Zawadzki, P. and Żywicki, K. (2016). Smart Product Design and Production Control for Effective Mass Customization in the Industry 4.0 Concept. Management and Production Engineering Review, 7(3).

[55] Zhang, L., & Wang, Z. (2006). Integration of RFID into Wireless Sensor Networks: Architectures, Opportunities and Challenging Problems. 2006 Fifth International Conference on Grid and Cooperative Computing Workshops. doi:10.1109/gccw.2006.58

8. APPENDICES

8.1 Interview Guideline (German)

1. Bitte beschreiben sie was unter ihre Jobverantwortung fällt und welche Tätigkeiten sie täglich ausführen?
2. Was bedeuten die Begriffe „Industrie 4.0“ und „Internet der Dinge“ für sie persönlich?
3. Was sind ihre Erfahrungen im Bereich Industrie 4.0? Könnten sie ihren Industrie 4.0-Ansatz beschreiben, sowie dessen Effekt auf Firmen und/oder dessen Firmennetzwerke?
4. Führt ihr Ansatz zu mehr vertikaler oder horizontaler Integration und inwiefern? Hat ihr Ansatz einen Einfluss auf die Kooperation mit anderen Firmen?
5. Welche Rolle spielen die folgenden neun Eigenschaften für ihre Industrie 4.0-Lösung?
    a) Koordination
    b) Engagement
    c) Vertrauen
    d) Kommunikationsqualität
    e) Teilen von Informationen
    f) Anteilnahme
    g) Gemeinsame Problemlösungskompetenz
    h) Runterspielen von Problemen
    i) Drastische Problemlösungsmaßnahmen
6. Auf welche Faktoren müssen sie bei der Implementierung ihres Industrie 4.0-Ansatzes achten? Welche Spannungsfelder entstehen für ihre Lösung und wie lösen sie Probleme, die auftauchen?
7. Wie positiv oder negativ sehen sie die Entwicklungen in Industrie 4.0 und warum?
8. Welche Chancen sehen sie für Firmennetzwerke und -partnerschaften in Industrie 4.0?
9. Welche Herausforderungen sehen sie für Firmennetzwerke und -partnerschaften in Industrie 4.0?
10. Wo sehen sie zukünftige Entwicklungen in der Industrie 4.0, gerade in Bezug auf ihre Firma? In wie fern werden Firmennetzwerke in der Zukunft wichtig für Industrie 4.0 sein?
11. Gelegenheit für Kommentare und weitere Informationen/Fragen.

8.2 Interview Guideline (English)

1. Could you describe your current responsibilities within your company and what you do on a daily basis?
2. What does “Industry 4.0” and “Internet of Things” mean for you personally?
3. What are your experiences with Industry 4.0? Could you describe your Industry 4.0-approach and its possible effects firms and/or their networks?
4. Does your approach lead to more vertical or horizontal integration and by how far? Does your approach have an influence on cooperation with other firms?
5. Which role do the following nine factors play for your Industry 4.0-solution?
    a) Coordination
    b) Commitment
    c) Trust
    d) Communication Quality
    e) Information Sharing
    f) Participation
    g) Joint Problem Solving
    h) The Use of Smoothing over Problems
    i) Severe Resolution Tactics
6. Which factors are important for the implementation of your Industry 4.0-solution? Which areas of conflicts arise for your solution and how do you handle problems?
7. How positive or negative do you see the developments in Industry 4.0 and why?
8. Where do you see chances for business relationships in Industry 4.0?
9. Where do you see challenges for business relationships in Industry 4.0?
10. Where do you see future developments in Industry 4.0, especially regarding your firm? By how far are business networks going to be important for Industry 4.0?
11. Opportunity for comments and further information or questions.