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Organizational impacts of supply chain digitalization
an empirical study

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Organizational impacts of supply chain digitalization

An empirical study

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Abstract

In this thesis, the influence of digitization on a firm's information availability, organizational structure, decision making, employee well-being, and subsequent business performance were studied. The industrial context of the thesis was the intersection of the chemicals- and process industry, which is known for its high degree of automation. After an extensive literature review with respect to supply chain digitalization and its effects on information sharing, a research model was developed. This research model was validated and adapted based on expert interviews within Accenture. Besides that, for each of the relationships in the research model, propositions were formulated based on theory and the expert interviews. Consequently, the propositions (and the research model) were tested using a comparative case study at a leading chemical company. This case study encompassed three cases: one case in which there was no automation in place for the decision-making process, one case in which a decision-support system was in place, and one case in which the decision-making process was partially automated. Main findings were that decision-support systems based on IoT and cloud computing increase the amount of relevant information available for decision-making, and help to speed up the decision-making process. This results in better decisions, which lead to increased business performance. Furthermore, decision-support systems are a valuable resource for decision makers and reduce job demands. As a result, overall well-being of decision makers will increase. Fully automated systems based on IoT and cloud computing internalize the information relevant for decision making, but are able to provide more information about the process itself. These systems maximize the speed of the decision-making process, and make more accurate and reliable decisions, if implemented correctly. These decisions result in an increase in business performance. Furthermore, fully automated systems cause a decrease in perceived task autonomy and other job resources by decision makers. On the other hand, they reduce job demands. Depending on actual job characteristics, employee well-being may either increase or decrease.

Keywords: information sharing, industry 4.0, digitalization, decision making, organizational structure, employee well-being, internet of things

Management summary

A key determinant of supply chain performance is supply chain integration. Due to increasing global competition, organizations are becoming increasingly aware of the need to integrate their supply chains. To integrate a supply chain, material flows, financial flows, and informational flows need to be integrated in a firm, as well as in the supply chain as a whole. Too often, attention is paid to the integration of material- and financial flows, leaving the integration of informational flows unattended. This while the key to success for any supply chain is the effective and efficient exchange of information.

Context The research was performed at the management consulting department of Accenture, with a focus on the resources industry. The resources industry is composed of the energy, chemicals, and utilities sectors. The main focus of the thesis was on the intersection between the resources- and process industry, since this is most similar to a 'regular' manufacturing industry.

Information sharing A literature review regarding supply chain information sharing was conducted. Only good information can be used to integrate informational flows and increase business performance. Good information is (1) useful for decision making, (2) of an appropriate quality (i.e. accurate and reliable), (3) available on time, (4) easy to access, and (5) controllable, meaning that individuals should be in control of the information they share. Business performance improvements resulting from good information are realized through (a combination of) service level improvements, or cost reductions.

Unfortunately, in practice, information is not shared effectively or not shared at all. This is the result of information sharing barriers. The most important barriers are (1) a lack of trust in IT, (2) high (perceived) costs associated with IT systems facilitating information sharing, (3) lack of (top)management support, and (4) low quality of information shared. Thus, the barriers are mainly of a managerial and a technological nature.

To facilitate information sharing between supply chain partners, intra-firm (i.e. within the organization) information sharing should be in order first. This is often not the case in practice, therefore, it was decided to focus the research on intra-firm information sharing.

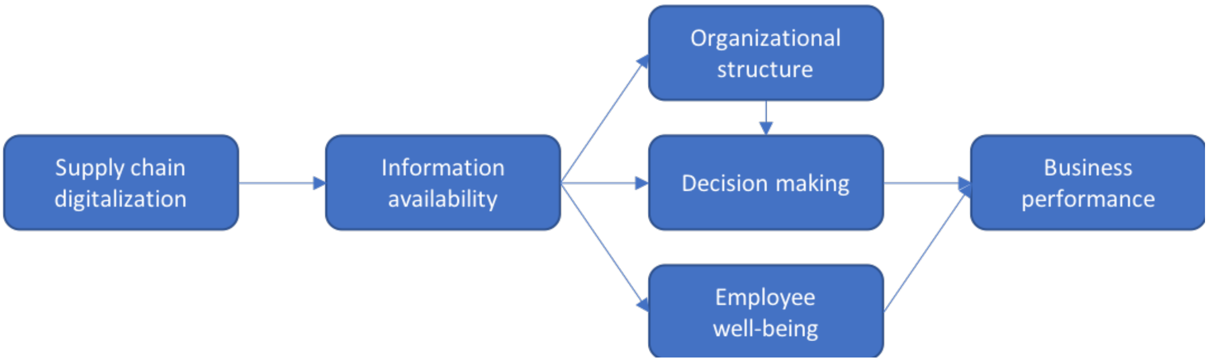
Factors hindering intra-firm information sharing are mainly the result of intra-organizational turf battles and organizational silos which do not communicate or collaborate with each other. Intra-organizational turf battles are the result of misalignment of incentives between employees. Organizational silos lead to duplicated effort, efficiency limits, hampered decisions, and make performance measurement and improvement nearly impossible. This is the result of every silo optimizing its performance locally, which hardly ever leads to a globally optimal solution.

Digitalization The fourth industrial revolution is currently on its way and inherent to this is the digital transformation of the supply chain, as well as organizational processes. digitalization can help bring down the walls of organizational silos, and may be used to align incentives between employees. The digital transformation involves the use of sensors, machines, and IT systems to fully integrate intra- and inter-firm functions. Technologies enabling the digital transformation are the Internet of Things (IoT), cyber physical systems, robotic process automation, big data analytics, machine learning, cloud computing technologies, and blockchain technology. These technologies may be combined to mitigate each other's shortcomings, such as the combination of IoT and cloud computing. Furthermore, the technologies can play an important role in facilitating the sharing of good information.

The digital transformation of an organization's processes changes information availability in an organization. This mainly affects decision makers, since they act on the information they receive. Three effects were analysed in the literature review: (1) organizational structure, which may change due to increased transparency and shorter 'lines of communication', decreasing bureaucracy, (2) the decision making process itself, since higher quality and more informed decisions can be made based on increased availability of good information, and (3) the decision-maker's motivation, which is affected by a decrease in job demands such as work pressure and/or an increase in job resources such as performance feedback.

Interviews In the literature review, theory was explored to find propositions for the relationships in the model. Consequently, 10 semi-structured interviews with professionals from within Accenture were held to (1) determine the most promising technologies and their use cases, (2) formulate additional propositions, (3) perform an initial test on the readily-formulated propositions. In the interviews, it was found that the most promising combination of technologies was IoT & cloud computing. These technologies can mainly impact the resources supply chain by improving efficiency.

From these results, the research model given below was formulated.



Case study To test the propositions and the research model in general, a proof-of-concept on which Accenture was assisting a leading chemical company was analysed. Here, IoT & cloud computing were leveraged to assist in efficient allocation of production to equipment, and to efficiently manage the production level. There were three phases in the implementation of the proof-of-concept, which were the old situation, a readily-implemented decision-support system, and a to-be implemented system which automates part of the decision-making process.

Analysis of the proof-of-concept was done using a comparative case study approach, which involves a combination of multiple data sources. The cases were (1) the old situation, (2) a situation with a decision-support system, and (3) a situation with an automated system. The automated system was not implemented yet, but there was enough data available to formulate reliable expectations. Data was collected by means of documentation analysis regarding the project, a plant tour, observation in the control room, and interviews with people involved and affected by the project. Interviews were held with people from different hierarchical levels: operators (who are the end user of the solution), a production coordinator, a production engineer, the production manager, and the plant manager of the plant at which the project is being carried out.

Decision-support system Analysis of the case with a decision-support system led to several findings. First, the decision-support system increased the amount, quality, and reliability of information. In addition, the timing and ease of access of information relevant for decision making improved and the controllability of information (i.e. the extent to which individuals can keep information to themselves) decreased. This change in information availability resulted in more rapid and accurate identification of opportunities to optimize production. Besides that, less time was required to make decisions and authorize actions. As a result, the chemical company indicated that better decisions were made and that business performance improved. In addition, the information availability affected the motivation of the operators. The operators perceived an increase in role clarity, performance feedback, and task autonomy. This increased their engagement and resulted in a higher rate of adoption of the decision-support system. Because the adoption rate had increased, the new system was used whenever possible, resulting in cost savings.

Automated system The automated system was still in development, but opinions were asked and a forecast of the impact of the automated system was made. The amount, quality, and reliability of information relevant for decision making were expected to increase. Timing and ease of access of information were expected to improve, and controllability of information was expected to decrease. The automated system was expected to speed up the decision-making process since less actors would be involved in authorizing proposed decisions and authorization would become faster. Opportunities to optimize production were expected to be identified more rapidly and accurately than before, because of increased automation. These changes were expected to lead to higher quality decisions which would improve business performance. Opposed to the decision-support system, the fully automated system is expected to have less positive side-effects for the workforce. This was mainly the result of a perceived decrease in task autonomy, and less positive influence of performance feedback, since a bigger part of a task was automated. This was not expected to affect business performance in a negative way, since the magnitude of the effect was minimal.

Conclusion For both the decision-support system, as well as the fully automated system, the proposed research model holds and is an adequate representation of reality. The research model can be seen as a solid basis for further research regarding the influence of digitalization on information availability, organizational structure, decision making, and employee well-being. However, the industrial and situational context in which the model was formulated and tested should be taken into account when applying the model, since the model has not yet been extensively tested and validated.

Preface

This report marks the end of my master thesis project carried out at Accenture for the master Operations Management & Logistics at the Eindhoven University of Technology. It would not have been possible to complete this project without the support of the people around me.

First, I would like to thank Pascale Le Blanc, my supervisor from the TU/e, for providing me with timely and high-quality feedback. Our meetings were always pleasant to attend and helped me to make progress with my thesis quickly. You provided me with valuable feedback and insights for carrying out scientific research.

Furthermore, I would like to thank everyone at Accenture involved in helping me with the research. Special thanks go out to my thesis supervisor at Accenture, Adriana Begeer. You know how to trigger me with questions that were (sometimes) out of my comfort zone during our weekly meetings. In addition, you provided valuable inputs and insights for the thesis, put me in contact with the right people, and taught me important soft skills. Thanks for making time for me on a weekly basis, despite your full agenda.

Finally, I would like to thank my friends and family who have been there for me during my thesis. Your mental support (especially in the weekends) was important to me in this period to blow off some steam. Special thanks go out to my uncle, Joep Brekelmans, who put me in contact with Accenture. Furthermore, I would like to thank my parents. Thank you mom for being there for me during difficult times, but more importantly, to celebrate successes. Thank you dad for helping me become the person who I am and always being confident in my success.

Sjors Wagemakers, January 31, 2018.

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Chapter 1

Introduction

Supply chain performance is measured by the flexibility of the supply chain, integration of the supply chain, customer responsiveness (i.e. speed at which a firm is able to respond to customer orders), and supplier performance (i.e. the ability of the supplier to deliver goods on time and in good condition) (Al-Shboul, Barber, Garza-Reyes, Kumar, & Abdi, 2017). The increase of global competition has incentivized organizations to think about integrating their supply chains, since it is a well-accepted thought that the best supply chain wins (Flynn, Huo, & Zhao, 2010; Shub & Peter, 2009). However, supply chain integration (SCI) is only as of recent on the agenda of researchers, though it has always been a vital dynamic capability (Fawcett, Wallin, Allred, & Magnan, 2009; Huo, 2012). Key motivations for SCI are minimization of governance costs, reduced product/service costs, reduced supply chain lead times, and increased flexibility in supply chain design (Korpela, Hallikas, & Dahlberg, 2017). However, the current readiness for integration is hindered by a significant gap in many supply chain functionalities. These functionalities include standards, monitoring and tracking of information, and secure end-to-end delivery of information.

To reap the benefits of supply chain integration, internal cross-functional integration is required, as well as external integration with suppliers and customers (Al-Shboul et al., 2017). Furthermore, an organization first needs to be integrated internally, before supply chain integration with all of the supply chain partners can be achieved (Lotfi, Mukhtar, Sahran, & Zadeh, 2013).

Both internal and external integration require integration of material flows, information flows, and financial flows (Huo, 2012; Leuschner, Rogers, & Charvet, 2013). However, supply chain practitioners find it far more challenging to manage information flows, compared to physical or financial flows (Prockl & Wong, 2017). As a result, in many supply chains, information is not shared efficiently or not in a timely manner (Nakasumi, 2017). Consequently, those supply chains are less successful than their counterparts where information is shared efficiently (Schrauf & Berttram, 2016). Thus, for a flexible, integrated supply chain, one of the most important conditions is good information sharing (Bian, Shang, & Zhang, 2016; Lotfi et al., 2013; Varma & Khan, 2015).

Currently, the fourth industrial revolution is on its way, which inevitably includes the digital transformation of supply chains, organizations, and processes. This digitalization can aid supply chain practioners in managing the information flows and lower the barriers to internal as well as external information sharing (Schrauf & Berttram, 2016). However, digitalization of business processes is not enough. The effectiveness of a digital transformation is a function of (digital) technology, people, and organization (Fawcett et al., 2007). This means that for a successful digital transformation technology, people, and the organization must be aligned.

From a research among nearly 1000 C-suite executives in the products, high tech, and resources industries, it was found that there is a high interest for a digital transformation (Zachar, 2017). 99% of the surveyed executives stated that leveraging digital to transform their core businesses while growing new ones is a top goal. 64% of them agree agree that failure to leverage digital will cause them to struggle for survival. However, only 34% of the surveyed companies are already transforming their core, and only 44% grow new businesses. All in all, only 13% of the companies both transform the core and grow new businesses simultaneously.

Often-mentioned factors hindering digitalization are (1) insecurity about where to start or how to proceed, (2) a high perceived risk of implementing and operating new technology, (3) fear of change due to a disruption of traditional organizations and functional roles, and (4) a lack of perceived urgency (Frandina, Bjacek, & Clos, 2016). These factors are mainly the result of a lack of knowledge of (or attention to) the organizational impacts of digitalization. digitalization affects an organization in its core: decision-making processes, employee motivation, and even organizational structure may change. However, current research efforts on the influence of digitalization on an organization are limited to 'hard' factors', for example, potential cost savings. This, combined with the fact that organizations see digitalization as one of their top priorities (Abood, Guilligan, & Narsalay, 2018), results in the following main question leading this thesis: What are the organizational impacts of supply chain digitalization? This question addresses the gap in the literature identified in the literature review, while simultaneously solving the practical problem of organizations being unaware of the impact digitalization has on their organizations.

The aim of this thesis was to determine and test factors influencing successful supply chain integration and information sharing, in the light of current technological developments. The remainder of the thesis is built up as follows: chapter 2 assesses the current state of literature on information sharing, digitalization and its effects on an organization as well as its employees. Here, a gap in the literature was identified. In chapter 3 research questions are formulated based on the literature review, and the research methodology to answer these questions is given. In chapter 4, the most relevant (combinations of) technologies for a digital transformation are identified and their most promising applications are given. Besides that, in this chapter, propositions regarding the most promising application are formulated. Chapter 5 involves a pilot case study regarding digitalization at a leading chemical company to test the formulated propositions. Finally, in chapter 6 the results of the research are discussed, implications for both theory and for practice are given, as well as limitations and directions for further research.

Chapter 2

Literature review

2.1 The role of information sharing for a competitive supply chain

Information sharing is a key enabler of supply chain integration, and thus, firm performance. However, a lack of information sharing forms an important bottleneck hindering supply chain integration, as well as internal integration of an organization (Nakasumi, 2017; Wu, Xiaohang, Jin, & Yen, 2016).

The nature of the information and the way in which the information is shared both play an important role (Wu et al., 2016). More specifically, there are six main characteristics good information has to satisfy. (1) Useful information needs to be shared which can be used to create value. For example, to make production decisions, it is useful to know the current logistics situation. (2) Information quality is important, meaning information should be accurate and reliable. (3) The timing of information is of relevance: the earlier information is available, the better. (4) The speed of the information transfer should be as close to real-time information as possible, minimizing delays in the transmission of the data. (5) Information should be accessible in an easy way, to reduce barriers to usage of the information and to maximize the potential benefits of the information. (6) Firms and individuals should be in control of the information they share and their privacy should be protected.

2.1.1 Advantages of information sharing

There is a great deal of literature describing the advantages of information sharing. For example, Lotfi et al. (2013) studied information sharing in supply chain management and came up with the list of potential benefits given below. Note that some of the mentioned benefits are mutually exclusive, i.e. a trade-off exists between cost reduction while maintaining the same service level, or service level improvement while keeping the same costs.

- Inventory reduction and efficient inventory management
- Cost reduction
- Increased visibility, reducing uncertainties
- Improved resource utilization

- Increased productivity, organizational efficiency and improved services
- Building and strengthening social bonds
- Early problem detection
- Quick response
- Reduced cycle time from order to delivery
- Better tracking and tracing
- Shorter time to market
- Expanded network
- Optimized capacity utilization

In a meta-analysis by Yang and Mu (2015), information sharing advantages are discussed as well. They found that on average a 2.2% reduction in the total cost of the supply chain is achieved as a result of improved information sharing. Furthermore, information sharing can reduce the impact caused by the bullwhip effect, i.e. it can reduce variance in upstream demand through, for example, collaborative planning, forecasting and replenishment (CPFR). Lastly, they found that information sharing allows for improvements in service levels.

A more recent study by Nakasumi (2017) found the following advantages of timely and accurate information. (1) The supplier and manufacturer both could realize a reduction of capacity risk, which is the risk associated with having too much or too little capacity. Through information sharing, the manufacturer can obtain a more accurate forecast of demand, and is thus able to optimize its production capacity. Besides that, the supplier usually carries inventory risk, which can be reduced due to the availability of downstream information. Using the shared information, processes can be automated, for example through automatic replenishment. (2) The transport business can optimize its transportation processes if real-time information is available. Full truck loads can be shipped more often by consolidation of shipments of different suppliers. Besides that, increased visibility as a result of information sharing allows for on-time collection and delivery, since the transport business can incorporate real-time process information in its planning. (3) If all distributors share their information, it is possible for the retailer to automatically select the optimal distributor, i.e. the distributor which provides the retailer with the shortest lead time. This, combined with the improved alignment of replenishment and capacity utilization could lead to a reduction in the amount of lost sales. Finally, the whole supply chain benefits from an overall cost and/or lead time reduction. The benefits mentioned in this paragraph are summarized in Figure 1.

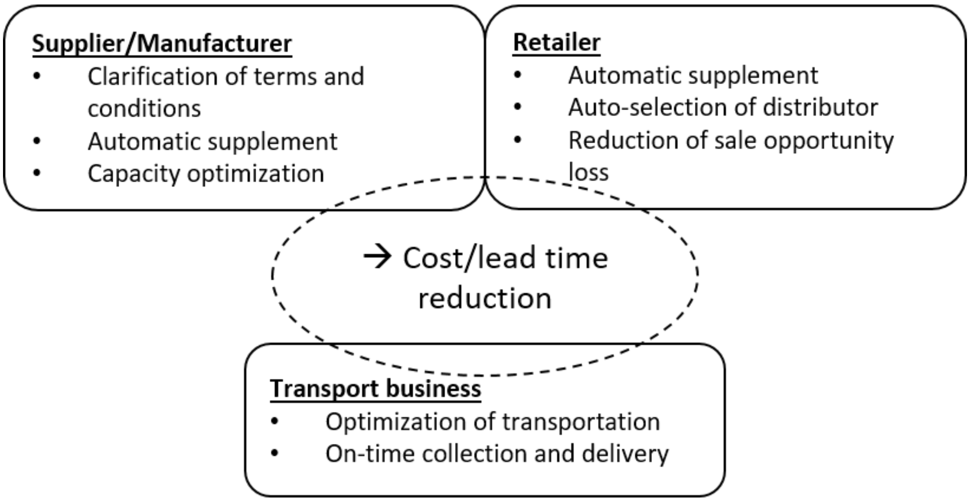

Figure 1: Benefits of information sharing (Nakasumi et al., 2017)

2.1.2 Barriers to information sharing

Not every party in the supply chain or an organization is willing to share information. There are various factors of resistance against information sharing. Lotfi et al. (2013) researched these and came up with the following barriers to information sharing. (1) Confidentiality of information shared may form a barrier if one supplier serves two competing customers. If the supplier shares sensitive information from one customer with the other customer, the first customer may be put at a disadvantage. (2) Incentive issues arise when other partners misuse the information shared by one partner. For example, a supplier will not give away information about production yield or the purchase price of parts, since this may give its customers an incentive to demand a lower price (H. L. Lee & Whang, 1998). (3) Information technology enabling information sharing may be very costly and time consuming to implement. This is the result of standards needing to be agreed upon and the technology which should work for the whole integrated chain. (4) Anti-trust regulations may impede information sharing. These regulations emerge from the risk of price influencing when firms collude. (5) Timeliness and accuracy of shared information affects its usability. For example, if customer demand data is shared with an upstream supplier a month later than the demand is realized, the data may be useless for operational decision making. (6) The information may be shared, but if there are no applications for the obtained information, the advantages of information sharing will not materialize.

Khurana, Mishra, and Singh (2011) studied barriers to information sharing in the supply chain of manufacturing industries and split up the barriers into six different categories. These categories are managerial, organizational, financial, technological, individual, and social-cultural barriers. Managerial barriers arise when managers do not realize the before-mentioned advantages of information sharing and when they do not have confidence in the information sharing system. Organizational barriers originate from attitudes of the organization towards the implementation of information sharing. Financial barriers mainly concern cost considerations associated to the purchase of information- and technological systems. Technological barriers mainly consist of problems concerning the interoperability between systems. Individual barriers arise from behaviour or actions of individuals or groups of individuals within or between various business functions. Social-cultural barriers originate from the misinterpretation or misuse of shared information.

Khurana et al. (2011) found that mainly financial, technological, and organizational barriers are of importance for information sharing problems. Financial barriers are of the highest importance, followed by technological barriers. Together they make up for 50% of all of the information sharing problems in the studied manufacturing industries. The top 10 of most relevant problems is given in Table 1.

Table 1: Barriers to information sharing (Khurana et al., 2011)

Rank	**Problem**	**Type**
1.	Financial constraint for high cost of maintenance	Financial
2.	Data and information security	Technological
3.	Cost of specialized manpower and training	Organizational
4.	Incompatibility of information systems with process functions	Technological
5.	Lack of top management support	Managerial
6.	Rapidly changing technology	Technological
7.	Lack of financial support for cost of software	Financial
8.	Centralization of hierarchical structure	Organizational
9.	Lack of trust and confidence in information sharing system	Individual
10.	Fear of penalty if shared information is misused	Social-cultural

A study by Yang and Mu (2015) analysing barriers to information sharing yielded similar results as the studies seen before. The barriers found include lack of will of sharing, misalignment of interest and IT, high costs of information sharing systems, hazard of unused information (if safety and right of access are not well defined), and lack of confidence in the information sharing systems. Furthermore, effective information sharing depends on whether firms are ready to share information with supply chain partners. They should see the common interest for all of the supply chain members. Here, key factors determining success are trust and cost of implementation of IT systems enabling information sharing. Since the retailer's information is often most useful, the retailer has to be willing to share information. If the cost of information sharing is high, the retailer will not share information. Consequently, three main causes of resistance against information sharing are identified. The first cause concerns technological and financial constraints. Second, barriers of (top) management play a significant role. This is often due to managers not having accurate understanding of the information system. Third, enterprises usually have a short-sighted vision which hinders strategic long-term partnerships.

Summarizing, the barriers of supply chain information sharing mainly consist of a lack of trust in IT, high costs associated with the IT systems, lack of (top) management support, lack of trust in supply chain partners, and low quality (i.e. timeliness and accuracy) of information shared . Thus, the barriers could mainly be classified as technological and managerial barriers according to the definitions given by Khurana et al. (2011).

Barriers to external information sharing

The barriers to external information sharing are mainly due to strategic concerns. Fawcett, Magnan, and McCarter (2008) split up these barriers in barriers due to inter-firm rivalry, and barriers due to managerial complexity. Barriers due to inter-firm rivalry predominantly include the misalignment of incentives among key supply chain partners within the strategic supply chain. This misalignment of incentives is the result of inter-firm rivalry are internal- and external turf protection and lack of partner trust (Fawcett et al., 2008; Wu et al., 2016). Barriers due to managerial complexity are information system and technological incompatibility, inadequate measurement systems, and conflicting organizational structures and culture.

All in all, the barriers to external information sharing are the result of incentive misalignments, IT misalignment, and lack of trust.

Barriers to internal information sharing

Hatala and Lutta (2009) found that intra-firm barriers to information sharing emerge from concerns about diverting or overloading employees' work-related attention, individual's perception that sharing information will lead to a loss of power, loss of position of influence, diminished chances of receiving a promotion, high effort of using technology (e.g. databases), and differences in levels of relative knowledge. The main directions for reducing these barriers were making boundaries (i.e. functional silos) permeable, and dismantling hierarchical silos.

Fawcett, Wallin, Allred, and Magnan (2011) concluded that the most important resistors to supply chain information sharing are organizational structure, functional conflict, and poor strategic alignment. The resistor emerging from organizational structure and functional conflict is the result of intra-organizational turf battles and functional silos (Fawcett et al., 2011; Serrat, 2017). Poor strategic alignment is caused by poorly aligned goals and metrics, meaning different employees may have conflicting goals (Skipworth, Godsell, Wong, Saghiri, & Julien, 2015).

Organizational silos It can be seen from the previous paragraphs that organizational silos play an important role hindering intra-firm information sharing. Serrat (2017) defines an organizational silo as: "organizational entities - and their management teams - that lack the desire or motivation to coordinate (at worst, even communicate) with other entities in the same organization". These siloed organizational structures originated in the early 1900s, with the underlying thought that specialization would lead to excellent performance (Dell, 2005). The idea of silos itself is not necessarily a bad thing. However, there has to be communication and collaboration among the silos.

Due to the financial crisis, an emphasis was placed on accountability resulting in business units being monitored tightly (Chakravarthy, 2010). Consequently, every business unit locally optimized its processes, with no eye for the 'big picture'. This reduced inter-unit cooperation and eventually leads to a reduction of long-term performance of the firm. Furthermore, if information is not shared internally, external information sharing is not possible either, which makes supply chain integration impossible.

Other problems emerging from organizational silos include (Dell, 2005):

- **Duplicated effort** since the same information is re-entered and stored in multiple databases

- **Efficiency limit** because of local optimization which hardly ever results in global optimization
- **Hampered decisions** because of incomplete and/or insufficient information
- **Performance measurement and improvement nearly impossible** for key business processes

Schrauf and Berttram (2016) pose that digitalization brings down the walls of the silos, where every link in the internal supply chain will have full visibility into the needs and challenges of the others. A digital transformation of a firm's processes and the whole supply chain is therefore a promising solution to overcome the barriers to internal information sharing and enable external information sharing.

Conclusion In order to facilitate supply chain integration and effective information sharing, a firm must first make sure its internal information sharing is in order. The most common barriers to intra-firm information sharing arise from organizational silos and intra-organizational turf battles. Process digitalization can help in bringing down the walls of the silos and align goals within an organization, as well as in a complete supply chain, moving from local optimization to global optimization.

2.2 Industry 4.0 and the digital transformation

The relevance of SCI and information sharing is emphasized even more by the ongoing fourth industrial revolution, which is also known as industry 4.0 (Lasi, Kemper, Fettke, Feld, & Hoffmann, 2014). In industry 4.0 it is envisioned that a supply chain becomes an integrated supply network, enabled by data sharing and advanced analytics such as machine learning. Currently, there is no shortage of data, but the data is not shared efficiently or not in a timely manner (EY, 2016; Rüßmann et al., 2015). Large amounts of data need to be standardized through an enterprise data management strategy if firms want to gain the benefits of the fourth industrial revolution. IT-enabled supply chain management can easily be used to manage and optimize the supply chain flows (i.e. informational, material and financial), improving quality and reducing coordination costs and transaction risks (Varma & Khan, 2015).

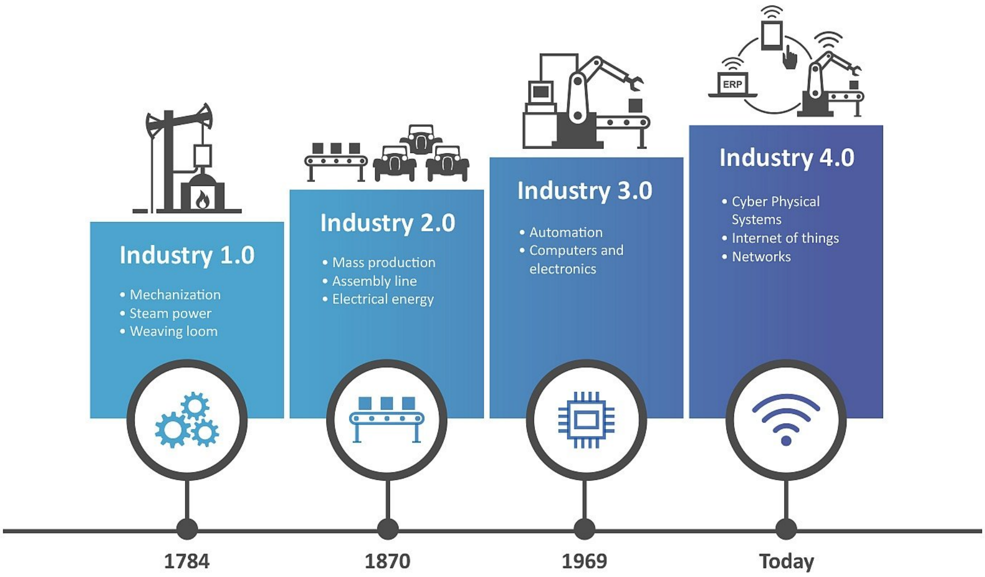

Figure 2: Industrial revolutions (Amtage, 2017)

Inherent to the industry 4.0 transformation is the digital transformation of the supply chain and the digital transformation of organizational processes (Schrauf & Berttram, 2016). This transformation is based on the integration of sensors, machines, and IT systems. These technologies will be connected along the supply chain and beyond a single enterprise, resulting in full integration of intra- and inter-firm functions (Rüßmann et al., 2015).

Key elements of the digital supply chain are integrated planning and execution, logistics visibility, procurement 4.0, smart warehousing, efficient spare parts management, autonomous and B2C logistics, and prescriptive supply chain analytics. Integrated planning and execution (e.g. through collaborative forecasting, planning, and replenishment) is an essential part of the digital supply chain since it is the key requirement to deliver the right product at the right time. Data integration leads to significant reduction of lead times and improvements in inventory management. Logistics visibility is closely linked to the digital supply chain because the supply chain becomes increasingly complex, which increases the potential for disruption and makes it hared to solve problems quickly. Procurement 4.0 efficiently integrates and manages firm's suppliers using big data tools and techniques. This results in lower costs and faster delivery throughout the supply chain because of the higher degree of automation. Smart warehousing improves efficiency and safety by automating almost every normal warehousing activity. For example, by using cyber-physical systems. Efficient spare parts management is accomplished using 3D printing, since spare parts are typically slow movers and it can be the case that they must be kept in a warehouse for many years. Autonomous logistics are the result of driverless and semi-driverless vehicles. Last mile (B2C) logistics can be robotised as well, or via the use of initiatives similar to Uber. Finally, prescriptive supply chain analytics systems can transform the data obtained using the before-mentioned techniques into useful information. These analytics are decision support systems for managers based on the enormous amount of data which is gathered, to give accurate prescriptions and could even operate independently.

A key enabler of the elements of the digital supply chain are the strategic and operative exchange of information between supply chain partners to enhance communication between actors in the chain (Korpela et al., 2017). A wide range of new technologies enables these elements of the digital supply chain.

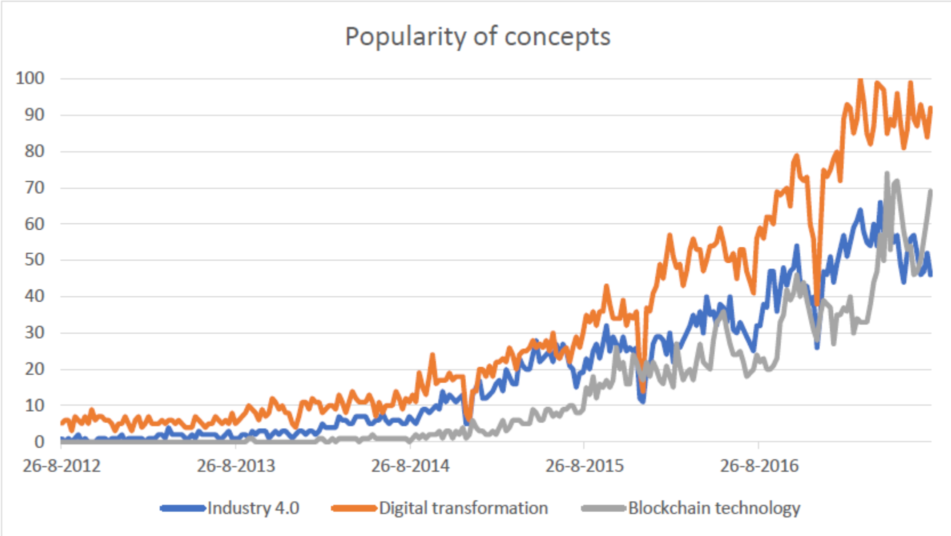

Figure 3: Popularity of concepts over the last 5 years (Google Trends)

2.3 Digital supply chain technologies

Briefly introduced in the preceding paragraph, supply chain digitalization is an increasingly important tool in supply chain integration. The digital transformation is mainly fuelled by the digitalization of processes via the use of new technologies. This digitalization can help overcome the barriers to supply chain information sharing and bring down the walls of organizational silos. 1400 supply chain practitioners agreed on five key technologies inherent to the digital supply chain, namely big data analytics, cloud computing, advanced robotics, internet of things, and machine learning (Manenti, 2017). Advanced robotics is a broad concept, thus it was chosen to split it up in robotic process automation and cyber-physical systems, as seen in Rüßmann et al. (2015); Sikorski, Haughton, and Kraft (2017). Furthermore, one disruptive technology which has been given a lot of attention in the media and literature recently was included as well, namely blockchain technology. The reason for inclusion of this technology is its big potential and attention it has been given by supply chain professionals as well as researchers (Hasse et al., 2016; Korpela et al., 2017; Nakasumi, 2017). In this section, the key technologies are briefly introduced and potential applications for supply chain management will be given, as well as their potential to affect supply chain information sharing.

2.3.1 Internet of things

One of the central enablers of the digital transformation is the Internet of Things (IoT). The idea behind IoT is a devices or sensors connected world, where "things" are able to interact with each other (I. Lee & Lee, 2015; Zhou, Chong, & Ngai, 2015). These devices could be consumer goods, such as connected refrigerators which automatically place orders at a supermarket when you run out of certain product. Besides that, the devices can be applied in an industrial context, connecting manufacturing systems to the internet. This is called the Industrial Internet of Things (IIoT) and this will be the form of IoT which will be considered in this thesis. Thus, for the remainder of the text, when the term IoT is used, the industrial application (IIoT) is meant.

IoT may allow machines to make autonomous decisions while minimizing the need for intervention by a human. The greatest potential for IoT in supply chain management emerges when connected devices communicate with each other, and integrate with solutions such as vendor-managed inventory systems, customers support systems, business intelligence application, and business analytics. IoT has the potential to improve operational processes and reduce costs because of its transparency, traceability, adaptability, scalability, and flexibility (Zhou et al., 2015). There are three categories where IoT enhances the supply chain which are mentioned and explained below (I. Lee & Lee, 2015).

- **Monitoring and control:** through the collection of data on equipment performance, energy usage, environmental conditions and similar factors, managers and/or automated controllers can constantly track performance in real time, possibly intervening timely and accurately when necessary.
    - A simple example of monitoring and control is the concept of a smart home. Here it is possible to check your house's current temperature on your smartphone and alter it if desired.
- **Big data and business analytics:** IoT generates a huge amount of data through connected devices, which allows data to be collected, stored, and analysed to improve decision making.
- **Information sharing and collaboration:** because of the connectedness of devices to each other, it is possible to get real-time updates of processes, making it easier to share information which allows for collaboration with supply chain partners.

Furthermore, there are five technologies which aid the successful deployment of IoT-based products and services (I. Lee & Lee, 2015):

- **RFID**: This technology allows for automatic identification of data, which it captures using radio waves, a tag, and a reader. An RFID chip can store more information than a regular barcode, and there are chips which are able to measure environmental conditions as well.
- **Wireless sensor networks**: These networks consist of spatially distributed sensor-equipped devices, which are able to measure physical or environmental conditions. These networks can work combined with RFID chips.
- **Middleware**: A software layer which allows for the communication between software applications communicating in different languages. This is useful for IoT because of the different, heterogeneous data sources. The heterogeneity of IoT's data sources emerges from the use of different sensors made by different manufacturers, communicating over different protocols.
- **Cloud computing**: This is a software distribution model which allows for on-demand access to a shared pool of configurable resources. It also provides database and/or infrastructure access, which makes it useful for the IoT since it is able to handle the huge data streams generated by the IoT devices in real time.

- **IoT application software**: This software can visualize and give meaning to the data, since the raw data itself first needs to be transformed into meaningful information before it can be used.

2.3.2 Cyber physical systems

The next technology central to the digital transformation of the supply chain considers Cyber Physical Systems (CPS). These are embedded systems, with a human-machine interface, which are connected to other systems (Frazzon et al., 2015). These systems are – looking at the given definition of IoT – an embodiment of IoT in smart machines. CPS have the potential of operating autonomously and forming a heterogeneous system, being able to interact with themselves, other systems, and human actors. Because of their connectedness and physical embodiment, they can be used for synchronization of physical and information processes in the supply chain. This allows the link between an object's physical identity and virtual identity. Because the CPS are equipped with sensors and are connected, they enable full transparency of a supply chain's material- as well as information flow. Examples of aspects enabling transparency are tracking, access to a data communication platform, and facilitation of information about demand, stock, sales and other factors. Finally, CPS facilitate improvements in terms of service level and flexibility due to timely and accurate information sharing. A graphical representation of a supply chain without- and with CPS is given in Figure 4 and Figure 5 respectively.

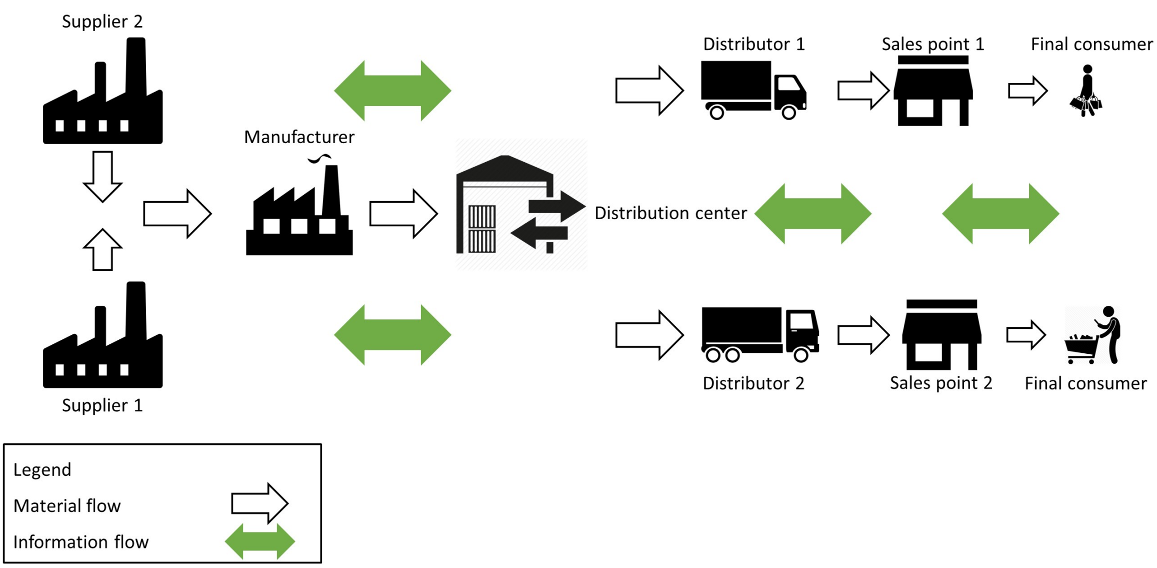

Figure 4: Supply chain without CPS (Frazzon, 2015)

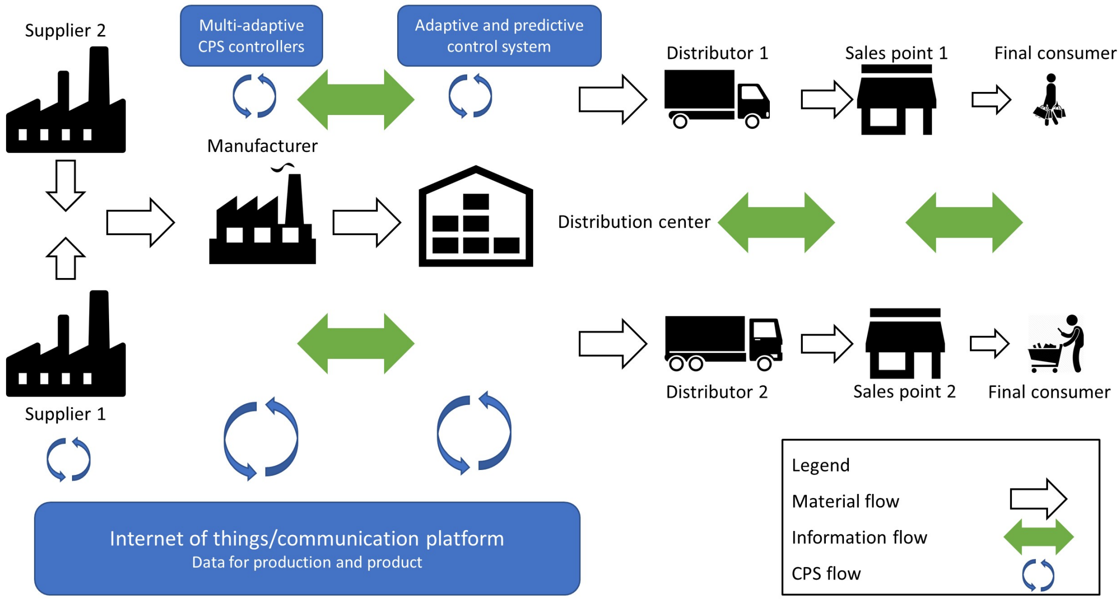

Figure 5: Supply chain with CPS (Frazzon, 2015)

2.3.3 Robotic process automation

Another important technology for the digital transformation of the supply chain is Robotic Process Automation (RPA). Briefly said, RPA uses work flows and business rules to interface with multiple information systems as if it were a human user (Davenport & Kirby, 2016). In other words, RPA does not require programming of rules in the information systems, but it is a robot using the information systems. In many firms, there are still a lot of repetitive processes which are done by hand by an employee, while this is unnecessary. RPA may reduce this by automating certain tasks. Examples of applications of RPA in supply chain management are automation of order processing and payments, automation of emails (automation of communication) and automation of procurement and inventory management processes (Ostdick, 2016). The functionalities of RPA are summarized in Table 2.

Table 2: What today's cognitive technologies can - and can't - do (Davenport & Kirby, 2016)

Task type	**Support for humans**	**Repetitive task automation**	**Context awareness and learning**	**Self-awareness**
Analyse numbers	Business intelligence, data visualization, hypothesis-driven analytics	Operational analysis, scoring, model management	**Machine learning**, neural networks	Not yet
Analyse words and images	Character and speech recognition	Image recognition, machine vision	IBM Watson, natural language processing	Not yet
Perform digital tasks	Business process management	Rules engines, **RPA**	Not yet	Not yet
Perform physical tasks	Remote operation of equipment	Industrial robotics, collaborative robotics	**CPS**, vehicles	Not yet

2.3.4 Big data analytics

A concept which is gaining a lot of attention lately is Big Data Analytics (BDA), which is the use of advanced analytical tools to obtain information from huge datasets. BDA generally is characterized by 5Vs (Feki, Wamba, & Boughzala, 2016; Nguyen, Zhou, Spiegler, Ieromonachou, & Lin, 2017):

- **Volume**: the magnitude of the data, which is exponentially increasing, posing a challenge for storage of the data
- **Variety**: the heterogeneous sources the data is generated from and the way it is sent to databases (i.e. in a structured/semi-structured/unstructured manner)
- **Velocity**: the speed of data generation and delivery, which could be in batch, real time, near-real time, or streamlines
- **Veracity**: the quality of the data and reliability due to the concern that many data sources inherently contain a certain degree of uncertainty and unreliability
- **Value**: the process of revealing underexploited values from big data to support decision making

Of these 5Vs, veracity and value are particularly important, because if analysis of the data is not possible, then it does not make sense to store the data at all. Using the 5Vs, Feki et al. (2016) define big data analytics as: "a holistic approach to manage, process and analyse 5Vs in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages".

Big data sources could be internal or external, where internal data is mostly available in a firm's own IT systems and considers its own processes. This data is relatively easy to analyse because of the standardized format it is saved in (Leveling, Edelbrock, & Otto, 2014). An example of internal data is past demand data. External data is data from other sources, for example social media and/or datasets from data portals. This kind of data is more heterogeneous than internal data, making it harder to analyse, but the amount of available data is generally larger.

Areas of supply chain management where BDA is applied are logistics (e.g. real-time traffic operation monitoring), production planning and control (e.g. reducing the variability in the production process), warehousing operation (e.g. inventory control), procurement (e.g. supplier selection), and demand management (e.g. real-time alignment of demand and production capacity) (Nguyen et al., 2017). The most popular research area is that of production planning and control. Furthermore, the most popular application of BDA is to obtain prescriptive analytics, closely followed by predictive analytics and finally followed by descriptive analytics. Prescriptive analytics suggest a course of action based on analysis of the data, predictive analytics say something about the possibility of future events happening, and descriptive analytics give an explanation of a past event.

Application of BDA can provide benefits in different fields. These include increased operational efficiency, improved customer experience, and improved supply chain agility (Leveling et al., 2014; Nguyen et al., 2017).

All in all, BDA is indispensable in making sense of big amounts of data by transforming it into useful information suitable for supporting decision making (Zhou et al., 2015).

2.3.5 Machine learning

As mentioned before, information sharing reduces forecast errors and Collaborative Planning Forecasting and Replenishment (CPFR) permits firms to collaboratively optimize planning, forecasting and replenishment. However, if information is not shared and thus not available, firms need to try to forecast the demand individually. Machine learning techniques can help in this case, since they can learn from the data and build dynamic models (opposed to the regularly static models) (Wang, 2017). Thus, machine learning improves the accuracy of forecasts and increases the efficiency of supply chain management since it is able to automatically find trends and factors of influence in the data. The link with the preceding technique is quite clear: machine learning is one of the analytical tools which may be used in BDA, mainly for forecasting demand and prices.

2.3.6 Cloud computing technology

Cloud computing technology (CCT) is an often-mentioned technology and is defined by Vemula and Zsifkovits (2016) as: "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". What this basically means is that firms do not need to have an ERP instance installed on their premises, but they can pay for it as a service, similar to a Spotify subscription for streaming music. CCT can be deployed in four different ways (Vemula & Zsifkovits, 2016):

- **Private cloud**: Here, the cloud is operated exclusively for one organization, which can be managed by the organization itself or by a third party.

- **Community cloud**: In this case, the cloud is shared by several organizations, which are sharing the same concerns. This could be supply chain partners.
- **Public cloud**: This is available to the public and owned by an organization specialized in selling cloud services.
- **Hybrid cloud**: This is a combination of private, public, or community cloud which can have the same standards which enables data and application portability, as well as inter-organizational information sharing.

Furthermore, there are four levels of integration (counting no integration as well), as depicted in Figure 6.

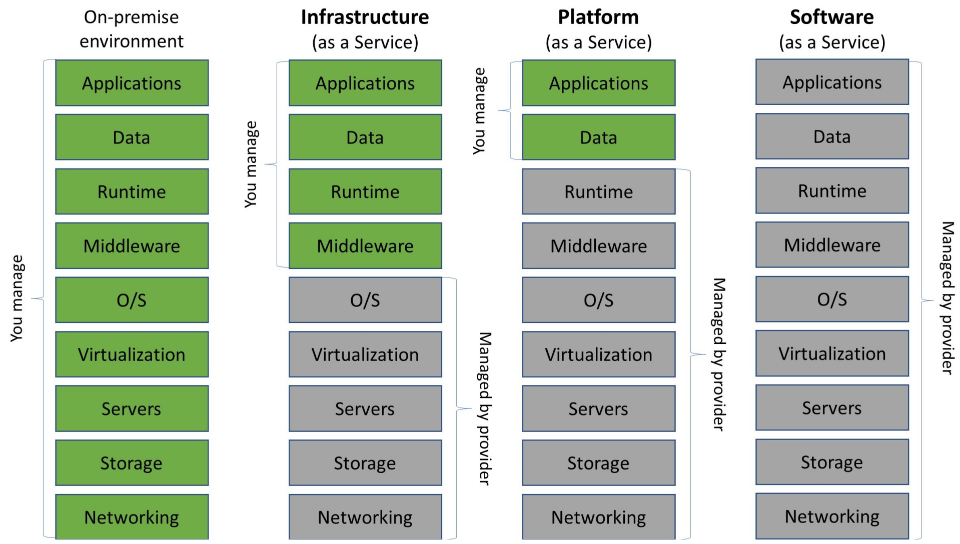

Figure 6: Levels of cloud integration (Vemula & Zsifkovits, 2016)

From the four levels of integration, Infrastructure as a Service (IaaS) is in general the most customizable, but also the most expensive not taking into account an on-premise environment. Consequently, Software as a Service (SaaS) is more standardized but carries lower costs and a faster time-to-value. Platform as a Service (PaaS) is the middleway between the two. In general, CCTs have a lower cost, better information visibility (since everyone is on the same system), and faster deployment than on-premise environments (A. Singh, Mishra, Imran, Shukla, & Shankar, 2015).

Specific advantages for CCT in supply chain management are (Vemula & Zsifkovits, 2016):

- **Cloud-based platforms** help organizations to identify more accurate demand forecasts for all the parties in the supply chain, by coordinating all the involved parties. This can partly eliminate the bullwhip effect.
- **(Shared) databases** can help in supplier selection if information is stored about suppliers. Customers can then select the supplier with characteristics that best fits their requirements (e.g. lower cost but longer lead time).
- **Real-time data communication** between involved parties to monitor the supply chain network.

- **Influence capabilities of logistics players** to adequately organize and execute order processing, logistics network design, inbound and outbound transportation, inventory management, freight and fleet management, global trade management, customs clearance, warehousing, distribution, and other value-added services.

CCT is promising in the context of supply chain information sharing, since by using a hybrid model a firm can choose to keep some (sensitive) information to itself, whilst sharing the rest of the information with its supply chain partners. If the CCT is rolled out in the whole supply chain, there is no need to worry about system interoperability issues, and all participants can access all of the relevant data in real time.

2.3.7 Blockchain technology

There are some disadvantages in the use of CCT which may be overcome by blockchain technology, the technology behind the infamous cryptocurrency Bitcoin (and other cryptocurrencies). For example, for CCT a trusted third party is often needed in practice to manage the system and gain the benefits. Besides that, it is based on a centralized information depository, which can become a single point of failure (Abeyratne & Monfared, 2016).

Blockchain integration in the supply chain minimizes the need for unnecessary third-party intermediaries and can be applied for business-to-business transactions (Korpela et al., 2017). As the word itself says, a blockchain is a chain of blocks, where each block contains a record of transactional data since the last block was added to the chain (Abeyratne & Monfared, 2016; Bahga & Madisetti, 2016). A blockchain is a distributed database with all of the transactional data on the network, meaning that every participant (often called 'node') can read the transactions. Since all of the nodes in the network can read the transactional data, and this data is stored on every node in a decentralized way, it is almost impossible for one party to change data in past blocks. The majority of the nodes has to agree about changing past data, making fraud nearly impossible if the network size is big. A schematic overview of a blockchain transaction is given in Figure 7.

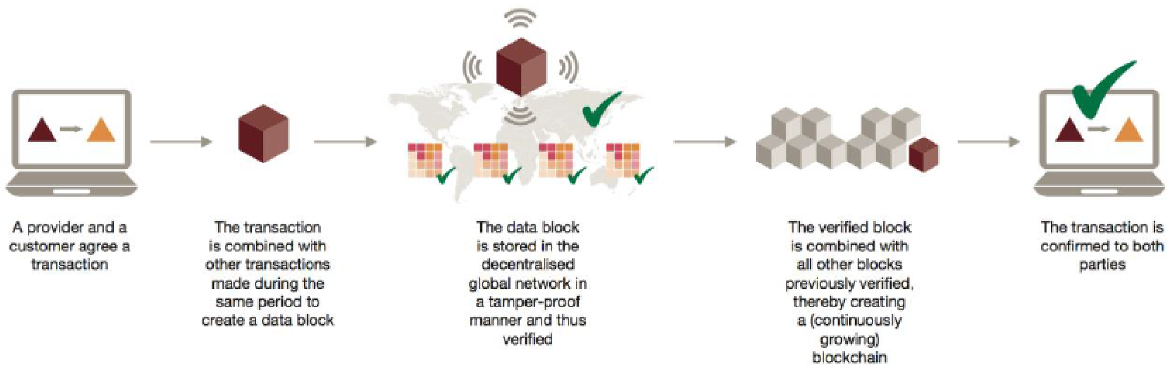

Figure 7: The Blockchain process (Hasse et al., 2016)

The technological advantages of Blockchain technology are summarized below (Abeyratne & Monfared, 2016).

- **Durability**, since there is no more single point of failure (i.e. a centralized database)

- **Transparency**, since an identical copy of the blockchain is made on every node of the network
- **Immutability**, since changes need to be validated by the majority of the nodes, and changes are traceable
- **Process integrity**, since the distributed open source protocols are by nature executed exactly as written in the code

There are two applications of blockchain technology which are gaining attention and are useful in supply chain management, which are (1) the blockchain ledger (i.e. the shared transactional database) and (2) smart contracts (Korpela et al., 2017; Sikorski et al., 2017).

The blockchain ledger is of interest since it has the potential to provide full end-to-end visibility of a production process. This has many applications, such as tracking the ingredients of a pharmaceutical, or demonstrating the authenticity of a luxury handbag (Kim & Laskowski, 2016). Furthermore, it could be used as a platform for the industrial internet of things (Bahga & Madisetti, 2016), improving traceability (e.g. supply chain tracking), on-demand manufacturing, and smart diagnostics & machine maintenance. Examples of product data included in the blockchain are ownership data, time stamping, location data, and product specific data.

The other main application of blockchain technology is the use of smart contracts. A smart contract is defined as: "a piece of software that represents a business arrangement and executes itself automatically under pre-determined circumstances" (Kim & Laskowski, 2016). For example, when a customer receives a product and scans its RFID tag, an automatic transaction is made to the supplier.

Blockchain technology has very promising applications to supply chain management, improving visibility and efficiency. Because of the characteristics of blockchain technology, it can be used to overcome some of the most significant barriers to information sharing. These barriers include lack of interoperability of IT systems, high cost associated with IT systems, and not enough trust in IT systems.

2.4 Combinations of technologies

To achieve the maximum potential of a digital supply chain, a combination of the beforementioned technologies is necessary. The number of combinations and possible applications for the new technologies is infinite. However, there are some combinations and applications of technologies which receive special attention in the literature. According to Eastwood (2017) and Spend Matters Team (2016), the combination of Blockchain technology and IoT has the biggest potential to complete revolutionize the supply chain. Another promising combination of technologies is integration of cloud computing and IoT, resulting in the Cloud of Things (Díaz, Martín, & Rubio, 2016).

2.4.1 Blockchain & IoT

Eastwood (2017) describes some areas where IoT and blockchain can be combined. The most promising area is leveraging of the blockchain to improve the workflow and provide instant overviews of business processes. All the supply chain partners can view any aspect of the supply chain and status of the documents in real time. Besides that, asset life cycles can be managed on a blockchain, providing information about the full asset history, maintenance, breakdowns, and (previous) ownership.

Blockchain technology can improve supply chain management by its two main properties: transparency and immutability. Currently, there is increasing demand from consumers for transparency, accountability, and social responsibility in the supply chain (J. H. Lee & Pilkington, 2017). Combining blockchain technology with IoT enables a connection between the physical and digital identity of an object. This results in more traceability, satisfying the need for accountability and social responsibility. Furthermore, increased process complexity due to the trend of outsourcing increases the need for real-time data flows between key supply chain partners. Again, blockchain can help facilitate these real-time data flows. However, implementation of blockchain technology requires full cooperation of all parties involved in the supply chain, which poses significant problems for implementation.

2.4.2 Cloud computing & IoT

The combination of cloud computing and IoT is almost inevitable, because cloud computing is able to mitigate the drawbacks of IoT (Díaz et al., 2016). IoT sensors usually are low power, low memory, low battery, and have limited network access. This results in a need for computing, storage, access, and analysis of IoT data. Furthermore, there is often a large amount of devices ('things') present and these devices produce heterogeneous data. Cloud computing offers virtually unlimited capabilities in terms of storage and processing power, and can handle heterogeneous data. The resulting combination called Cloud of Things resolves the limitations of IoT and provides new opportunities, for example, Sensing-as-a-Service (SaaS).

The full integration of cloud computing and IoT has to satisfy three different categories (Díaz et al., 2016). (1) There need to be cloud platforms which are used to mitigate IoT's limitations, offer new business opportunities, and enable scalability. (2) There needs to be a cloud infrastructure to deploy, manage, and control the cloud platforms. (3) IoT middleware is needed to allow communication between IoT devices and the cloud system.

2.5 Effect of information availability on the organization

The before-mentioned technologies have the potential to provide real-time end-to-end visibility of the whole supply chain. IT can help to facilitate information sharing (Wu et al., 2016). This makes it interesting to find out how the before-mentioned technologies can reduce the identified barriers to information sharing. The increased information availability and resulting supply chain visibility have the potential to affect an organization in various ways. (1) The organizational structure may be affected, as well as its hierarchy. (2) Decision making may change due to changed availability and nature of information. For example, employees could be affected in their decision making since they have a lot more objective information to act upon because of accurate, real-time information availability. (3) Well-being of employees may change, for example, due to the availability of performance data, or reduced job demands since tasks are partially taken over by a system.

2.5.1 Organizational structure

The impact of supply chain digitalization on organizational structure is important because organizational structure is a driver of firm performance (Farhanghi, Abbaspour, & Ghassemi, 2013). In the past, information technology which increased availability of information led to the change of organizational forms (Farhanghi et al., 2013). The organizational structure changed from a vertically integrated, functional structure to a divisional structure. This was the result of increasing popularity of information technology in the 1980s. Information technology kept gaining popularity and organizational structures evolved further to matrix, hybrid, and network structures ("The evolution of information systems: their impact on organizations and structures", 2002). These new organizational structures were necessary to cope with new environmental realities and were enabled by the increased possibilities of information sharing due to IT developments. Thus, changed information availability due to new technologies may alter an organization's structure enabling it to cope with a changed environment.

Due to increased information availability, more decisions are made at lower organizational levels (Bloom, 2016; Farhanghi et al., 2013; Mocetti, Pagnini, & Sette, 2017). As a result, the number of hierarchical levels in the organization can be reduced, i.e. the organizational structure can become flatter. In practice this means there would be more delegation of decision making to lower-level employees (Mocetti et al., 2017). Furthermore, in an early study it was found that increased availability of information through information systems would lead to a decline in operators and supervisors, an increase in upper-level managers, and consolidation of departments, meaning that departments are combined into a more effective and coherent whole ("The evolution of information systems: their impact on organizations and structures", 2002). The decline of the number of operators and supervisors is justified by the increasing automation of processes. Since more and more processes are automated, the role of the regular factory operator changes from operating a machine to supervising a group of machines. In addition, less operators results in a decrease in the amount of supervisors needed, narrowing the span of control in the organization (Farhanghi et al., 2013). Finally, due to the organization being less hierarchical, with narrower spans of control, the level of bureaucracy decreases, resulting in a more flexible organization. These effects are summarized in Table 3.

Table 3: Early impact of computers on organizations (Mukherji & Ananda, 2012)

Organization structure	**Decision making**	**Authority and control**	**Job content**
Decline in clerks and supervisors	Consolidation of separate decision systems	Centralization of control	Routinization at lower levels and broadening at upper levels
Increase in upper-level managers	Upward shift in decision making	Increase in machine control	Decline in interpersonal communication after computers
Decline in number of levels	Rational and quantified decision making	Control over individual behaviour	Increase in communication during system development
Consolidation of departments	Rigidity and inflexibility in decision making	Blurring of traditional lines of authority and control	Decline of skill levels at lower and middle levels, increase in skill levels at upper levels

2.5.2 Decision making

Up until now, not much has been written about the effects of information availability on decision making in a digital supply chain context. However, parallels could be drawn with past technological implementations enhancing information availability. For example, Huber (1990) researched the effect of advanced information technologies on organizational design, intelligence, and decision making. Huber (1990) formulated several propositions regarding the effect of advanced information technologies on an organization's structure and decision-making processes. These include that advanced information technologies lead to higher quality and more informed decisions, reduce the time required to authorize proposed strategical actions, and reduce the time required to make operational decisions. Furthermore, Huber (1990) proposed a conceptual model regarding the effect on advanced information technologies on an organization. This model is given in Figure 8.

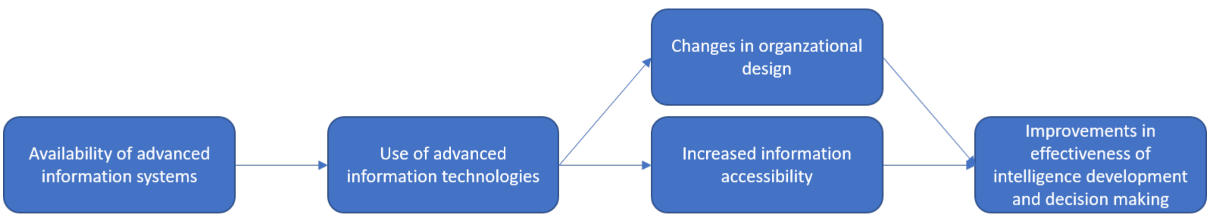

Figure 8: Conceptual model on the influence of advanced information technologies on an organization (Huber, 1990)

However, increased information availability may require more manual manipulation of the data, which could result in a burden of data rather than a benefit of information (Carton & Adam, 2010).

Marusich et al. (2016) conducted a study on the influence of accurate, task-relevant information on human decision-making performance in a command-and-control decision environment. Command-and-control environments are domains where information from diverse sources of varying quality must be quickly assimilated and shared among team members to make critical decisions (e.g. military operations). In the study, it was found that increasing the amount of accurate, task-relevant information would not necessarily lead to increased performance, due to the effect of information overload (i.e. getting too much information to process). In theory, this information would lead to better decisions, but due to the high amount of available information, humans choose to only use a selection of the available information. It was concluded that to benefit from increased information availability, better and more distributed information processing is needed.

A. K. Singh and Garg (2015) conducted a study on the influence of information integration on decision-making performance. They concluded that an increase in information integration would lead to more supply chain focused decision making, i.e. global optimization, rather than local optimization. Consequently, this improved supply chain performance.

It can be concluded that the effect of information availability on decision making is dependent on the characteristics of the information shared. If the additional information adds more noise than real information, and there is only a human decision maker, the additional information could be left unused as a result of information overload. If this is not the case, increased information availability leads to faster, more informed decisions, improving the quality of decision making. Furthermore, integration of information throughout the supply chain results in decision making which is more focused on global optimization rather than local optimization.

2.5.3 Employee well-being

An organization's employees are affected by the digital transformation as well. "The evolution of information systems: their impact on organizations and structures" (2002) state that information systems would lead to routinization of tasks at lower levels and broadening of tasks at upper levels. Therefore, employees at upper levels would become more motivated in performing their tasks, whereas employees at lower levels would become more easily bored. Furthermore, information systems would lead to a decline in interpersonal communication, but in an increase in communication during the development of the information systems. Besides that, there would be a deterioration of skill levels for the lower and middle level employees, and an increase in skill levels for employees at the upper levels.

Increased process visibility allows for more accurate tracking and tracing of business processes. As a result, performance data of individual employees may become available. Availability of performance data could lead to an increase in the amount of perceived job demands, due to employees perceiving a pressure to perform. However, a decline of interpersonal communication could reduce perceived emotional job demands. Job demands are negatively related with job performance if job demands are above a certain level (Bakker et al., 2004). Thus, assuming that job demands are above this level, a decrease in job demands is related with an increase in job performance. On the other hand, increased process visibility could function as a resource for employees, since it could enable them to anticipate high-demand periods and prepare themselves accordingly. The increased job resources would lead to increased work engagement, which has a positive relationship with job performance (Bakker et al., 2004). Because there are multiple factors changing due to information availability and process visibility, it is not possible to draw a conclusion about the effect of the technologies on job performance ex ante without empirical research. The relationships between the concepts (i.e. job demands, resources, exhaustion,...) are given schematically in Figure 9.

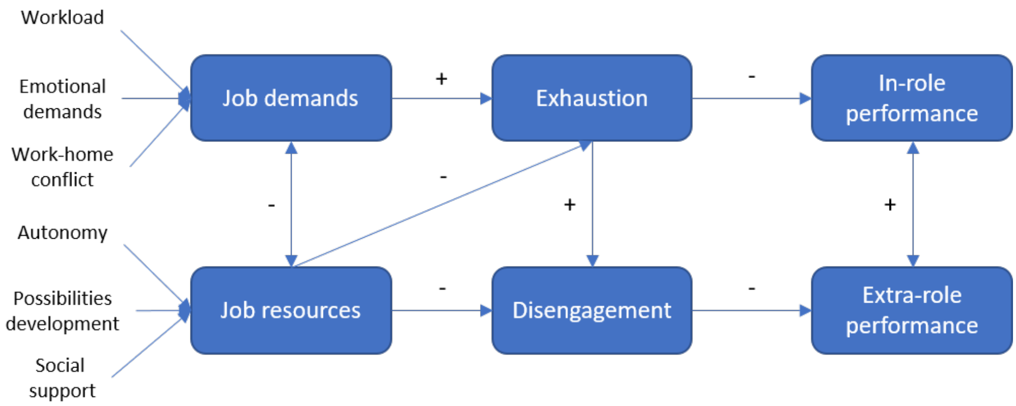

Figure 9: Schematic job-demands resources model applied to burnout and performance Bakker et al. (2004)

2.6 Concluding remarks

The most important enabler of an integrated supply chain is sharing of good information. Information sharing on itself is not necessarily sufficient; the characteristics of the information shared determine the effect of information sharing on business performance. Several advantages of- and barriers to information sharing were identified. The advantages of information sharing deal with improvement of service levels or reduction of costs. Main barriers to information sharing are of managerial or technological nature. Furthermore, for effective information sharing, a firm first needs to organize its internal information sharing, before considering external information sharing.

The fourth industrial revolution is happening now and inherent to this revolution is the digital transformation of the supply chain. In the digital supply chain, integration is achieved through digitalization of processes, greatly increasing the amount and quality of information available. Several technologies enabling the digitalization of processes were identified, as well as potential applications to supply chain management. Finally, potential impacts of changed information availability on business performance have been identified on the organizational, and employee level.

Research model formulation Based on the found organizational impacts, the research model given in Figure 10 is proposed. From Huber (1990), the influence of supply chain digitization (i.e. advanced information technologies) on organizational structure, information availability, decision making, and decision making was derived. However, the findings in section 2.5.1 indicated that a relationship between information availability, organizational structure, and decision making would be more likely. Thus, the model by Huber (1990) was adapted to represent this relationship. Consequently, the relationship between decision making and business performance was found from the results of

A. K. Singh and Garg (2015). The effect of changed information availability on employee well-being and subsequent business performance was derived from Bakker et al. (2004).

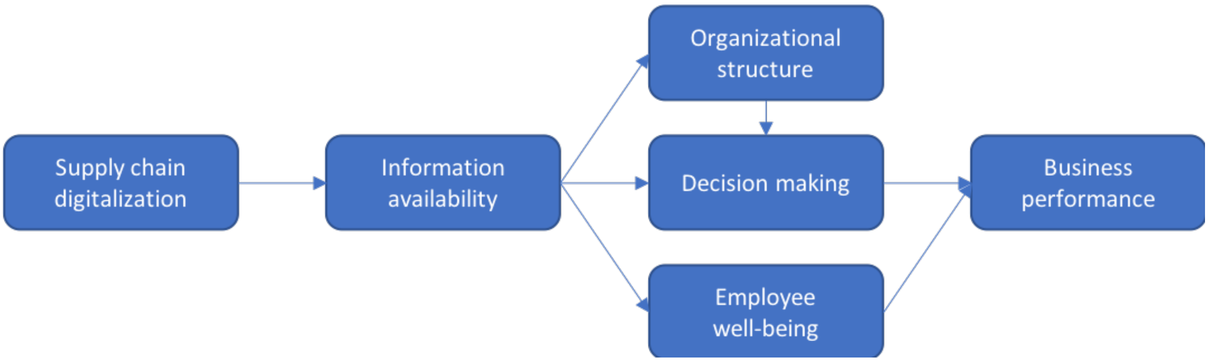

Figure 10: Research model

Chapter 3

Methodology

3.1 Organizational and industry context

The research was conducted as a part of an internship at the management consulting department of Accenture, with a focus on the resources industry. The resources industry encompasses three different sectors: energy, chemical, and utilities. Because of the focus on supply chain digitalization, the energy and chemical sectors are most relevant for theory induction purposes since the supply chains in those sectors are closest to a 'traditional' manufacturing supply chain. More specifically, the focus of the thesis was on the intersection between the process industry and the resources industry, as depicted in Figure 11. This resulted in a higher degree of generalisability for the thesis' results, whilst maintaining the specificity of the results such that they are useful and can be directly applied for Accenture and its clients.

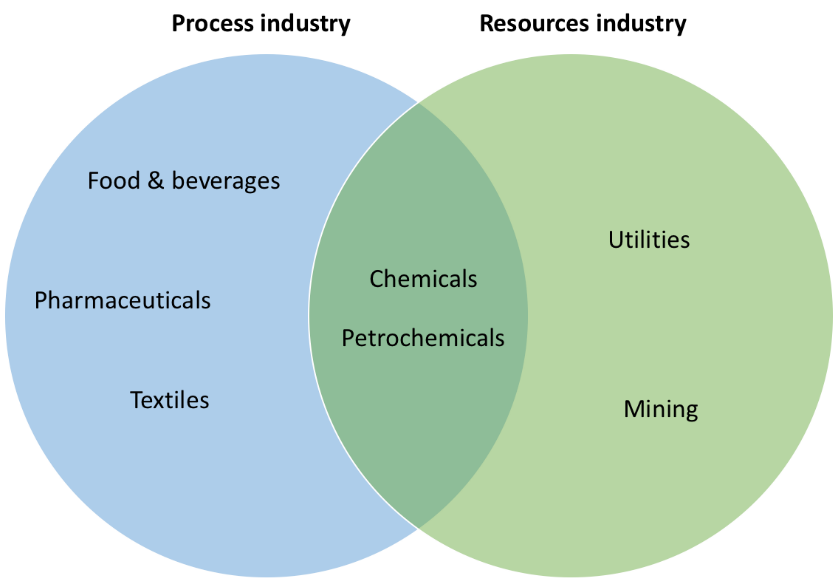

Figure 11: Industrial context of the thesis

3.2 Problem statement

As uncovered in the literature study, the digital transformation of the supply chain will have a big impact on supply chains, organizations, and individuals. The digital supply chain is a novel subject where not much research has been conducted on. Research efforts mainly focus on technology, rather than the combination of technology, organization, and people. Furthermore, information sharing plays a crucial role in supply chain digitalization, enabling collaboration and improving alignment throughout the supply chain, but also for firms internally. Information sharing is accelerated because of the huge increases in data and the development of novel technologies to put this data to work and transform it into valuable information. Thus, information availability increases due to supply chain digitalization. However, the impact of this information availability on an organization and its performance is not known. Therefore, the management question leading this study was: **"How does supply chain digitalization affect information availability and how does this in turn affect business performance?"**. Note that information availability is the result of effective information sharing.

3.3 Research objectives

3.3.1 Research questions

Based on the information obtained in the literature study, the proposed research model and guided by the problem statement, the subject of study was delineated. Using this information and keeping the main question in mind (i.e. "What are the organizational impacts of supply chain digitalization?"), the following research questions and sub-questions were formulated:

1. What are the most promising use cases for the digital transformation of the resources supply chain?
    - Which technologies play a role in these use cases?
    - What is the advantage of these use cases compared to existing technologies?
2. How does within-firm information availability change due to the digital transformation of the supply chain for the selected use cases?
    - What is the effect on the type of information?
    - What is the effect on the quality of information?
    - What is the effect on the timing of information?
    - What is the effect on the ease of access of information?
    - What is the effect on the controllability of information?
3. How does the changed information availability affect the organization?
    - What effect does the changed information availability have on organizational structure?
    - What effect does the changed information availability have on decision making?

- What effect does the changed information availability have on employee well-being?

4. How do changed organizational structure, decision making, and employee well-being affect business performance?

Since supply chain digitalization is a broad concept, a selection needed to be made considering the technologies and their applications enabling a digital supply chain. To do so, the most promising and potentially disrupting use cases of new technologies were explored and selected. A use case is a specific application of a technology, e.g. a use case for a mobile phone could be to make phone calls. The requirements for selecting these use cases were that they still should have the potential to change supply chains, i.e. the technologies are not yet mature. On the other hand, it had to be reasonably likely that the use cases would be applied in the future. It was allowed and encouraged for the selection to include combinations of technologies, for example IoT and blockchain, as seen in the literature review. The use case selection process is described in chapter 4

The technologies and corresponding use cases inherent to the digital transformation of the supply chain change the way information is shared and becomes available in the supply chain. The information will be shared in a different way, on different places and at different times. This will affect the availability of information to several stakeholders in a firm in different ways. Therefore, it was important to understand what type of information becomes available as a result of application of the use cases and if this information creates value. Furthermore, the quality of the information was important; the information should be accurate and reliable. The timing of the information affects its usefulness: real-time information has more potential to improve performance. Information should be easily accessible to lower the barriers of putting it to work. Finally, access to the shared information should be controlled and privacy should be protected. For example, when two retailers are sharing information with one common supplier, the information shared by the retailers should only be available to the supplier and not to the other retailer (unless this was agreed upon).

Consequently, the impact of the increased availability of information was analysed on three different aspects. These aspects were organizational structure, decision making, and employee well-being. Note that decision making and employee well-being consider the decision making and well-being of the decision makers in an organization or process. Decision makers are chosen as a focus point of this study, since they are the ones directly affected by changed information availability. Examples of the potential influence of changed information availability are: (1) increased information availability can make the organizational structure more decentralized and flatter, (2) the decision-making process may be sped up or slowed down by increased information availability, and (3) well-being may be affected by the availability and accessibility of performance data, increasing well-being if the performance data is made public because people in the organization can see what they contribute to the firm.

Finally, the altered organizational structure, decision making, and employee well-being respectively affect business performance. This research question is important since it relates the scientific research to real-life applications. If the changed factors do not lead to increased business performance, then the incentives to implement the change (i.e. implementation of a digital supply chain) will diminish. Since managers often have a short-term focus while considering an investment, the short-term effects on business performance were assessed. Furthermore, if some of the selected use cases were already implemented and running for an extended amount of time, the long-term effects could be assessed as well.

3.3.2 Research goals

This research has two main goals. The first goal is business related, i.e. help Accenture and its clients to better understand the influences of supply chain digitalization on information sharing, and the resulting impact of the changed information sharing on the organizational structure, managerial decision making, and employee well-being. Consequently, the effects of these organizational factors on business performance will be assessed.

The second goal is scientific, i.e. contribute to the literature on supply chain digitalization. To achieve these goals, the relationships between the concepts must be analysed thoroughly. By answering the research questions, the two goals can be achieved simultaneously.

To document the research goals, multiple deliverables were produced. First, the thesis report, presentation and mandatory scientific poster are guaranteed outputs of the study. Besides that, a specific report for one of Accenture's clients was produced, regarding a case study on the effect of digitalization which was used for this research. This report includes a thorough description of the case, opinions of stakeholders, and managerial recommendations. Finally, a document called a "point-of-view" was produced for Accenture, which contains a summary of the study with a focus on the business implications.

3.4 Research methodology

The comparative case study approach proposed by Dul and Hak (2007) was used as a framework for conducting the research. It was clear theory-oriented research had to be used, since there existed a gap in the literature regarding the effect of supply chain digitalization on an organization and its employees. Consequently, in the literature study, an exploration of theory was conducted, to be able to formulate propositions. However, there was not enough information in the literature to formulate propositions for each of the relationships in the research model. More specifically, propositions were found regarding the impact of information availability on the organizational factors and on business performance. However, no propositions were found on the effect and use cases of the technologies on information availability.

Therefore, an exploration of practice needed to be undertaken to find propositions the missing propositions. Since a set of propositions was readily found in the exploration of theory, the exploration of practice was also used to confirm the relevance of the readily-identified propositions. To identify the most promising use cases in the digital transformation of the supply chain, and to determine the effect of these use cases on information availability (i.e. finding the missing propositions), semi-structured interviews with various supply chain- and technology experts from within Accenture were held. The identification of the use cases still dealt with delimitation of the problem, i.e. determining where the focal points would lie Dul and Hak (2007). It was chosen to use semi-structured interviews since they have the potential to identify a large number of factors affecting information availability, which helped to achieve the most scientific rigour given the novelty of the technologies (Mason, 2017).

In the exploration of practice, the missing propositions were determined, and the existing propositions were (partially) verified. Because there were now propositions available for all relationships, it was clear that theory-testing research had to be used. Furthermore, since most of the propositions were not tested in the same context as for the selected use cases, initial theory testing was required.

Consequently, the most promising use case was analysed and the propositions were tested using a comparative case study of a proof-of-concept. This will be referred to as the pilot case study. According to the guidelines by Dul and Hak (2007), the preferred research strategy for the formulated propositions was an experiment. However, organizing an experiment was not feasible because of limited resources. Therefore, a case study approach was chosen as the research method. In the case study, multiple data sources were combined to achieve reliable results. The cases were different phases in a project on which Accenture was assisting a leading chemical company on a digitalization project. The exact methodology regarding the case study is given in chapter 5.2.

The decisions made, as well as the methodologies used are summarized in Figure 12.

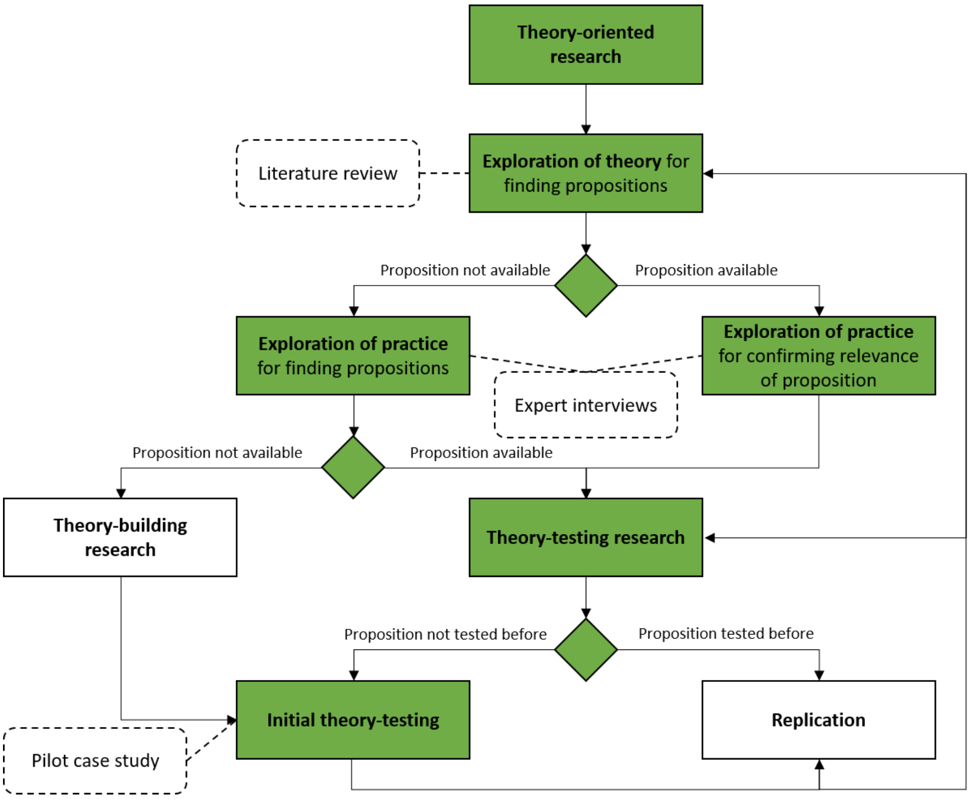

Figure 12: Research choices and methodologies based on Dul and Hak (2007)

3.5 Importance

The importance of this study stems from the fact that the digital transformation of the supply chain is happening now and will significantly impact supply chains, individual organizations and their employees. However, current research on the organizational impacts of the digital transformation of supply chains is limited. This could be the result of the novelty of the technologies and unclear applications. This study aims to identify the most promising use cases of the new technologies, their influence on information availability, and the effect of the changed information availability on decision makers and decision making. The results of this study may be used as a basis for further research on supply chain digitalization and application of new technologies.

This study is relevant for business purposes since it aims to identify the impact of the technologies on an organization, identifying potential factors of resistance against implementation, and assessing the impact on business performance. The specific applications of the technologies are the use cases, and one technology or combination of technologies can have multiple use cases. The study provides advantages and disadvantages of the identified use cases, making it easier to identify the use case which fits a given real-world scenario best.

Chapter 4

Use case selection

In this part of the research, an identification of the most promising technologies as well as the corresponding use cases was made. Consequently, it was determined which of the selected use cases would have the most impact on future supply chains and how this use case(s) would affect future supply chains. The observations were used to scope the thesis more, formulate additional propositions, and confirm the relevance of (some of) the previously identified propositions.

Because literature on the topic of supply chain digitization was very limited, information regarding the most promising use cases needed to be found in another way. Therefore, interviews were held with several professionals within Accenture, since they work with these technologies and are in close contact with clients. As a result, they have an idea where current bottlenecks lie, which technologies can resolve this, and how they should be applied.

4.1 Interview methodology

4.1.1 Interview development

The objective of these interviews was twofold: the interviews were used to (1) determine which use cases of supply chain digitalization technologies are the most promising and disruptive for a resources supply chain (i.e. provide additional scoping for the research) and (2) get an idea of the influence of these use cases on information sharing and availability (i.e. finding additional propositions, and confirming the relevance of readily-determined propositions). Keeping these objectives in mind, semi-structured interviews were chosen as the interview method. This method was chosen because semi-structured interviews offer more guidance (compared to unstructured interviews), such that the desired interview objectives can be achieved. That is, using the semi-structured interview method, it is ensured the main questions are answered. Besides that, the semi-structured interview method gives the interviewee the opportunity to explain why something is as described and provide additional inputs. That is, it could provide more insight in factors influencing relationships between concepts, compared to structured interviews (Mason, 2017).

Scoping of interview questions Because the semi-structured interviewing method was used, it was necessary that (the scope of) the interview questions had a good balance with respect to how structured they were. If this was not the case, either the interview objectives could not be achieved or potentially valuable insights would be missed. Too broad interview questions (i.e. too unstructured) would lead to not obtaining the specific knowledge required to satisfy the interviews objectives. Too narrow interview questions (i.e. too structured) would lead to the interviewees solely answering the questions, missing potentially important insights. The right scope of the interviews was achieved by asking open, but specific questions. This meant that some questions had to be split up in sub questions. For example, to determine the impact of a technology on information availability, it was asked what the influence of the technology was on the type of information, the quality of information, etc. (see Appendix A).

Interview structure

The interview was split up in three parts: the goal of the first part was to select and describe the most promising use cases, the second part served to understand the influence of the use case on information sharing and availability. Finally, the third part was used to get a general idea of the influence of information sharing on organizations.

Use case identification In the first part, the questions asked dealt with which technologies and combinations of technologies are promising, how they should be put to work (i.e. what is the use case), and what advantage these use cases offer over existing use cases. If necessary, additional questions were asked to determine the reasoning behind the statements. For example, why a specific technology or combination of technologies would be promising.

Effect of use cases on information The second part of the interview was used to assess the expected impact of the selected use cases on information availability. This part was used to identify the missing propositions (i.e. the influence of the selected use case on information availability). The selected use cases were given by the interviewee in the first part of the interview. To determine the change in information availability, the framework of classifying information by Wu et al. (2016) was used for guidelines. Here, it was asked how information sharing and the available information to decision makers would change as a result of the use case(s) selected in the first part, according to the six dimensions by Wu et al. (2016) and as described in section 2.1. The dimensions are:

- Type of information
- Quality of information
- Timing of information
- Speed of information
- Accessibility of information
- Controllability of information

The questions asked in this part were quite specific, for example, "What do you think the effect is of use case x on the quality of information?". This resulted in a more structured interview, which proved to be useful in formulating the propositions.

Organizational impact of information availability The third part of the interview was, opposed to the second part, rather unstructured and open-ended. This part dealt with an exploration of the effects of changed information availability on an organization. included to get a preliminary idea of the effects of the different use cases, and to confirm the relevance of the propositions identified from the literature study.

During the closing of the interview it was asked whether the interviewee had experience with or knew if there were some proof-of-concepts or pilots with the use case(s) discussed. These inputs were then used to target potential candidate cases for the subsequent case study.

The general interview format is given in Appendix A.

4.1.2 Interviewing process

In total, 12 interviews were held, of which the majority was held face-to-face. However, because of full agendas two interviews could not be conducted face-to-face and were held via Skype. The face-to-face interviews were either held in private workspaces or in a more public part of the office (with background noise), depending on the availability of private workspaces. Furthermore, one of the interviews was held with two interviewees at once. Because of the interviewing locations and to retain an informal character (i.e. 'conversations with a purpose', rather than formal interviews (Mason, 2017)), notes were taken during the interviews, rather than recording and transcribing the interviews. Furthermore, if it was chosen to require transcription of all of the interviews, interview planning would have been a lot more difficult. Besides that, note-taking did not significantly affect the quality of the interview results, because of the interview objectives. That is, statements did not have to be analysed to the smallest detail to satisfy the interview objectives.

The interviews were conducted in Dutch, because all of the interviewees were Dutch and this would reduce any potential language barriers. In case the answers to the interview questions were (too) short, several probing techniques were studied beforehand. However, this surprisingly did not occur and all of the answers were lengthy and well supported with real-life examples. Usually, there was sufficient time to conduct the interviews, so this generally did not impose any obstacle. In the cases where time was pressing, it was mentioned beforehand such that the interviewee could anticipate on this. The interviews took between 30 and 45 minutes each.

4.1.3 Sample requirements

To conduct the interviews and achieve the interview objectives, several experts and practitioners from within Accenture were targeted. These potential interview candidates were found using (1) inputs from the thesis supervisor at Accenture, (2) the people page, which is similar to an internal Facebook page, and (3) a 'snowballing method', where interviewees provided input for additional interview candidates. The interview candidates were preferably specialized in the resources industry, since this is the industry context of the thesis. Furthermore, from these potential candidates it was desirable to interview people who have expertise in supply chain management, the digital transformation (of supply chains), change management, and experts on the technologies involved.

Description organizational structure

To describe the demographics of the interview sample, it is useful to first describe the basics of Accenture's organizational structure. Accenture specializes in five different service domains: strategy, consulting, digital, technology, and operations. Important to note is that the consulting specialization is split up in management consulting and technology consulting. Within the service domains, there are different fields, such as supply chain & operations, finance, human resources. All of the service domains, except for strategy, are split up in industry specializations, to provide clients with industry-specific knowledge. Examples of industries are resources (which is composed of utilities, energy, and chemical), financial services, and retail. As can be seen from the resources example, the industries can be further split up in sub-industries. Finally, besides their official role, some of the interviewees are specialized in a certain technology, for instance, by being a member of an internal focus group.

Demographics of interviewed sample

Using the basics of the organizational structure explained in the preceding paragraph, the demographics of the interviewed sample will be explained according to seniority, field specialization, industry, and specializations through focus groups. In total 12, interviews were held.

The interviewees are all employed at Accenture and are from different seniorities in the organization. These seniorities span from consultants to managing directors. The seniorities indicate a level of experience, i.e. of the interviewees, a consultant has the least experience in the field, where a managing director has the most experience. The group of interviewees consists of two consultants, five managers, four senior managers, and one managing director.

These interviewees are from different service domains. Two interviewees are from the digital branch, four interviewees are from the strategy branch, two are from the technology branch, and four interviewees are from the consulting branch, of which three are from technology consulting, and one from management consulting.

Furthermore, seven interviewees specialize in the resources industry, the remaining five interviewees do not specialize in a specific industry and work cross-industry.

Some of the interviewees have one or more specializations regarding specific technologies. The sample included people with additional knowledge in blockchain technology, analytics, AI, RPA, IoT, cloud computing, and mobility. Furthermore, the sample included a digital transformation expert, change management professionals, and supply chain management professionals.

The specific demographics are given in Appendix B.

4.2 Interview results

In the interviews, several technologies were mentioned, of which one (mobility) was not analysed in the literature review. However, this technology was only mentioned once and does (according to the interviews) not play a pivotal role in the future of resources supply chains. The technologies and the frequency of them being mentioned as 'most promising' are given in Table 4.

Table 4: Frequency of mentioned technologies

Technologies	# times mentioned
IoT	6
Blockchain	5
Cloud computing technologies	4
Advanced analytics	2
AI/machine learning	2
RPA	1
Mobility	1

Note that the sum of the number of times mentioned is greater than the amount of interviews held. This is because it was allowed and encouraged to give a combination of technologies, inherent to a use case. The most often-mentioned combination of technologies was the combination of IoT and cloud computing, sometimes complemented by advanced analytical techniques.

The interview results are presented in the remainder of this section. The results are grouped based on the technology which plays the most important role. Consequently, each of the use cases found in the interviews is described, advantages are given, as well as the effect on information sharing, and (when available) the potential organizational impact is described.

4.2.1 Blockchain

Blockchain - Use cases

Manager 1 and Consultant, both blockchain experts from the strategy department, state that the most promising use case is without doubt blockchain technology. The best use case for blockchain technology is dependent on the situation of the organization. In other words, the best use case depends on the bottlenecks an organization faces and where these inefficiencies lie.

According to them, the main advantages of blockchain technology in a supply chain context are transparency and reliability. For example, if a company has a transparent decision making process about demand forecasting, its supply chain partners will be more willing to cooperate if they know the rationale behind its decisions.

Manager 4 works in technology consulting, specializing in the resources industry with a focus on utilities, he has blockchain expertise. He sees a great potential in the use of blockchain technology in the supply chain, and sees asset tracking as the main use case. Hemainly sees asset tracking as tracking the location and status of assets, including a maintenance history. Furthermore, provenance of the assets could be recorded on the blockchain as well. However, he states that companies should be cirtical about the block chain use cases that would make sense to them. For example, if you are the sole owner of the assets and do not intend to sell them later, there might be more suitable options for tracking that blockchain. Thus, blockchain is mainly useful in multi-stakeholder contexts. In these contexts, the tracking information could be leveraged to increase efficiency, because location and status (including maintenance history) of the asset can be seen, providing opportunities for reduction of downtime.

Senior manager 2 specializes in industry strategy, and has a general interest for new technologies. He envisions a future where blockchain and IoT can be combined, which can be used for asset tracking, but also for order tracking. IoT could then be used in a firm to internally collect a big amount of data, and put this data to work to be used for (internal) decision making. After the transformation of this data into information, some of it can be put on a blockchain. Examples are order status, throughput time, and information about assets (e.g. pallets and/or containers).

According to Senior manager 2, the combination of these technologies increases the amount of (reliable) data available for decision making, increasing transparency. This increased transparency leads in its turn to more objective decision making, giving the decisions more 'power', because the reasoning behind a decision becomes visible.

Finally, Senior manager 1, specializing in technology architecture, poses that smart contracting is a promising application of blockchain technology. It can be used to digitalize contracts which are not uncommonly over 50 pages in length. In the short term, this reduces the paper trail, in the long term it is also helpful to prevent discussions about the terms of a contract. This way of contracting makes sure the contract is executed in the pre-specified way.

Blockchain - Influence on information sharing and availability

According to Manager 1 and Consultant, blockchain does not necessarily affect the type of information shared, since a blockchain is just another database technology. What changes is the way information gets transferred. Furthermore, the quality and reliability of the information improves significantly, since everyone in the blockchain saves the information in their own 'notebook' (i.e. in a decentralized way). The information stored is mainly useful for track & trace purposes, as well as ex-post analysis of the information. As a result, the advantages of the technology do not lie in a context where real-time information is required. The information could be in near-real time available for private blockchains. This is due to the need to validate transactions, which takes a short amount of time (a couple of seconds). The accessibility of the information depends on the chosen mechanism. A blockchain could be completely public (e.g. in the case of Bitcoin). Besides that, private blockchains exist, where new participants either get accepted by consensus from the other participants in the network, or by one or more 'authorities' in the network. Finally, a member of the blockchain can choose to whom the shared information becomes available, preventing competitors accessing sensitive information. Control over the information is hard, i.e. in most cases it is not possible to change or delete something from the blockchain, so when a blockchain member puts something on the blockchain, this could be eternally visible for the other blockchain members. This is one of the advantages of blockchain technology, i.e. create an auditable trail of information.

In the cases of asset and order tracking, where IoT is involved, data sources are combined. This provides a big, heterogeneous data stream from the IoT sources, which could be advantageous according to Senior manager 2. The data stream is useful since it can be used to obtain more and better information to improve decision making. Furthermore, due to the transparency the blockchain provides, production and/or transaction data becomes available upstream and downstream. This results (at least) in an improved overview of demand. For IoT, data could be available in real time, and for blockchain this could be near-real time because of the characteristics of the technology (i.e. transactions need to be validated in the networks, which takes some time). For the gathered data, privacy could be an issue, but the biggest challenge is ownership of the data. This holds mainly for solutions where data is shared and stored in a cloud, since the question could arise whether the data is owned by the one who put it in, or by the one who analysed it, by the one who owns the physical location of the data, or by someone else. Furthermore, it is hard to know whether all data gets shared. For example, it could be useful to know for supply chain partners why a pallet fell in a certain factory, to identify potential bottlenecks. However, the factory may want to keep the information to itself.

Blockchain - Conclusion

Blockchain is a technology which has many potential applications and is set to significantly impact supply chains and business processes. With its main advantages of transparency and reliability, blockchain technology brings trust in a trustless world and is therefore especially suitable in multi-stakeholder contexts. Blockchain enables effective sharing of accurate, reliable information, provided that the information does not need to be available in real time. Finally, it has the potential to increase transparency and provide end-to-end visibility in supply chains. The current main use case of blockchain technology in a supply chain context is asset tracking.

4.2.2 Internet of Things

IoT - Use cases

According to Senior manager 2, there are three main applications of IoT. The first application is to realize efficiency improvements, and is regarded as a rather low-level use of IoT. The second application is facilitation of customer intimacy. For example, IoT can be used to tell a customer where its product currently is and what the remaining processing time is. The third and considered to be the most promising application of IoT is new business model generation. An example of new business model generation through the use of IoT is by selling products as a service, automatically replacing them when they wear out. IoT sensors play a role in this case, since they give an indication when a product needs to be replaced.

Manager 5 shares the same vision as Senior manager 2, and states that the main application of IoT should make use of sensors in places which are not physically connectible to a database. For example, by placing sensors in car/truck tires, to monitor their status and replace them when they are almost worn out. Applications in existing factories are possible as well, but there often is no real need for IoT: there are already sensors in place which are linked to a (local) database, only the different databases need to be integrated. Furthermore, Manager 5 states that IoT should be linked to a cloud-based solution, because of the transmission of data over the internet. It is possible to connect IoT sensors to an on-premise database, but this constrains the advantages of IoT because of limited potential to scale up.

A use case proposed by Senior manager 1 is a simple application of IoT. He states that IoT/RFID can be used to track containers and other packaging to ship full containers more often and reduce the amount of empty container transports. Integration could be difficult in the case of horizontal competition because competitors could anticipate each others movements. These tracking technologies could be used to save costs, making it for instance possible to ship 9 containers instead of 10. This provides efficiency improvements.

Senior manager 3, specializing in the digital transformation of the supply chain, envisions a use case which is more integrated. According to him, the most promising use case is IT IoT integration, coupling the physical world to its virtual twin. This use case could provide more insights in business processes, for example, a ship builder uses IT IoT integration to measure several factors on a ship (e.g. weather), in order to determine the optimal route. Furthermore, the data could be used to obtain information about a crew's performance and change the reward structure accordingly. Another example is in the mining industry, when a mine is undergoing maintenance by a subcontractor. This could be used to track where workers are (using RFID tags), to assess their safety and performance. Besides that, IT IoT integration could be used to track rapid eye movement from operators working with heavy equipment to assess when an operator is getting tired, and plan tasks accordingly. In a chemicals context IT IoT integration could be used to change the mixture of chemicals in a mixing vessel to prevent a peak or overflow in the process. The main advantage of these use cases is that they provide decision makers with new information which was not available beforehand. This facilitates efficiency improvements.

Senior principal, specializing in supply chain & operations strategy, sees a combination of analytics, IoT, and cloud solutions to be promising. Analytics could mainly be used for applications such as demand forecasting. IoT and cloud computing combined could be useful for tracking & tracing of goods. Analytics, IoT & cloud combined could be used for e.g. automatic replenishment (new business model generation). Besides that, these technologies could be coupled in an integral supply chain control tower. This gives a base-forecast using all of the available supply chain information.

Furthermore, Senior principal states that unused assets can be mapped and full end-to-end visibility can be achieved, including all assets (not only material flows). Implementation of this use case allows for an increased degree of automation and a more efficient use of assets, saving costs or improving service levels.

Senior manager 2 states that, in practice, the quality of the data could decrease drastically as a result of misuse of IoT solutions. Data sets could be incomplete or contain wrong data because of temporary malfunctioning of IoT sensors. If the data set does not get cleaned up first, wrong conclusions can be drawn from the data. This is the result of a big amount of sensors and the heterogeneous data stream, leading to a loss of overview over the data streams.

IoT - Influence on information sharing and availability

Using IoT to track containers and other assets, as envisioned by Senior manager 1, the information which becomes available will add value because there are less assets which get lost. The information is available at all times, such that it can be taken into account in the supply chain planning process. For example, if it is known there is an empty container on a ship, the route of the ship can be deduced to determine where the empty container will be in the future. This information is near-real time available, dependent on the chosen characteristics. The timing of information here is a cost consideration, i.e. information could be available in (near-)real time, but this has higher associated costs than information which is less frequently updated. Because the information is sent over the internet, it is easily accessible. However, accessibility could pose a challenge in case competitors could track each other's assets. In that case, suboptimal situations could emerge.

Following Senior manager 3, the integration of IT and IoT leads to an increase of unstructured data as a result of a variety of sensors from different brands, working with different standards. This unstructured data could encompass several environmental factors, which could then be used to improve processes. Because the information is measured by sensors and transmitted in a digital way, it is less sensitive to human error. The data and/or information does not necessarily have to be available in real time, but this is possible. This is a cost consideration, since it is costly to have a big amount of sensors connected to the internet, continuously transmitting big amounts of data. An option to reduce costs is to connect all sensors using a local network, for example, something similar to bluetooth, to a central transmission tower. Devices which have make this possible are called edge devices. Thus, there exists a trade-off between up-to-dateness of information versus costs. In the end, this trade-off is balanced based on process characteristics. The use case allows for a bigger amount of information to be available within the organization, which is easier to access. Furthermore, the technologies allow easier information sharing with supply chain partners, if this is desirable. Because of the wireless sensors, data has to be transmitted over the internet and the cloud. This imposes challenges for control over the data, and privacy. An often-mentioned solution by clients is an on-premise cloud, which is a cloud solution where the cloud infrastructure (i.e. the servers) is stored on the client's premises. However, this possibly is less secure and more susceptible to hacks than a cloud solution by a firm which is specialized in cloud solutions.

Consequently, Senior principal sees a more directed effect of data, where the sensors do not measure a lot of factors, but are installed to measure a pre-determined factor of interest. Because of this use case, there will be additional information available which was not available before, increasing transparency and providing orchestration opportunities. The quality of the new information depends on the type of sensors used, i.e. GPS provides quite inaccurate location data, while the accuracy of location data obtained via WiFi is higher. Besides that, the reliability of data (and thus information) depends on how the sensors are handled and in what kind of casing they are installed. The timing of the information provides real advantages in this case. For example, take a sensor which measures the amount of gas in a cylinder and transmits this on a daily basis to a gas provider. Using this data, the usage pattern can be determined and 'preventive replenishment' could take place. Thus, with this use case, information about an event is available before the actual event happens. As is the case with all IoT solutions, the speed of information depends on the application and its requirements, and is a trade-off between cost and timeliness. The information is available to the owner of the information and depends on the system it gets sent to. Usually, there is no data stored on the sensor itself, so the accessibility of the data does not depend on the physical location of the sensor. Privacy and accessibility pose challenges for IoT implementation, and this is mainly a problem when it is applied at end consumers.

IoT - Organizational impact

According to Manager 5, publication of performance data could increase production. This is the result of employees taking it as a challenge to become the best and improve their productivity. However, only top performance should be published and not, for example, the bottom 5. This is because publishing the worst performance will demotivate employees. Even when every employee is producing on a good level, there will always be a worst performer. This might increase the employee's perceived work pressure. Furthermore, publication of performance data will only affect employees' motivations if the employees are able to directly influence the performance of the process, i.e. if an employee puts in more effort than usual, the performance should increase. Besides that, due to improved information availability, decision making will become more objective and faster. This is the result of (1) more information being captured into systems, automating decision making more, and (2) less manipulation of data to transform it into useful information being needed.

In the container tracking case from Senior manager 1, decision making can be made easier, more objective, and potentially automated as a result of the technologies. The amount of repetitive, boring jobs decreases as a result of increased automation. On the other hand, there will be an increase in the amount of specialistic jobs, for instance, in data science departments or maintenance of robots. Furthermore, the organization will become flatter and decision making will become more decentralized. Finally, because the most boring jobs disappear, overall employee well-being will increase.

For IT IoT integration, as envisioned by Senior manager 3, it is important that the new models are developed in close collaboration with an engineer with hands-on experience. In 80-90% of the cases the models are right and perform well, but there will still exist a need for an engineer. The focus should lie on creating a good solution instead of many 'good enough' solutions.

IoT - Conclusion

There are three main applications of IoT, which are efficiency improvements, customer intimacy, and new business model generation. The first is the most easy to implement, and is closest to the current state of developments, but has a limited impact. New business model generation is the most disruptive application of IoT, but harder to realize. IoT devices create huge data streams containing accurate, but sometimes not reliable, data. The timing of the information is a cost consideration, i.e. obtaining real-time information is possible, but this requires a bigger investment. Because the information is transmitted via the internet, it is accessible from nearly everywhere.

4.2.3 Advanced analytics

Analytics - Use cases

An application of advanced analytical techniques is done by Manager 2. These analytical techniques can be used to quickly improve the accuracy of forecasts by including a lot of (seemingly unrelated) factors in the forecast. In this specific example it is used to increase the accuracy of promotions and to improve the chance of success of these promotions. This use case could be leveraged to obtain more accurate, objective, and automated forecasts. However, it is not really disruptive since it is just an extended version of normal demand forecasts, only now using a bigger amount of data.

Another application of analytics comes from Consultant 2, who applied analytics for increasing forecasting accuracy. He also stated that he sees potential in IoT and blockchain technology. However, these technologies require a bigger up-front investment compared to the return. Thus, for many firms analytics is the go-to solution to achieve a

’quick win’. Furthermore, he stated that the combination of IoT and analytics is almost inevitable to transform the huge data streams of IoT into useful information.

Manager 3 states process mining technology will play a pivotal role in the digital transformation of supply chains. Process mining is a technology used to map intransparent business processes. This could be a useful tool for the digital transformation of the supply chain, since it increases process visibility where this usually might not be possible (potentially due to a lack of willingness to share information). This could also be used to identify factors which influence these processes, to identify the bottlenecks and act on them. Briefly said, process mining is a kind of data mining, but focused on processes.

Analytics - Influence on information sharing and availability

The application of advanced analytical techniques to make forecasts does not change the output information itself, i.e. it remains a demand forecast. However, more information inputs are used. The quality and accuracy of the forecast significantly improve. Furthermore, because the forecasts are automated, their reliability improves and decision rules could be made visible. The information currently is available in a predictive manner, but the techniques could be improved to change to prescriptive information in the future. This information is mainly available to the planner, but because it is stored digitally it could be accessed from virtually anywhere, providing (top) management insights as well. Privacy of the data is a challenge, because the more data you can incorporate in your model, the more accurate the forecast generally becomes (at least it does not become less accurate), but the customer generally is not too eager to give up privacy.

According to Consultant 2, who applied analytics to make/improve forecasts, more information becomes available, because factors which used to be qualitative can be quantified using analytics. Furthermore, he agrees that the reliability and accuracy of the information increases, but that one should be wary for drawing conclusions about causal relationships based on relationships purely found in a dataset. Thus, analytics can be used to increase the accuracy of forecasts, incorporating a huge amount of variables, but it should not be used for the discovery of true causal relationships. That is, the models obtained are models for forecasting and are not explanatory models.

Analytics - Organizational impact

The use of advanced analytical techniques leads to the emergence of new functions in an organization which need to be filled, according to Manager 2. These functions are in the data science spectrum, and deal with the maintenance and improvement of the models. The question then rises whether to insource these functions and create a data science department, or outsource them. This will be determined by the scale of the operation, i.e. if the scale of the operation is small, it may be more beneficial to outsource rather than insource a data science department.

Consultant 2 states that the ’old’ functions in supply chain planning change from end-to-end planning to more exception based interventions. In the long term, planning jobs might disappear, but there is enough time for employees to retrain themselves, for example, into data scientists.

Process mining improves process transparency, making the decision making process more transparent. Furthermore, the additional information can be leveraged to obtain performance data, allowing for a different reward structure, potentially improving the perceived fairness of rewards. This, in its turn, has the potential to increase overall employee well-being.

Advanced analytics - Conclusion

From the interview results, advanced analytical techniques can be used to enable improvements in existing forecasts. However, they should not be used stand alone to find causal relationships. These techniques increase information quality, reliability, and timing (prescriptive instead of predictive).

4.2.4 Other

Cloud-based middleware

Cloud - Use case Manager 3 sees a future for a solution which is best described as cloud-based middleware. Cloud-based middleware facilitates a supply network by integration of different ERP systems. This enables automatic placement of orders at upstream suppliers. This could result in an integration of customer and supplier, or even horizontal collaboration, where, for example, one retailer sells its product to another retailer. This mainly results in service level improvements.

Cloud - Influence on information sharing and availability The main influence of cloud-based middleware on information availability is, according to Manager 3, that it allows for obtaining additional demand information (from supply chain partners). This is due to automated, real-time ordering, which allows for real-time demand to be known as well. Collaborative planning, forecasting, and replenishment are possibilities in the future, but are currently not facilitated by the technology. The demand information allows for more accurate forecasts. Furthermore, orders can be placed in real time at each other, but, since competitors could also be involved, privacy and accessibility of information remain challenging.

Cloud - Conclusion Cloud-based middleware is a tool which can be leveraged to integrate ERP systems in a supply network, providing opportunities for collaboration. However, privacy and accessibility of information remain challenges, due to competition.

Robotic Process Automation

RPA - Use case MD finance is enthusiastic about the role RPA can play in the invoice-payment process. This process can be automated, but it only applies to a small part of the supply chain. RPA automates small tasks, which were done before by humans. Implementation of this solution is almost completely automatic because of the use of machine learning. Automation of the invoice-payment process can lead to a 50-80% reduction in processing costs. Furthermore, the quality is improved as a result of touchless processing, making it less prone to human error. End-to-end process control and digitalization of the whole process allows for improved auditability. In addition, the automated implementation via machine learning techniques results in a relatively low up-front investment and potential to scale up easily.

RPA - Influence on information sharing and availability According to MD it becomes easier to analyse data and obtain more valuable data, because of the application of AI. The data can then be transformed in useful business insights, for example, the amount of working capital required. Furthermore, the amount of information increases, since from existing data information is created (the business insights). Besides that, the ease of up-scaling increases the potential amount of available information. Because the information is handled in a systematic and consistent manner, the reliability of the information improves due to constant quality (i.e. if a system makes a mistake, it makes it consistently). This information is almost instantly available after receiving the invoice, i.e. when the invoice (data) is received, it gets immediately booked into the system.

RPA - Organizational impact The organizational impact mainly consists of automation of a large amount of repetitive tasks. In practice, this implies that jobs will disappear in the accounts payable department. Improving overall motivation on the one hand, since repetitive tasks are now done by a robot, but possibly decreasing motivation on the other hand, since employees might fear their jobs will disappear. Besides that, the timing of the payments can be optimized, improving (financial) asset efficiency. Because of the high degree of standardization, analysis is more easily realizable, providing quick insights in, for example, working capital.

RPA - Conclusion RPA is a technology which can be used to eliminate repetitive tasks. The technology is mainly useful to automate (small) steps of a firm's operations, and thus does not have a huge supply chain impact. Combined with machine learning, RPA makes it easier to obtain valuable information. Furthermore, for implementation, only a limited up-front investment is required and an existing solution can be scaled up rapidly.

4.2.5 Summary interview results

The interview results are summarized in Table 5.

Table 5: Interview results

Technology	Use case	Main advantages
Blockchain	Asset tracking	Efficiency improvements, provenance
IoT & blockchain	Asset & order tracking	Transparency, more objective decision making
Blockchain	Smart contracting	Less burden of paperwork, direct sharing of one source of truth
IoT	IT IoT integration	Efficiency improvements
IoT, cloud & analytics	Tracking & tracing	Visibility, new business model generation, efficiency improvements

IoT & RFID	Asset tracking	Visibility, efficiency improvements
Analytics	Process mining	Visibility, enables digitalization
Analytics	Forecasting	Forecast accuracy improvements
Cloud-based middleware	ERP-system integration	Automatic order placement, service level improvements
RPA & machine learning	Invoice-payment automation	Efficiency improvements

4.3 Discussion interview results

First, it should be noted that the data obtained in individual interviews could be biased. For example, it is often the case that experts on a certain technology, or people working with that technology see 'their technology' as the most promising and disruptive future technology. This is taken into account for analysis, putting less weight on the results of the use case identification from the experts and more weight from interviewees with general supply chain or digital transformation expertise. Besides that, the seniority, which is an indicator of the expertise of an interviewee, was taken into account.

For the information sharing and availability part, this works the other way around. The experts have a better understanding of how the technologies can be put to work, and what their implementation looks like. Therefore, this will be taken into account by increasing the weight of their responses on this part.

Another consideration that should be taken into account is the maturity of technologies. There is a trade-off between the maturity of the technology and its future potential. That is, a mature technology generally does have less future potential compared to a technology which is still in its infancy. This trade-off affects the reliability of the inherent prediction of future organizational impacts. A mature technology has less potential, but more certainty about its most useful (future) application, since it is in a farther stage of development. A technology in its infancy has a lot of future potential, but it is unclear what the 'winning' use cases are going to be. This is illustrated in Figure 13. An example from the interviews is blockchain technology. Blockchain technology has a lot of future potential and is definitely going to change future supply chains. However, the exact application of blockchain technology is not yet known, but some well-reasoned ideas exist.

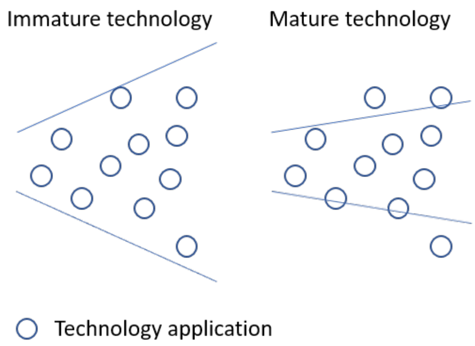

Figure 13: Difference in potential applications of technologies depending on maturity

4.3.1 Selected use cases

According to the interviews and confirmed by the literature, one technology playing a central role in the future will be IoT. IoT was mentioned in every interview. IoT can basically be applied in two ways: (1) a firm installs sensors measuring a huge amount of factors in order to try to find relationships using data mining techniques, or (2) a firm has the idea a set of factors is influencing a certain process, and installs sensors measuring these specific factors, trying to find true causal relationships. The latter is more useful to gain insights in factors affecting processes, and the first application is more useful to get 'quick wins'.

Furthermore, some applications of IoT are fixed, on-premise installations. This could be, for example, a sensor measuring the vibrations on the axes of a fixed machine. This is not where the true potential of IoT lies, since this could be measured by fixed sensors (i.e. connected to a system via a wire) as well. One of the main advantages of IoT is the ability to measure and transmit data from places where it was first not possible, for example, a car tire. This is where IoT can make a real difference and this is where the most potential lies to generate new business models.

IoT & cloud computing Because of the wireless connectivity of IoT, it is not useful on its own, i.e. it should be complemented by another technology. Cloud computing is the best candidate to complement IoT. This combination is definitely going to be a part of the future, is already in a mature phase (such that applications are clear), but still has a decent amount of future potential due to the possibility of new business model generation. A cloud-based solution is highly desirable to overcome inefficiencies and limitations on potential to scale up, as seen in section 2.4.2. Therefore, IoT and cloud computing are almost always linked in practice. The use case will be the collection of production and asset data, to reduce inefficiencies and potentially generate new business models. This use case will have priority due to its balance between potential and maturity.

Blockchain The second most promising technology is blockchain. The majority of the interviewees agreed that blockchain is going to change the future supply chain. However, most of the interviewees did not have a clear idea about the exact role blockchain is going to play in the supply chain, because the technology is not mature yet and its main applications are still to be discovered. Furthermore, blockchain technology is mainly useful in a multi-firm context. As of now, there probably is only a small amount of proof-of-concepts with blockchain technology in a multi-firm context, making analysis difficult. The most promising use case identified in the interviews is that of asset & order tracking, maintenance and provenance (i.e. keeping track of an asset's history). It was chosen not to pursue this use case, because data collection would be incredibly hard (or even impossible), hindering research. This is the result of the limited number of real-life applications of blockchain technology. That is, the number of firms having conducted a pilot with blockchain is small, and often, firms do not publish information about such a pilot on the internet. This makes case selection for the pilot case study virtually impossible.

4.4 Propositions

One objective of the interviews was to determine and confirm propositions based on expert knowledge (i.e. exploration of practice) and the literature study (i.e. exploration of theory). The propositions were formulated for the selected use case only.

First, based on the interview results (i.e. the found most promising use case), the research model was adapted. The adapted research model is includes the same relationships as the initial research model, but it is scoped more. This is beneficial for the thesis, since it provides a better delineation of the research subject. The adapted research model is given in Figure 14. The letters in the research model denote the relationships and the corresponding propositions, which are described in the subsequent sections.

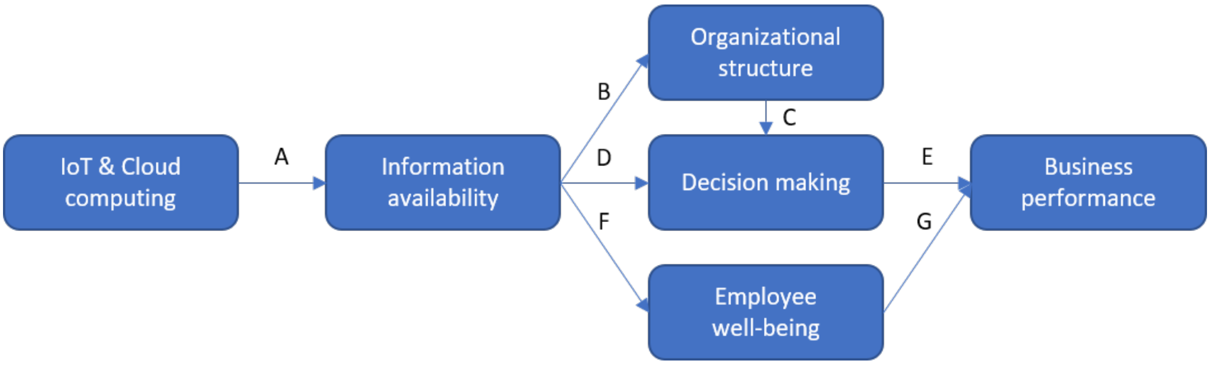

Figure 14: Adapted research model

4.4.1 A - Effect of IoT & cloud computing on information availability

In this section, propositions regarding the effect of IoT & cloud computing on information availability are formulated (relationship A). Information availability with respect to the decision-making unit is considered. The propositions are mainly based on data obtained from the expert interviews, since literature on this relationship was not available.

Type of information In the interviews it was often mentioned that a wide array of new information becomes available. This includes for instance, information about environmental factors such as temperature and humidity. The type of information which becomes available depends on the type of sensor installed. Because the sensors have a cost associated to them, it is assumed the firm only installs sensors which provide usable and relevant data. If this is the case, additional relevant information for decision making becomes available.

P_1 : *The implementation of IoT and cloud computing increases the amount of relevant information available.*

Quality of information The experts did not unanimously agree on whether the quality of the data, and thus the information, would increase. This mainly depends on (1) the type of sensors used, and (2) environmental factors influencing transmission of data. The type of sensors used is a cost consideration. If the cost allocated to the sensors is too low, the information quality will be low and investing in IoT would not make any sense. Therefore, it is assumed that the amount invested in the sensors is sufficient to improve the quality of the information.

Environmental factors may result in data transmission being interrupted or aborted, which leads to incomplete datasets. These incomplete datasets can result in a decrease of the quality of information. On the other hand, because the data is obtained by sensors and sent to a database electronically, without human intervention, the data is less prone to 'handling errors' compared to data which is transmitted with human intervention.

The experts indicated that the reliability of information will improve, since if there is an error in the system, the error will be made continuously. That is, if a system makes a mistake in a given circumstance in situation A, you know the system will always make the same mistake in this situation, all else being equal. This is confirmed by Huber (1990), who proposes that the use of advanced information technologies leads to organizational intelligence that is more accurate, comprehensive, timely, and available.

P_2 : *The implementation of IoT and cloud computing increases the quality and reliability of information.*

Timing of information As with the quality of information, the experts indicated that the timing of information is a cost consideration. That is, the closer the timing of information needs to be to real time, the more expensive it will get. The timing of the information thus depends on process and application requirements, i.e. some processes require real time monitoring, while other processes will benefit from hourly data updates. The timing of information can be adjusted on-the-fly, e.g. by increasing/decreasing the frequency of updating and transmitting sensor data. Furthermore, the data can immediately be transformed into useful information as a result of the cloud integration, resulting in quick responses. Thus, it is proposed that the information is available when needed.

P_3 : *Use of IoT and cloud computing ensures the required timing of information.*

Accessibility of information The information is stored in the cloud, which is (in theory) easily accessible according to the experts. This accessibility depends, of course, on the chosen configuration. Information can be available form virtually anywhere at any given time. This is not the case for 'analog' processes, where information is stored locally. Thus, IoT and cloud computing makes information more easily accessible compared to non-digitalized situations.

P_4 : *The IoT and cloud use case improves the ease of access of information.*

Controllability of information An often-mentioned disadvantage of the use of cloud technologies is the controllability of data. If an information system is used in an offline way, it cannot be hacked from remote locations. However, if an information system is used in an online way, there is a possibility of it being hacked from virtually everywhere in the world. Furthermore, the use of cloud technologies usually involves storing your data at an external party, which raises ownership issues, i.e. does the data belong to the party who owns the infrastructure, or to the party who put it on the infrastructure? Besides that, because more information is stored in systems, it is harder for individual decision makers to keep information to themselves. This further reduces the controllability of information.

P_5 : *The use of IoT and cloud computing results in lower controllability of information.*

4.4.2 B - Effect of information availability on organizational structure

It is proposed by Huber (1990) that the use of advanced information technologies leads to a more evenly spread organizational structure with respect to decision making. This is the result of increased transparency in the organization, i.e. the walls of functional and hierarchical silos are broken down. Because of the increased transparency, higher level managers can obtain local information from low(er) organizational levels more quickly and accurately. This allows for these managers to make decisions which they were unwilling to make before, as a result of a lack of information availability. Consequently, this results in managers being more involved in decisions at lower organizational levels, increasing the degree of centralization of decision making. On the other hand, IoT and cloud computing allow lower- and middle level managers to make globally optimal decisions more easily, increasing the degree of decentralization of decision making. Thus, decisions can be made at more hierarchical levels without quality loss. Because of this, decision making will become more evenly spread out in an organization. As a result, the following proposition is formulated:

P_6: *The changed information availability leads to more decentralization for highly centralized organizations, and more centralization for highly decentralized organizations.*

Because of the increased organizational transparency and increased ease of communication, Huber (1990) proposes an organization becomes less bureaucratic. Therefore, decisions and messages do not have to go through the full organizational 'pyramid'. This results in the following two propositions:

P_7: *The changed information availability reduces the number of organizational levels involved in authorizing proposed organizational actions.*

P_8: *The changed information availability reduces the number of organizational levels involved in processing messages.*

4.4.3 C - Effect of organizational structure on decision making

The propositions regarding the effect of organizational structure on decision making originate from Huber (1990) and are adapted for this thesis.

Since communication is made easier using advanced information technologies, more information sources can be used. Furthermore, working with a cloud solution breaks down the walls of functional silos, making communication between employees in different business units easier. Thus, the expertise of more employees may be taken into account for making a decision.

P_9*: The changed organizational structure leads to a larger number and variety of people participating as information sources in the making of a decision.*

On the other hand, since IoT and cloud computing are used as decision-support systems, and they incorporate more and more data, human decision makers can be replaced by these systems. However, some decision makers have an expertise which cannot be taken over by these systems (yet), therefore, they will remain in the decision-making unit. As a result, there will be more specialized people in the decision-making unit, increasing its variety. On the other hand, the amount of people in the decision-making unit decreases as a result of the new decision-support systems taking over the decision-making process partially.

P_{10}*: The changed organizational structure leads to a decrease in the number of people in the decision-making unit.*

P_{11}*: The changed organizational structure leads to an increase in the variety of members comprising the decision-making unit.*

Because of the lines of communication being shorter, and the possibility of replacing humans by expert systems, decision-related meetings are needed less frequently. Therefore, the total amount of time an organization spends on these meetings decreases.

P_{12}*: The changed organizational structure results in less of the organization's time being absorbed by decision-related meetings.*

4.4.4 D - Effect of information availability on decision making

The propositions regarding the influence of the changed information availability on decision making are formulated using Huber (1990) and are all confirmed by the interview results. First, IoT and cloud computing can be leveraged for real-time process monitoring. This in turn, can be used to identify problems in a process, possibly even before they happen. One important requirement is that the data obtained via these technologies is transformed into useful information immediately, for example, using a proper dashboard. Furthermore, one interviewee mentioned IoT was used to monitor a chemical process in a way which was not possible before, observing antecedents of a process overflow, and leveraging this information to keep the process under control.

P_{13}*: The changed information availability leads to more rapid and more accurate identification of problems and opportunities.*

Because there will be more objective information available from data which can be used for decision making, the decisions can be made in a more objective way, i.e. decision makers can base their decisions more on facts and less on feelings. Furthermore, the information is available to more people in the organization, increasing the transparency of the decision-making process. This increases the 'power' of decisions, as found in the interview results. First, this reduces the time a higher-level manager requires to authorize the decision of a lower-level manager. This, in turn, reduces the time required to make decisions in general, combined with the fact that less information needs to be looked up or estimated.

P_{14}: The changed information availability reduces the time required to authorize proposed organizational actions and make decisions.

4.4.5 E - Effect of decision making on business performance

The most relevant question for the future of these technologies is whether IoT and cloud computing - when used as decision-support tools - actually improve business performance. This depends on (1) if the changes in decision making lead to higher quality decisions, and (2) if higher quality decisions lead to improved business performance.

P_{15}: The changes in decision making lead to improved business performance.

P_{15a}: The changes in decision making lead to higher quality decisions.

P_{15b}: Higher quality decisions lead to improved business performance.

4.4.6 F - Effect of information availability on employee well-being

The propositions below are formulated using the results of Bakker et al. (2004), and some of the propositions are initially confirmed by the interview results. Bakker et al. (2004) build upon the job demands-resources model and extend this model by including an effect on employee performance. In this case, job demands are defined as physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological costs. These include high work pressure, emotional demands, role overload, and poor environmental demands. Furthermore, job resources are defined as the physical, psychological, social, or organizational aspects of the job that are either functional in achieving work goals, reduce job demands and the associated physiological and psychological costs, or stimulate personal growth and development. These can be located at four different levels which are (1) organizational level, including salary and career opportunities, (2) interpersonal level, including supervisor and co-worker support, (3) organization of work, including role clarity and participation in decision making, and (4) task level, including performance feedback, skill variety, task significance, task identity, and autonomy. From the interviews it was found that IoT and cloud computing will affect the task level most.

The additional information becoming available is meant to ease the life of the decision maker. Therefore, it is expected that the increased availability of information leads to an increase in employee well-being.

P_{16}: The increased availability of information leads to an increase in employee well-being

Due to the additional information becoming available, process transparency increases, giving more insight into an individual's performance. This enables opportunities for (real-time) performance feedback, which is considered a job resource. This is confirmed by the interview results, where one interviewee mentioned that employee productivity increased as a result of 'live streaming' the top 5 best performers in a factory. Furthermore, because of the increased process transparency, an employee is able to see why s/he performs a certain task, increasing perceived task significance. This transparency increases perceived task identity and role clarity as well. However, task autonomy is expected to decrease due to the increased process insights. Because the process is more transparent, it will occur earlier that other people start questioning the way someone executes his/her tasks.

P_{16a}: *The increased availability of information increases role clarity, performance feedback, task significance, and task identity.*

P_{16b}: *The increased availability of information decreases task autonomy.*

However, the increased visibility of one's performance might increase job demands. If an employee has the idea that his/her boss tracks performance data all the time, this increases perceived job demands such as work pressure. This is the result of the employee thinking there is someone looking over their shoulder continuously.

P_{16c}: *The increased availability of information increases job demands (e.g. work pressure).*

Furthermore, as was found in (Bakker et al., 2004), there is a positive relationship between job resources and employee engagement. Besides that, there is a negative relationship (via exhaustion) between job demands and employee engagement. The effect of job resources on engagement is stronger than the effect of job demands on engagement. Since both job demands and job resources are expected to increase, it is expected that the overall change in job demands and job resources leads to more engaged employees.

P_{16d}: *The overall change in job demands and job resources (as described in P_{16a} & P_{16b}) leads to more engaged employees.*

Besides that, a positive relationship between job demands and exhaustion and a negative relationship between job resources and exhaustion exist (Bakker et al., 2004). Job demands have a stronger relationship with exhaustion than job resources. Since both job demands and job resources are expected to increase, it is expected that the overall change in job demands and job resources leads to higher exhaustion among employees.

P_{16e}: *The overall change in job demands and job resources (as described in P_{16a} & P_{16b}) leads to higher exhaustion amongst employees.*

From the interviews, it is proposed that the effect of the increase in engagement is stronger than the increase in exhaustion, increasing overall employee well-being.

P_{16f}: *The changed engagement and exhaustion lead to an increase in employee well-being.*

4.4.7 G - Effect of employee well-being on business performance

The effect of employee well-being on business performance is twofold: (1) it can improve in-role performance, i.e. the performance of the tasks which are officialy in the employee's job description. And (2), it can improve extra-role performance, i.e. the performance of the tasks executed which are not officialy in the employee's job description (Bakker et al., 2004). Since employee well-being is expected to increase, it is expected that in-role and extra-role performance increase as well. As a result, the following propositions are formulated.

P_{17}: The increased employee well-being results in employees exerting increased in-role performance.

P_{18}: The increased employee well-being results in employees exerting increased extra-role performance.

The propositions can then be mapped on the research model as can be seen in Figure 15.

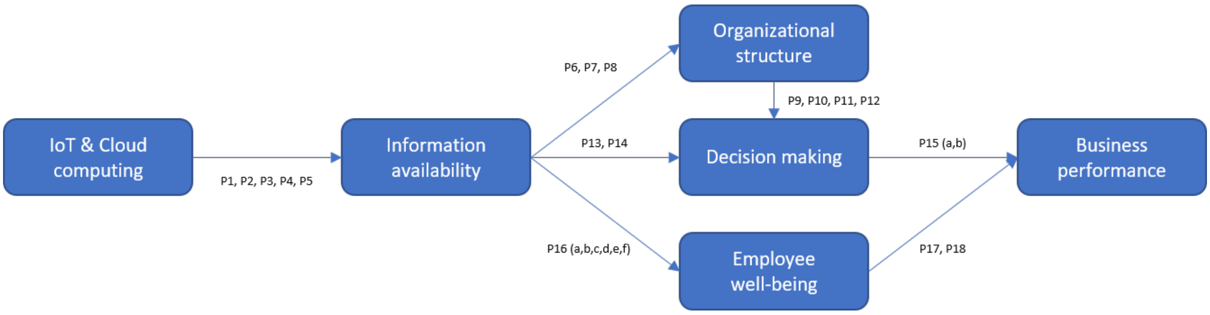

Figure 15: Research model with propositions

Chapter 5

Pilot case study

5.1 Introduction

The combination of interview results, combined with a thorough analysis of literature yielded several noteworthy results. First, the combination of technologies which is going to influence the resources industry most consists of IoT and cloud computing. Here, cloud computing does not solely consider the location of the data (i.e. the cloud), but also includes analytical systems which transform the data to information. These technologies should be used as (automated) decision-support systems, to improve process efficiency and potentially generate new business models. In this case, cloud computing mitigates the shortcomings of IoT, as discussed in section 2.4.2 of the literature review.

The remainder of the results consists of the propositions formulated in chapter 4.4, which are summarized in Table 6. The column "Nr." refers to the number of the proposition and the column "Rel." refers to the relationships as mentioned in Figure 14.

Table 6: Propositions and relationship letters

Nr.	Rel.	Proposition
1	A	The implementation of IoT and cloud computing increases the amount of relevant information available.
2	A	The implementation of IoT and cloud computing increases the quality and reliability of information.
3	A	Use of IoT and cloud computing ensures the required timing of information.
4	A	IoT and cloud computing improves the ease of access of information.
5	A	The use of IoT and cloud computing results in lower controllability of information.
6	B	The changed information availability leads to more decentralization for highly centralized organizations, and more centralization for highly decentralized organizations.
7	B	The changed information availability reduces the number of organizational levels involved in authorizing proposed organizational actions.

8	B	The changed information availability reduces the number of organizational levels involved in processing messages.
9	C	The changed organizational structure leads to a larger number and variety of people participating as information sources in the making of a decision.
10	C	The changed organizational structure leads to a decrease in the number of people in the decision-making unit.
11	C	The changed organizational structure leads to an increase in the variety of members comprising the decision-making unit.
12	C	The changed organizational structure results in less of the organization's time being absorbed by decision-related meetings.
13	D	The changed information availability leads to more rapid and more accurate identification of problems and opportunities.
14	D	The changed information availability reduces the time required to authorize proposed organizational actions and make decisions.
15	E	The changes in decision making lead to improved business performance.
16	F	The increased availability of information leads to an increase in employee well-being
17	F	The increased employee well-being results in employees exerting increased in-role performance.
18	F	The increased employee well-being results in employees exerting increased extra-role performance.

5.2 Methodology

5.2.1 Research strategy

In chapter 4.4, the propositions for the specific use cases were given. According to chapter 4 of Dul and Hak (2007), to determine the research strategy, first the propositions needed to be classified into four categories. These categories are sufficient conditions, necessary conditions, deterministic relations, and probabilistic relations. The first three propositions are called deterministic propositions, and the last one is a probabilistic proposition.

First of all, it was easy to see that all of the propositions are deterministic, i.e. there were no propositions stating "if A increases then it is likely that B increases". Furthermore, sufficient conditions are defined in chapter 5 of Dul and Hak (2007) as conditions stating that "if there is A, then there will be B". Necessary conditions are of the form: "B exists only if A is present", and deterministic relationships state that "if A is higher then B is higher (or lower)". The formulated propositions are either sufficient conditions (if IoT and cloud computing are used, then ...), or deterministic relationships (e.g. an increase in job resources leads to more engaged employees). It was hard to determine whether the propositions were sufficient conditions or deterministic relationships, because most of them were of the form "if A is present, then B increases".

To solve this issue, concept A was seen as a binary variable, and concept B was seen as a (more or less) continuous qualitative variable. That is, concept B usually was of a form such as "an increase in ease of access of information", which was not measured using quantitative date, but deduced from qualitative insights. Using this insight, all of the propositions were regarded as deterministic relationships. An example of this is given in Figure 16, which explains the influence of IoT & cloud computing on information accuracy. In addition, according to chapter 6 of Dul and Hak (2007), the research strategy for sufficient conditions and deterministic relationships is the same. The only difference is that a single case study should be used to test a sufficient condition, whereas a longitudinal or comparative case study should be used to test a deterministic relationship.

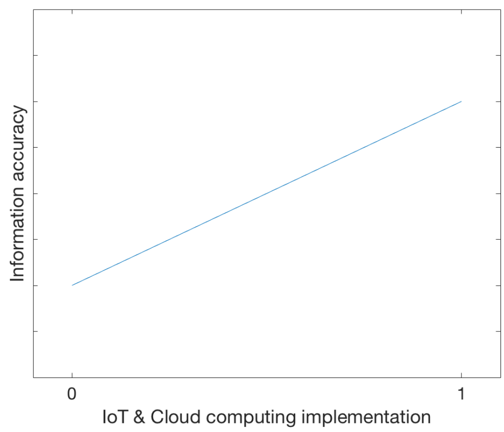

Figure 16: Example deterministic relationship

In chapters 5 and 6 of Dul and Hak (2007) it is stated that the experiment is the preferred research strategy to test sufficient conditions and deterministic relationships. However, as this was not possible because of time and budget constraints, the second-best research strategy is chosen, which is a case study. As mentioned before, sufficient conditions are best tested using single case studies, whereas deterministic relations are best tested using longitudinal single case studies or comparative case studies. Because of the limited timespan of this thesis, the longitudinal case study was not a feasible option. Therefore, a comparative case study was required to test the deterministic relationships. This resulted in three cases which were analysed: one case without the proof-of-concept, one case with the proof-of-concept, and one case with a further developed version of the proof-of-concept. Because of the characteristics of a PoC (i.e. short timespan), the interviewees had a good recall of the situation without the PoC. Thus, it was asked how the situation has changed as a result of the PoC, obtaining the results of a comparative case study.

5.2.2 Candidate cases

Because of the novelty of the subject, the pool of candidate cases to choose from was limited. This was the result of a number of factors. First, there simply were not many firms that have conducted a proof-of-concept with IoT & cloud computing in a (internal) supply chain context. Second, the firms who did conduct a proof-of-concept often did not make this public in a way that can be found on the internet. Thus, the two best options to find candidate cases were (1) making use of the university's network, and (2) making use of Accenture's network. Unfortunately, use of the university's network did not yield cases relevant for this thesis. Fortunately, Accenture's network was more useful and suitable cases were found.

There were some requirements for the candidate cases. First, the proof-of-concept had to be finished within the last 6 months or still going on, because otherwise, the interviews would not yield reliable data since the interviewees would not be able to remember the situation well. Besides that, since the research was conducted from the resources department, it was desirable that the proof-of-concept was held in a resources industry context. More specifically, the focus of the thesis was on the intersection between the resources industry and the process industry, as described in section 3.1.

5.2.3 Case selection

Cases were selected based on whether a concept was present, i.e. whether cloud computing and IoT were implemented. Thus, a "most likely" case was selected, which is an instance of the object of study in which confirmation of the hypothesis is likely, which is mainly useful for initial theory-testing research (Dul & Hak, 2007). However, because of the complicated relationships in the research model, it was only possible to make a selection for the first relationship (i.e. relationship A in Figure 14), and not for the subsequent relationships (i.e. relationships B and further in Figure 14). For example, if the PoC did not change the amount of relevant information, this in turn could not affect decision making.

The first selected case is a project which is being carried out at a leading chemical company. This project used IoT and cloud computing to improve efficiency of the production of chlorine. For simplicity, this will be called case A.

5.2.4 Measurement

Stakeholders

Stakeholders were identified using a corporate sponsor, i.e. a person from within the firm who supports the case study research. The corporate sponsor was the lead of the project. The corporate sponsor gave inputs for potentially interesting people to interview. Furthermore, the corporate sponsor was used to obtain contact details and a 'warm introduction' to potential interviewees. The interviews were used to collect evidence for testing the propositions, but also to identify other sources of evidence (e.g. documentation, observation).

The stakeholders were selected based on their involvement in the project. That is, the stakeholders had to be familiar with- and affected by the project. Furthermore, the stakeholders had to be from different hierarchical levels in the organization, to get opinions about the project from different perspectives with different underlying incentives. The list of stakeholders was drawn up in consultation with the corporate sponsor.

This resulted in identification of stakeholders from several hierarchical levels. Their job title and responsibilities are summarized in Table 7.

Table 7: Overview stakeholders

Job title	Responsibilities
Plant manager	Final responsibility for the plant
Production manager	Final responsibility for the production process (safety, performance, ...)
Production engineer	Chemical components of the brine cycle
Production coordinator	Operational responsibility for the production and transportation of the end products, and planning & performing maintenance
Panel operator	Responding to irregularities in the production process, setting process parameters (e.g. energy consumption)

Data collection

To assess the impact of the project on the workforce and to test the propositions data was collected through analysis of documentation, observation, and interviews. This combination of data sources increases the validity and reliability of results.

Project documentation Project documentation was analysed to get a thorough understanding of project scope, goals, and progress. Because the project was still going on, the documentation was limited. However, the documentation was useful for analysis of the project scope, goals, and progress.

Plant tour A tour throughout the plant was used to observe the production process. This allowed a clearer understanding of how the process which is affected by the project interacts with other adjacent processes. For example, changing the production level requires changes in logistics planning as well. Furthermore, a change in the production level of the electrolysis section requires changes in its in- and outputs.

Observation Since the panel operators are the main decision makers affected by the project, their task was investigated most thoroughly. The final production level decision is made by the panel operators in the control room. Therefore, to get a feel of the decision-making process and to assess the impact of the project, additional data was collected by thorough observation in the control room.

Interview partners Finally, interviews with the identified stakeholders were held. These interviews were held on several hierarchical levels, spanning from managerial levels (plant manager, production manager) to the operator level. A total number of 10 interviews was held, of which 6 interviews were with panel operators. On the operator level, several interviews were held to assure operators of their anonymity. All of the interviewed operators were panel operators, i.e. the operators in the control room who are the end-user of the project. There were no interviews with field operators, since they are not significantly affected by the project. Other interviews were held with a production coordinator, production engineer, production manager, and the plant manager.

Interview capture All of the interviews were held in person, except for one interview which was held via Skype due to travelling constraints. When possible, the audio of the interviews was recorded (i.e. the interviews were not videotaped). One interviewee did not give permission to record the interview. In this case, the answers were recorded by note taking. During observation, notes were taken. The notes were detailed out immediately after the interviews and/or observation, and were stored digitally. The documentation was stored digitally. All of these sources of evidence were coded using QDA Miner Lite. The data was coded based on the variables and propositions defined before. The codebook, including descriptions of the codes, is given in Appendix C.

Interview guide To facilitate capturing the differences in knowledge level between the operators and the other interviewees, two interview guides were developed before conducting the interviews. This interview guide contained questions to be asked in order to test the propositions. The questions in the interview guide were used for guidance and did not need to be asked literally. It was possible to reformulate them in the actual interview. Besides that, it was possible that the interviewee already answered a question before it was asked. In this case, it was checked whether the answer was complete and elaborate, and if this was the case, the question was skipped. Thus, the interview guide served as sort of a checklist for questions needing to be answered.

The interview guide was adapted for each interview. This was the result of differences in knowledge for the various interviewees. For example, an operator is not involved in the higher-level decision-making process. Thus, the operator would not expect a change in decision making in that area. The complete interview guide, including all the questions is given in Appendix C.

Data analysis

The obtained data was analysed using QDA Miner Lite, by means of creation of a 'coded segments report'. Here, for each code (as given in appendix B), the relevant data is given as well as the source of the data. Consequently, this data was summarized and statements were compared.

Not all interviews yielded a statement about all of the codes or propositions. This is because not every involved party knows everything of the PoC. For example, an operator might not be aware of changes in organizational structure resulting from the PoC. This effect is the same as described in the development of the interview guide, i.e. the different interview guides for interviewees with different backgrounds.

5.3 Case A description

5.3.1 Industry description

The firm at which case A is analysed produces chlorine. Thus, it is active in the chemicals industry. The chemicals industry is a manufacturing industry, where the basic processes for producing key intermediates are mature (Heaton, 2012). However, improvements in the industry are still made on a continuous basis. This is the result of a great commitment to, and investment in R&D, with R&D expenditures averaging about 8% of total revenue. Major sectors in the chemicals industry are:

- Petrochemicals (e.g. chlor-alkali products)
- Polymers
- Dyestuffs
- Agrochemicals
- Pharmaceuticals

In the chemicals industry, a distinction is made between high-volume and low-volume sectors. The firm at which case A is analysed is active in the high-volume sector. Here, plants are generally dedicated to a single product, operate in a continuous manner (i.e. 24/7 production), and are highly automated, including computer control.

Chlorine is a basic chemical. Basic chemicals compose the middle ground between raw materials and end-products. Basic chemicals are characterized by very big to enormous production scales, producing fairly cheap end products. Since the products are homogeneous, i.e. there is no significant difference between chlorine from manufacturer A and chlorine from manufacturer B, firms do not have the ability to set prices. Thus, firms have to reduce costs in order to increase profits, explaining the high investments in R&D.

5.3.2 High-level description of production process

The process which is affected by the project is a production process to manufacture chlorine. The production process involves a small number of steps. First, a barge filled with salt (sodium chloride) supplies the factory; salt is the raw material for the production of chlorine. This salt gets dissolved in water using machinery to speed up the process (e.g. heating the water). This solution gets filtered in various ways to remove any remaining non-chlorine or sodium ions. Thereafter, the salt is decomposed using electrolysis. Electrolysis is a technique where an electric current is used to drive a chemical reaction. In this case, due to the electric current, the salt solution is decomposed in chlorine, hydrogen, and sodium hydroxide. The next step in the process is to purify the solutions containing the end products, i.e. remove a big portion of the water. After this step is completed, most of the chlorine is transported via a pipeline to the company's clients. The remainder of the chlorine is stored in on-site tanks. The on-site tanks have a limited capacity of about half a day of production together.

$$2Na^{+} + 2Cl^{-} + 2H_2O \rightarrow 2NaOH + Cl_2 + H_2$$

The critical part of the process is the electrolysis, where the sodium and chlorine from the salt are separated. Electrolysis may be done on one of the reactors on site. Each of these reactors have a varying efficiency depending for example on the year they were built, the last time they had maintenance, and several other factors. Currently, when the plant is not working at 100% capacity, the production is allocated to the newest reactors first, and the remainder is allocated to the older reactors.

The cost of salt, the main raw material, is driven by external factors. The firm has limited opportunity to optimize the raw material cost significantly. From a process perspective, the main cost determinant is electricity, needed for the electrolysis. Thus, the main potential for cost savings in the production process of chlorine lies in optimization of energy usage.

Production planning

The amount of end-product which is produced in the plant depends on the decisions of several actors. First, there is the production planner who makes a high-level, monthly planning of production. This is called the energy plan and shows required production in periods of one hour in terms of energy consumption. The production coordinator uses the plan of the production planner as an input, and is responsible for realizing the production on a daily basis. The production coordinator coordinates with logistics, maintenance, and production to realize the required production. Finally, the panel operator in the control room determines the actual level of production in real time. Thus, from the production planner to the panel operator, the planning horizon decreases, i.e. the production planner makes a plan for the long(er) term, whereas the operator changes the production on a real-time basis.

5.3.3 Description project

The project is aimed at reducing production cost. There are two ways in which this is done: (1) the optimization part and (2) the so-called 'flex' part. The optimization part automatically allocates production to the most efficient reactor. Reactor efficiency is established through the analysis of several factors of influence. Examples of these factors are the age of the reactor and the last time the reactor underwent maintenance. The data on these factors of influence are measured, stored, and analysed in a cloud solution. The flex part aims to optimize and automate the plant production level against the electricity prices. Electricity prices are determined by the laws of supply and demand. Peak moments in electricity usage, result in high prices, and bottom moments, result in low prices. As a result, it is cheaper to increase production when the electricity prices are low, and decrease production when electricity prices are high.

The project is focused on situations where the demand is not greater than or equal to 100% of the current production capacity. When this is the case, it is decided whether it will use the low demand as an option to flex or not, potentially adjusting the total production volume. In a second step, the production volume is determined and in an optimized way allocated to the reactors.

Currently, the project is still being developed and is not fully implemented. In the legacy situation, the flex decision was made based on the monthly planning and the current energy prices. This data was available in an Excel sheet (the flex sheet), but still required some (time consuming) manual calculations. The next step, which is the current status of the project, is a screen in the control room indicating whether to flex or not and by how much megawatt (MVP1). This solution automates the calculations otherwise required in the flex sheet and gives a clear yes/no advice about whether to flex or not. In this phase, the system serves as a Decision Support System (DSS). The next step (MVP2), considers an increase in automation of decision making with respect to MVP1. As is the case with MVP1, the production planner and production coordinator need to indicate that flexing is possible. However, in this case, the operator sets the parameters of the system in such a way that it allows flexing. Consequently, the system decides for itself when it starts flexing and by how much. This is under the condition that the production planner, coordinator, and operator all gave a 'go' for flexing. After MVP2 there are more phases in the project, continuously improving the preceding phase. For this case study, the time horizon spans until MVP2 since this is currently in development. After MVP2 there will be more iterations, depending on the results and performance of preceding iterations. The phases of the project will be referred to as legacy system, MVP1, and MVP2 in the remainder of this text. The steps in the project within the scope of this case study are summarized in Figure 17.

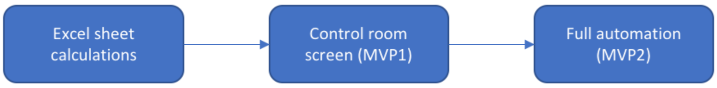

Figure 17: Steps in implementation of the E-Flex project

5.3.4 Decision-making process

Since the decision-making process is an important part of this case study, the decision-making processes in each iteration of the project (i.e. legacy, MVP1, and MVP2) are described here. In the legacy situation, the production planner makes a monthly planning regarding the required level of production expressed in megawatt (MW). This is called the energy plan and gives an hourly overview of the total production level the electrolysers need to have. The energy plan is a sheet which is visible in the control room of the operators, where different colours indicate whether it is possible to flex or not that day. The energy plan is updated on a daily basis. If the energy plan indicates that it is possible to flex, the production coordinator looks at the daily situation of the plan. Factors like planned maintenance and the current logistics situation are taken into account. If the production coordinator gives a 'go' for flexing, the panel operator looks when flexing is possible. He bases his decision on the current plant situation (e.g. unplanned maintenance, current production level) and current energy prices. The energy prices are given in the flex sheet and the operator has to forecast the energy prices himself. If he thinks flexing is profitable, he will decide to adjust the production level accordingly. A schematic overview of the actors in this process and their information sources is given in Figure 18.

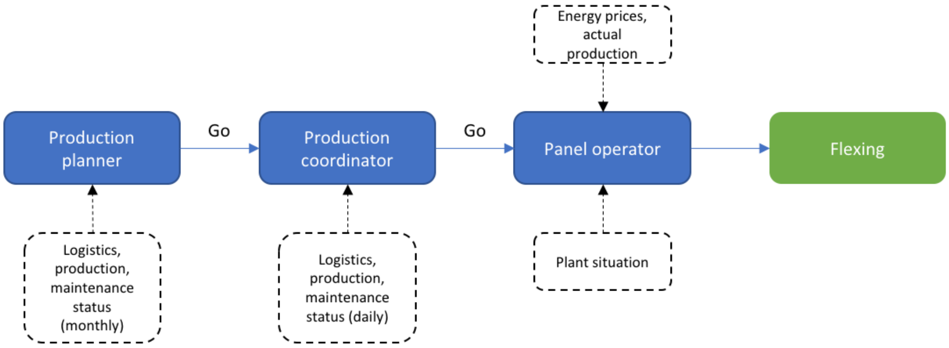

Figure 18: Decision-making process in the legacy situation

In the case of MVP1, the first two steps will remain the same (i.e. the decision-making process by the production planner and by the production coordinator). What is affected, is the decision making-process by the operator. Instead of having to forecast the energy prices himself, the operator uses the advice from MVP1 as an input for his decision-making process. If the production planner, production coordinator, and the system advice to flex, and the plant situation allows it, the operator decides to start flexing and adjusts the production level accordingly. This decision-making process is given in Figure 19.

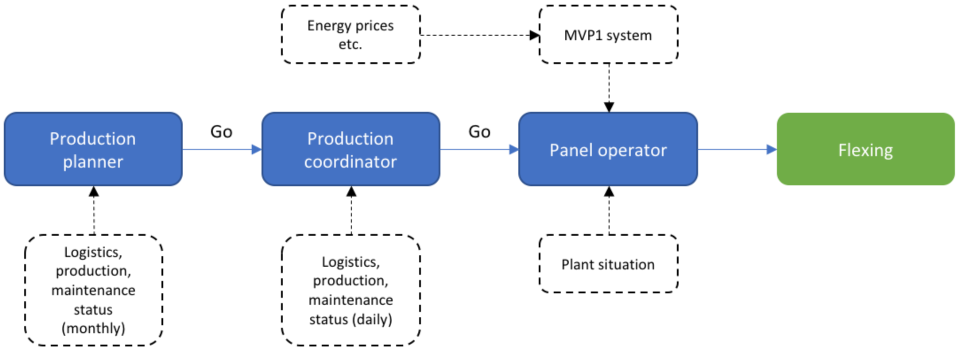

Figure 19: Decision-making process for MVP1

Finally, in the case of MVP2, the first two steps remain the same again. The panel operator now looks at the current plant situation and indicates whether flexing might be possible or not. If the operator and the preceding actors in the decision-making process have given a go for flexing, the MVP2 system autonomously decides to start flexing and changing the production level accordingly. The decision-making process under MVP2 is given in Figure 20.

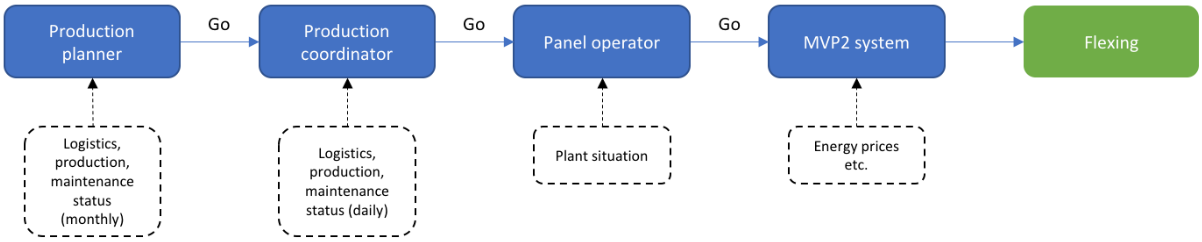

Figure 20: Decision-making process for MVP2

Thus, for MVP1, the operator decides when to flex or not and by what amount based on information from the system. If the operator decides to flex, he adjusts the production level. For MVP2, the operator switches the system to a 'flexing allowed' status and the system then decides when to flex and by what amount. In this case, the system adjusts the production level automatically.

5.4 Results

For each of the results, the abbreviations on the next page reflect the interviewee or group of interviewees that are the source of the statements. This information is useful to put the statements into context. For example, a plant manager has another perspective and other incentives than an operator.

- PM: Plant Manager
- PrM: Production Manager
- PE: Production Engineer
- PC: Production Coordinator
- OPS: Operators
- ALL: All of the above

5.4.1 A - Influence on information availability

Amount of relevant information According to the operators, the information from MVP1 is relevant for decision making since it gives a clear advice about whether to flex or not and by what amount, based on a profitability analysis. In the legacy situation, this advice had to be derived from a complicated flex sheet. Furthermore, the operators are still able to access the information about energy price and production level, so the amount of available information does certainly not decrease (OPS, PE).

For MVP2, the information that is currently provided through MVP1 to facilitate the flex decision (i.e. the yes/no flex indicator and amount to flex with), will be automatically processed by the system. Thus, the information will become embedded in the system and no longer subject to active decision making. Since the operators do not have to worry about flex calculations any more, they have more time to focus on the production dashboard. This production dashboard will be expanded, increasing information availability with respect to the production process. Using this production dashboard, the operators have more insight in the status of the plant, making it easier for them to see if they can give a 'go' for flexing (OPS, PM).

Quality and reliability of information In the legacy system, the flex calculations were made using the flex sheet. The electricity prices needed to be predicted by the operators, but they did not have the required skillset to do this. For MVP1, the electricity prices are analysed automatically and transformed into information (i.e. the advice whether to flex or not and by what amount). This increases the accuracy of the information, since more sophisticated algorithms to forecast prices can be used. Besides that, the reliability of the information increased due to automation of the calculation, which is less prone to human errors. Thus, the quality of the information improves significantly. Besides that, using the legacy system, the operator needed to have time to make the calculations. This resulted in the information being absent in some cases because the operator did not have the time to make the calculations (ALL).

For MVP2, the accuracy and reliability of information will remain constant since the calculations are made in the same way as in MVP1. The only difference is that the decision is made straight away based on the available information. This will allow the system to react more quickly to flex options, since there is no human intervention after the operator gives the 'go' for flexing (ALL).

Timing of information For MVP1, the flex decision is made continuously in near-real time. In the legacy system, the energy prices were updated once every 15 minutes and most of the calculations and forecasts (e.g. energy price forecast, required production) regarding the flex decision needed to be made manually. Thus, the timing of information has improved moving from the legacy system to MVP1. This is the result of a reduction in input lag and an increase in the speed of calculation due to automation (OPS). However, there are still improvements to be made in terms of input latency of the system (PE, OPS). The input latency is the result of a lag in the energy prices, i.e. the energy prices in the system are a few minutes behind the actual energy prices. Furthermore, the production level in the MVP1 system lags 15 minutes behind the production level of the plant.

For MVP2, the input latency will be minimized. This results in the timing of information moving closer to real-time information, which is an improvement (PrM, OPS).

Ease of access of information For MVP1, the ease of access of the flex information drastically increased. First, the flexing decisions had to be derived from the flex sheet. This decision is now directly visible (PE, OPS). Furthermore, the screen is visible in the control room by everyone and its information is stored in a cloud solution. As a result, the information is accessible from virtually anywhere.

For MVP2, the decision-making focus of the operators will shift from actively taking the flex decision to monitoring the production process and giving the 'go' for a flex opportunity. This 'go' is based on the current plant status, of which more information will become available on the dashboard. Thus, the ease of access of the information required for decision making has improved (OPS).

Controllability of information Controllability of information considers the possibility of decision makers to modify information and keep information to themselves. In the legacy system with the flex sheet, it was hard for a bystander (e.g. another operator or a wachtchef) to see if flexing would be profitable. However, for MVP1, it is easy to see whether or not flexing is advisable. This is because the screen gives a clear advice about whether to flex or not, with what amount and the potential cost savings if it is decided to start flexing, or the lost potential savings if flexing is foregone. Thus, for MVP1 there is less control over information (OPS, OBS).

MVP2 will result in less controllability of information, since the information about whether to flex or not and the amount to flex with will not be available to the operators any more. This information is now internal to the system. Furthermore, the information on which the operator can base his decision to allow flexing or not (e.g. (un)planned maintenance of reactors) will be available on the dashboard. This leads to a decrease in controllability of information, since the operator cannot keep this information to himself any more (OPS, PrM).

5.4.2 B - Effect of information availability on organizational structure

Centralization of decision making For MVP1, the final decision to flex is still made by the operator. The only change in the decision-making process is that the operator does not have to make the calculations to decide whether to flex or not any more. In this case, the system is a decision-support system which the operator uses to improve his decision making (OPS).

For MVP2, decision making is centralized around the system, i.e. it shifts from the operators in the control room to a system. The operators in the control room are still able to influence the decision, but this would be in a corrective manner instead of a proactive manner (OPS, PrM). Furthermore, the system uses parameters, which are given and/or determined by management. Examples of these parameters are the maximum allowed flex bandwidth, minimum inventory level required (i.e. safety stock). Therefore, decision making shifts indirectly to the actors setting the parameters of the system (OPS).

Organizational levels authorization In the old situation, the production planner first had to indicate if and when flexing was possible. Then, the panel operator had to calculate whether to flex or not via the flex sheet, and possibly check/justify this decision with the other panel operator. For MVP1, the panel operator does not have to make the calculation, but the screen in the control room gives a recommendation. Therefore, the operator does not have to justify his calculation, since it is an automatic calculation by the system (OPS, PM). However, there still needs to be a discussion about whether or not the plant can handle a change in the production level. This is relevant for the output side of the process (OPS). Thus, in the end the decisions still needs to be authorized by the other panel operator.

For MVP2, the number of organizational levels involved in authorizing a decision are reduced even more. This is the result of the final production decision being made by the system instead of the operator. That is, the operator does not have to authorize whether the system starts flexing and the quantity per flex operation. The role of the operator will be to give a 'go' for flexing, after which the system continuously calculates and decides whether to flex or not. Thus, the operator does not take the final decision any more (PM, PrM).

5.4.3 C - Effect of organizational structure on decision making

Nr. of human information sources For MVP1, there is an additional information source, which is the system. However, the number of human information sources used for decision making remains the same (ALL).

For MVP2, the operator's role as a direct information source changes to giving a 'go', i.e. the operator's expertise is not used directly. The decision to flex or not is automated. Because of this automation, most of the inputs are automated and fewer inputs are given by human actors. This reduces the required human interface (PrM).

Nr. of people in the decision-making unit For MVP1, the number of people in the decision-making unit remains the same, but their role in the decision-making process becomes less important. This is the result of the bigger portion of the decision being advised by the system, after which the operators only have to do a final check (PM). The decision-making role for the operator thus moves more towards a reactive decision maker.

As is the case with the number of information sources for MVP2, the number of people in the decision-making unit decreases as well. This is the result of the decision being taken over by the system. The role of the operator shifts from a proactive to a corrective actor. Thus, the operators do not directly participate in the decision-making process and are able to intervene once the decision is already made (PrM, OPS).

Variety of members in the decision-making unit In the old situation, the decision-making unit consisted of the panel operators, production coordinator and production planner. This is still the case for MVP1, since the system serves as a decision-support tool (OPS). Thus, the variety of members in the decision-making unit is not affected by MVP1.

For MVP2, a part of the operator's role is taken over by the system. This does not affect the variety of members in the decision-making unit(PM).

Time for decision-related meetings In the old situation, the time spent on decision-related meetings was already low, and they formally did not exist. However, the panel operators did discuss informally whether they should start flexing or not. For the intermediate situation, this time decreased since the screen gives a clear advice, so there does not have to be any discussion about that part of the decision. Thus, the information becomes more objective, 'harder' (OPS).

In the case of full automation, the time for decision-related meetings is reduced to a minimum. This is the result of the decisions being made instantaneously by the system (PM, OPS).

5.4.4 D - Effect of information availability on decision making

Rapid and accurate identification of opportunities For MVP1 it is easier to see when there is a flex opportunity, because the operator does not have to make manual calculations and forecasts. That is, in the old situation, the data (e.g. energy prices) had to be transformed into information first, which is not the case for MVP1 (OPS, PM). Since the transformation of the data is automated, the accuracy increases as well because of less mistakes in calculation and estimation. Besides that, the information shown on the control room screen is filtered. The information on the screen partially takes into account the process disturbances and associated costs resulting from changes in production level. This increases the accuracy of the identification of the opportunity even more (PrM).

For the full automation case, the lag in the system will be minimized, increasing the velocity of identification of opportunities. The accuracy of the opportunities can either increase or decrease, depending on which factors are taken into account in the model and the quality of the model. If all relevant real-life factors (e.g. plant situation, (un)planned maintenance, logistics) are taken into account, the accuracy of the final solution is an improvement over the accuracy of the intermediate solution (OPS). One thing that will certainly improve is the objectivity of decision making, since there will not be human interference any more (PM, OPS).

Time required to make decisions The time for decision-related meetings decreases, and the time required to authorize decisions remains the same or decreases. This results in a reduction of the time required to make decisions. This holds for both MVP1 and MVP2 . Another mechanism decreasing the time required to make decisions is the increased objectivity of decision making. MVP2 does not take opinions into account resulting from, for example, conflicting interests (PM). These conflicting interests emerge from conflicting incentives, e.g. production wants to maximize service levels and be always able to deliver a customer, whereas the project side has the goal to minimize costs, which possible decreases service levels. Furthermore, decision making will change from a daily, operational task to considerations like "How often do we update our model's parameters?"

or "How often are we going to do an evaluation of the system?" (PrM). Thus, horizon of decision making will shift towards a more tactical level.

5.4.5 E - Effect of decision making on business performance

Quality of decisions Because the automation of the calculation results in an increase in the quality, reliability, and timing of information, better decisions are made. In the old situation, the flex decision was often wrong, because of delays in the system or a wrong expectation of energy prices. In the intermediate situation, there is a better model for making the decision, which does not require human inputs to work, i.e. it is not prone to human error. By following this model and taking into account the current plant situation, the flex decision is profitable more often. Thus, comparing results from MVP1 to the legacy situation, the quality of decisions improved (ALL).

For MVP2, the quality of decisions remains the same. Operators can set parameters allowing the system to start flexing or not. Therefore, the real-life factors an operator faces which are not (yet) included in the model continue to be taken into account. However, the speed of decision making increases as flexing can occur in near-real time now, because of the increased level of decision making automation (PrM, PE, OPS, PC).

Business performance Fluctuations in the production level have an influence on the stability of the process. If the production level fluctuates, there are more resources required to re-stabilize the process. For example, fluctuations in production level affect the pH value in the brine section. This could result in an early replacement of brine filters or an increased usage of additives to stabilize the pH value. Besides that, in the sodium hydroxide section, more steam is required to create the same amount of end-product. Furthermore, these fluctuations could affect the quality of the final product, but this will be within the required margin, as proven in a pre-study regarding flexing (PE,DOC). The impact of these 'side effects' depends on several factors, such as the current temperature of the process, the flex interval (how often the production level is adjusted), and the flex magnitude (by what amount the production level is adjusted) (PC). Thus, if the factors are taken into account, flexing will have a positive impact on business performance in terms of cost reduction and profit increases. However, the quality of the end product may be affected slightly, but will still be acceptable and will not affect the client base.

An operator is able to take many factors affecting the current state of the process into account, on which he bases the flex decision. For MVP2, these factors should be modelled accordingly, to guarantee the effectiveness of the flexing. If this is not the case and the system starts flexing when the plant situation is not optimal, flexing could actually lead to a decrease of (financial) business performance (PrM, PE).

5.4.6 F - Effect of information availability on employee well-being

Job resources

Role clarity The flex calculation and decision was a side task, which did not have priority. This was not a core part of the job of operators, and only had to be done when time (and resources) allowed it (OPS).

For MVP1, operators do not have to make manual calculations in the flex sheet or energy price forecasts, increasing their role clarity.

For MVP2, this effect is stronger since the operators do not have to consider the entire flex decision any more, only the current status of the plant, which they are doing anyway.

Participation in decision making In the case of MVP1, participation in decision making remains the same, only the information on which the operator bases his decision becomes clearer.

Participation in decision making reduces as a result of MVP2. This is because first, the operator was able to make the decision himself. In the new situation, the decision is made by the system and the operator can only change it after it is made, i.e. make a corrective decision (OPS).

Performance feedback For MVP1, there is an increase in performance feedback. This is because the screen in the control room shows the cost savings obtained from flexing in near-real time. Four out of six interviewed operators indicated they liked this and could see this as some sort of competition, increasing their engagement. These were mainly the young(er) operators.

In MVP2, the performance feedback will be more elaborate. MVP2 will include the 'old' performance feedback, but also some new KPIs regarding process performance (e.g. product quality). Thus, compared to MVP1, there will be an increase in performance feedback in MVP2.

Task significance Theoretically, task significance (i.e. how important operators feel their task is to the organization) decreases as a result of MVP1 and even more for MVP2, because a machine takes over a (part of a) task. However, the operators did not see this task as being a core part of their job. As a result, perceived task significance was not affected.

Task identity For MVP1, task identity (i.e. how operators see their task as fitting in the 'bigger part') was not affected, since the operators still took the decision.

However, for MVP2 the decision becomes automated, and as such, the operators perceive this as a decrease in task identity. This is the result of automatic adjustment of the production level, which is a core task of their job.

Task autonomy The operators do not perceive any reduction in task autonomy for MVP1. On the contrary, they feel like they can focus on the core tasks of their job more. This increases the autonomy with which they can focus on the core tasks because they do not have to take the flexing decision into account any more. Besides that, they now have space to work on additional tasks (OPS).

For MVP2, operators perceive they will experience a decrease in task autonomy. This is the result of the system making automatic changes, resulting in the operators getting more production alarms and having to intervene more often. Thus, MVP2, in a certain way, dictates what they have to do (OPS). In MVP2, these alarms will be mitigated as much as possible, but these alarms probably will not be mitigated completely.

Job demands

In the case of MVP1, job demands are reduced because a non-core part of the task of operators is automated. The potential cost savings are visible, but if the operator decides not to flex, he will not be punished for his decision (PM). Thus, the increase in performance feedback is used to stimulate upside potential.

In the case of MVP2, the effect on job demands is less straightforward. Job demands are reduced because of the automation of a part of the task on one side. But on the other side, the automated decision leads to an automatic change in production, which could lead to an increase in the number of notifications and alarms an operator gets. This results in the operator experiencing more work pressure, since he has to act on the alarms (OPS, PrM, PC).

Besides the before-mentioned changes in job demands, one often-heard fear of employees with respect to digitalization in other contexts is that they risk losing their jobs because of automation. This is not the case with this solution, since a non-core task of the operators' jobs is automated, i.e. in the old situation, flexing was something additional they could do if time and resources allowed it.

Engagement

Employee engagement was hard to measure directly. One reason was that the MVP1 system has not been used a lot yet, because the factory had a long period of maximum production. Overall, employee engagement is expected to increase as a result of automation of a non-core task (i.e. the flex calculation) of the job of operators.

For MVP2, engagement is expected to decrease as a result of a decrease in job resources and an increase in job demands.

Exhaustion

As was the case with engagement, exhaustion was also hard to measure. For MVP1, a non-core task of the operators is automated (i.e. the flex calculation). This automation does not affect other (core) tasks. Furthermore, for MVP1, job resources are expected to increase and job demands are expected to decrease. Therefore, exhaustion is expected to decrease.

For MVP2, exhaustion is expected to increase as a result of a decrease in job resources and an increase in job demands.

5.4.7 G - Effect of employee well-being on business performance

In-role performance Real in-role performance could not be measured, since there is no performance data available on the operators. However, the operators indicated that as a result of the flex project, they would have more time to focus on other tasks. Thus, the operators could spend more time focusing on core tasks, which would increase in-role performance. Besides that, the majority of interviewed operators indicated they saw flexing as some sort of competition. With the MVP1 system, they can make better decisions and they are motivated to continuously improve their decisions because of the performance feedback.

For MVP2, the operators have more time to spend on their core tasks, possibly improving in-role performance. However, if their performance gets assessed on the number of alarms they get, measured in-role performance may deteriorate.

Extra-role performance There is no clear effect visible of the implementation of flexing on extra- role performance, because flexing was not allowed in the last two months.

However, a prediction can be made: because of the increased amount of time available, and a limited amount of in-role tasks, operators may spend more time on extra-role tasks. As a result, extra-role performance may increase. This holds for MVP1 and MVP2.

5.4.8 Remarks

Besides the regular interview questions, it was asked whether the interviewees wanted to tell something more about the project or their job. The results are presented below.

- There has to be a good evaluation about when to flex or not to flex. From the project side, the flexing decision is quite opportunistic (i.e. "flex more often"), on the production side, this decision is quite conservative (i.e. "flex less often"). This results in some tension between the project side and the production side.
- Some interviewees indicated that they thought flexing with 20 megawatt (MW) was a lot. They think this will lead to significant process disturbances, which could lead to an increase in costs.
- Currently, most of the panel operators did not know where to find the MVP1 system
- After the increase of the bandwidth (i.e. from 5 MW to 20 MW), flexing did not occur a lot

5.5 Discussion case study results

The purpose of this case study was to test the propositions formulated based on scientific literature and expert interviews within Accenture. Furthermore, the case study served the purpose of determining the stance of the chemical firm's employees with respect to the project specifically, and digitalization in general.

In this section, the results are discussed and compared with the propositions, to determine which propositions are confirmed by the case study and which propositions are not. If the propositions are not confirmed by the case study, it is analysed why this is not the case. Since the case study involved two phases of implementation, i.e. the decision-support system (MVP1) and the automated part (MVP2), the results will be discussed accordingly.

5.5.1 MVP1

A - Influence on information availability

In MVP1, the amount of relevant information increases, since the data previously available in the flex sheet (e.g. energy prices) is automatically transformed into information. This automatic transformation is done by an algorithm which increases the quality and reliability. While MVP1 currently has some issues with respect to timing of information (i.e. delays in information transfer), the automatic calculation provides significant timing improvements over the old solution. For the current situation, the timing of information suffices the current needs of the plant. The immediate transformation of data into information, combined with the control room screen, improves ease of access of information. This reduces the controllability of information, making it harder to keep information to oneself.

Thus, with respect to the influence of the solution on information availability, propositions 1, 2, 3, 4, and 5 are confirmed.

The results are summarized in Table 16. Here, a ✓indicates that a proposition is confirmed, a × indicates that a proposition is rejected, and a ? indicates that a proposition is not confirmed nor rejected.

Table 8: Confirmed propositions for MVP1 - relationship A

Nr.	Proposition	Conf.
1	The implementation of IoT and cloud computing increases the amount of relevant information available.	✓
2	The implementation of IoT and cloud computing increases the quality and reliability of information.	✓
3	Use of IoT and cloud computing ensures the required timing of information.	✓
4	The IoT and cloud use case improves the ease of access of information.	✓
5	The use of IoT and cloud computing results in lower controllability of information.	✓

B - Effect of information availability on organizational structure

The decision-making process in the old situation was not complicated in the sense that there were not many organizational levels involved. In the intermediate situation, this was still the case. The number of organizational levels in the decision-making process did not change. This was probably because of the nature of the system: it is a DSS and does not give a binding advice. Since the actors in the decision-making process remained the same, the centralization of decision making remained the same. Authorization of proposed organizational actions was still done by the same number of organizational levels. The number of organizational levels involved in processing messages did reduce. This is the result of the 'flex message' not needing to be processed by an operator any more, since this is taken over by the system.

The results in the preceding paragraph lead to the conclusion that proposition 8 is confirmed. Proposition 6 is rejected since the centralization of decision making remained the same, i.e. the same actors were involved in the decision-making process. Proposition 7 is rejected since the number of organizational levels involved in authorizing proposed organizational actions remained the same. This is the result of the size of the decision-making unit affected by the project. That is, because the decision-making unit is relatively small, there are not a lot of organizational levels involved in making a decision and authorizing proposed actions.

Table 9: Confirmed propositions for MVP1 - relationship B

Nr.	Proposition	Conf.
6	The changed information availability leads to more decentralization for highly centralized organizations, and more centralization for highly decentralized organizations.	×
7	The changed information availability reduces the number of organizational levels involved in authorizing proposed organizational actions.	×
8	The changed information availability reduces the number of organizational levels involved in processing messages.	✓

C - Effect of organizational structure on decision making

Since the organizational structure was only partially affected, it does not have a big influence on the decision-making process. Two main changes became visible as a result of the system. The role of the operator in the decision-making unit became smaller, since a system is now used for part of the flexing decision. Because of the small size of the decision-making unit, it is found that this is similar to a decrease in the number of people in the decision-making unit. Besides that, the time for decision-related meetings decreased, since the system gives an automatic signal.

The above results confirm propositions 10 and 12, and reject proposition 9 and 11. Proposition 9 is rejected because there was no change in the number and variety of people participating as information sources. If anything, the number and variety of people participating as information sources will decrease, since the system will obtain a larger and larger portion of the needed information automatically (e.g. from a database). Proposition 11 is rejected since it deals with the variety of members comprising the decision-making unit. The decision-making unit will only decrease as a result of more automation. This results in tasks of members of the decision-making unit being taken over by systems, resulting in less variety in the decision-making unit.

Table 10: Confirmed propositions for MVP1 - relationship C

Nr.	Proposition	Conf.
9	The changed organizational structure leads to a larger number and variety of people participating as information sources in the making of a decision.	×
10	The changed organizational structure leads to a decrease in the number of people in the decision-making unit.	✓
11	The changed organizational structure leads to an increase in the variety of members comprising the decision-making unit.	×
12	The changed organizational structure results in less of the organization's time being absorbed by decision-related meetings.	✓

D - Effect of information availability on decision making

With respect to the effect of information availability on decision making, the effects are better visible. First, opportunities to flex are identified more rapidly and in a more accurate way, as a result of the automation of the calculations and use of more sophisticated algorithms. Besides that, the automation results in a reduction in the time required to make decisions.

Consequently, propositions 13 and 14 are confirmed by the case study. p

Table 11: Confirmed propositions for MVP1 - relationship D

Nr.	Proposition	Conf.
13	The changed information availability leads to more rapid and more accurate identification of problems and opportunities.	✓
14	The changed information availability reduces the time required to authorize proposed organizational actions and make decisions.	✓

E - Effect of decision making on business performance

Compared to the old situation, there was a clear improvement in the quality of decisions. This was the result of the calculations from the flex sheet often being wrong (since energy prices had to be predicted), or too late. This increase in quality of decision making led to a subsequent increase in business performance, since the operators now had a reliable DSS to base their decisions on.

Thus, for this phase of implementation, propositions 15a and 15b are confirmed, confirming proposition 15. The changed decision-making process leads to higher quality decisions, and these decisions improve business performance.

Table 12: Confirmed propositions for MVP1 - relationship E

Nr.	Proposition	Conf.
15	The changes in decision making lead to improved business performance.	✓
15a	The changes in decision making lead to higher quality decisions.	✓
15b	Higher quality decisions lead to improved business performance.	✓

F - Effect of information availability on employee well-being

Since MVP1 is a DSS, the effects on employee well-being are not strong. Role clarity increases slightly, since the flexing calculation is now taken over by a system. Participation in decision making remains the same as in the old situation. Performance feedback increases as a result of the visibility of cost savings. This effect was found to be stronger for younger operators than operators with a higher age. Task significance, task identity, and task autonomy remained the same. Thus, overall job resources increased (slightly).

Flexing was not a core task of the operators' jobs, but they had to flex when time and resources allowed it. Therefore, they experienced some work pressure from the flexing.

Since a part of the flexing task is taken over by MVP1, work pressure and thus job demands are reduced.

Work pressure (a job demand) decreased, since the operators indicated they do not have to worry about making the flexing decision. This reduced exhaustion, allowing them to focus on core tasks of their job. These are mainly expectations, since it is hard to determine the changes in actual engagement and exhaustion using a comparative case study. A longitudinal case study would be more appropriate to test these propositions, but this was not possible due to time constraints. However, it is expected that overall employee well-being will increase as a result of the increased information availability.

The above findings result in propositions 16a, 16d, and 16f being confirmed.Proposition 16b is rejected since the operators have more autonomy in executing the core tasks of their job, not needing to focus on the flex calculation. Proposition 16c is rejected, because the automation of the flexing calculation reduces perceived work pressure. Consequently, proposition 16e is rejected as well, since job resources increase and job demands decrease. Finally, proposition 16f is accepted, since overall engagement has increased, and exhaustion reduced. As a result of the above, proposition 16 is confirmed.

Table 13: Confirmed propositions for MVP1 - relationship F

Nr.	Proposition	Conf.
16	The increased availability of information leads to an increase in employee well-being	✓
16a	The increased availability of information increases role clarity, performance feedback, task significance, and task identity.	✓
16b	The increased availability of information decreases task autonomy.	×
16c	The increased availability of information increases job demands (e.g. work pressure).	×
16d	The overall change in job demands and resources (as described in P_{16a} & P_{16b}) leads to more engaged employees.	✓
16e	The overall change in job demands and resources (as described in P_{16a} & P_{16b}) leads to higher exhaustion amongst employees.	×
16f	The changed engagement and exhaustion lead to an increase in employee well-being	✓

G - Effect of employee well-being on business performance

The effect of employee well-being on business performance was hard to measure, since (1) flexing did take place only once in the period since the system was last updated and (2) there is no performance data available for each specific operator. However, the operators indicated that as a result of increased automation they would have more time to either execute their main tasks better, increasing in-role performance, or to focus on additional, non-critical tasks, increasing extra-role performance. Examples of such additional tasks are (1) thinking about potential improvements for the system or the plant, or (2) 'digitizing' their decision-making process, i.e. putting their decision-making process on paper, including all factors they take into account.

Thus, it is expected that propositions 17 and 18 are confirmed, however, there is no hard evidence for this.

Table 14: Confirmed propositions for MVP1 - relationship G

Nr.	Proposition	Conf.
17	The increased employee well-being results in employees exerting increased in-role performance.	✓
18	The increased employee well-being results in employees exerting increased extra-role performance.	✓

Conclusion MVP1

The final model with the confirmed and not confirmed propositions in the case of MVP1 is given in Figure 21. The confirmed propositions are shown in green and the propositions which are not confirmed are shown in red.

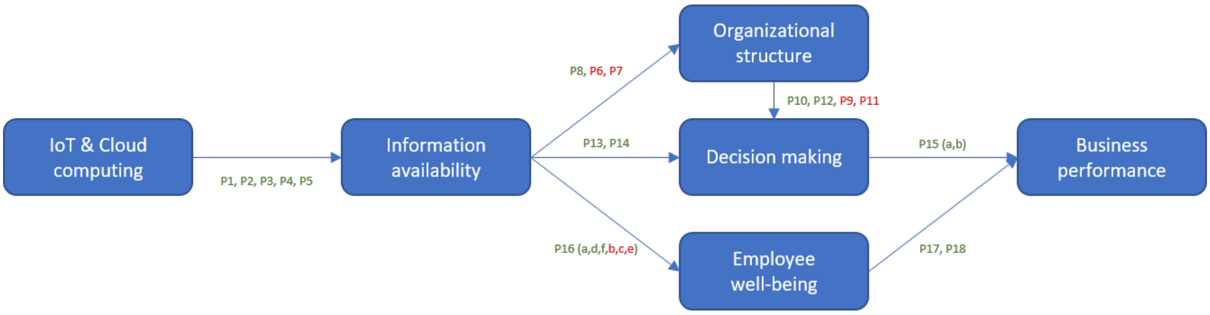

Figure 21: Confirmed propositions in MVP1

There is a strong relationship between process digitalization and information availability. This indicates that process digitalization leads to an increase in good information available to decision makers. In turn, this information availability leads to better decision making, improving business performance. The effect of information availability on organizational structure is weaker. This is the result of the small size of the task being automated, i.e. the flex calculation was only a minor part of an operator's job. If the task or set of tasks which are going to be automated are bigger, the effect on organizational structure may be stronger. For example, if tasks equivalent to 1 FTE are automated, there will be more impact on an organization then when tasks equivalent to 0.1 FTE are automated. Furthermore, the improved information availability leads to an overall increase in employee (operator) motivation. Mainly the increased performance feedback creates incentives for operators to make flexing decisions and to increase business performance. Furthermore, the performance feedback enforces the use of the new system.

Overall, there is enough evidence to accept the model in the case of MVP1, taking into account the effects when the decision-making process is more complicated and larger.

5.5.2 MVP2

The results of MVP2 are discussed compared to the situation of MVP1. Thus, a decrease in, for example, the quality of information could still be an increase with respect to the situation with the legacy system. Furthermore, the assumption is made that MVP2 considers full automation, i.e. that the operators do not have any influence over the flexing decision. This assumption was made since it was not clear what MVP2 is going to look like. If the decision to flex is not completely automated in MVP2, the impact on the workforce is basically the same as for MVP1.

A - Influence on information availability

For MVP2, the information will not be directly available to the operators. This is the result of the full automation. The operator does not have to make the flexing decision any more, he only has to make the decision about whether flexing is possible given the current state of the plant. In MVP2, more information about the state of the plant becomes available to the operator, increasing the availability of information. Furthermore, the information generated by the model on which it automatically decides improves in terms of quality, reliability, ease of access and controllability.

Consequently, in this phase of implementation, propositions 1, 2, 3, 4, and 5 are confirmed.

Table 15: Confirmed propositions for MVP2 - relationship A

Nr.	Proposition	Conf.
1	The implementation of IoT and cloud computing increases the amount of relevant information available.	✓
2	The implementation of IoT and cloud computing increases the quality and reliability of information.	✓
3	Use of IoT and cloud computing ensures the required timing of information.	✓
4	The IoT and cloud use case improves the ease of access of information.	✓
5	The use of IoT and cloud computing results in lower controllability of information.	✓

B - Effect of information availability on organizational structure

Decision making becomes centralized around the system in MVP2. The direct decision-making process becomes more centralized since it is completely taken over by the system. However, the parameters used in the model are set by management and technology. This decentralizes indirect decision making, since this was centralized around the operator before. Besides that, the number of organizational levels involved in authorizing decisions and processing messages decreases, since this is completely taken over by the system.

For MVP2, propositions 7 and 8 are confirmed. Proposition 6 is not confirmed nor rejected, since the results contradict each other. If only direct decision making is taken into account, proposition 6 is rejected. If only indirect decision making is considered, proposition 6 is confirmed.

Table 16: Confirmed propositions for MVP2 - relationship B

Nr.	Proposition	Conf.
6	The changed information availability leads to more decentralization for highly centralized organizations, and more centralization for highly decentralized organizations.	?
7	The changed information availability reduces the number of organizational levels involved in authorizing proposed organizational actions.	✓
8	The changed information availability reduces the number of organizational levels involved in processing messages.	✓

C - Effect of organizational structure on decision making

In MVP2, the decision-making unit consists of the production planner, production coordinator, operator, and the added system. The human actors give a 'go' allowing the flex decision when this is feasible. Consequently, the system calculates when it is feasible and automatically initiates flexing. Thus, the number of human information sources, and variety of members in the decision-making unit remain the same. If anything, the number of human information sources and variety of members in the decision-making unit decreases as a result of more automation (as was the case with MVP1). Due to this automation, the number of people in the decision-making unit will decrease in the long run, as automation increases. Time spent on decision-related meetings decreases, since the actors in the decision-making process do not have to discuss anything, they just give a 'go' individually.

The above results imply that propositions 10 and 12 are confirmed, and propositions 9 and 11 are rejected. Rejection of these propositions is the result of increasing automation, replacing human jobs (partially) with machines/systems like MVP2.

Table 17: Confirmed propositions for MVP2 - relationship C

Nr.	Proposition	Conf.
9	The changed organizational structure leads to a larger number and variety of people participating as information sources in the making of a decision.	×
10	The changed organizational structure leads to a decrease in the number of people in the decision-making unit.	✓
11	The changed organizational structure leads to an increase in the variety of members comprising the decision-making unit.	×
12	The changed organizational structure results in less of the organization's time being absorbed by decision-related meetings.	✓

D - Effect of information availability on decision making

Because MVP2 will include performance improvements in terms of reduction of input lag, the identification of opportunities will become more rapid. However, the accuracy might not be of the same level if real-life factors are not incorporated correctly in the model. Assuming MVP2 will incorporate the real-life factors correctly, the accuracy will improve. One thing which will certainly improve is the objectivity of decision making, because the human is partially factored out of the decision-making process. Furthermore, because the decision-making process if fully automated, the time required to make decisions is minimized.

Thus, propositions 13 and 14 are confirmed.

Table 18: Confirmed propositions for MVP2 - relationship D

Nr.	Proposition	Conf.
13	The changed information availability leads to more rapid and more accurate identification of problems and opportunities.	✓
14	The changed information availability reduces the time required to authorize proposed organizational actions and make decisions.	✓

E - Effect of decision making on business performance

It is not clear whether MVP2 will improve the quality of decision making, since it may be the case that not all relevant factors are taken into account. This may result in higher expenses for stabilizing the process, or an increase in unplanned maintenance. If these factors are included in the model, the objectivity of the decision making changes and the quality of decision making as well. All decisions are made based on the same set of rules, instead of different rules due to different levels of experience from the operators. This will as well improve financial business performance, but may result in a slight decrease of product quality. However, this decrease will be within the pre-determined bandwidth.

Consequently, propositions 15a and 15b are confirmed, confirming proposition 15.

Table 19: Confirmed propositions for MVP2 - relationship E

Nr.	Proposition	Conf.
15	The changes in decision making lead to improved business performance.	✓
15a	The changes in decision making lead to higher quality decisions.	✓
15b	Higher quality decisions lead to improved business performance.	✓

F - Effect of information availability on employee well-being

The absence of the flex decision increases operators' role clarity, and decreases participation in decision making and performance feedback. Task significance should theoretically drop as well, but since a non- core part of their job is eliminated, their perceived task significance does not decrease. Task identity decreases as a result of decreased performance feedback and automatic changes in the production level. That is, not all the changes in the production level are because of the operator's own doing.

The flex decision is a non-core part of the operators' jobs. However, setting the production level is a core part of the job. Automatically changing the production level thus leads to a decrease in perceived task autonomy for the operators. Because the before-mentioned changes in job resources contradict each other, the overall effect on job resources is inconclusive.

Job demands will decrease as a result of MVP2. The decrease in job demands is the result of automation of the whole flexing part, and indirectly shifting the flexing decision to a core part of the operators' jobs. The flexing decision is now given by the operator depending on the status of the plant, which he is monitoring anyway.

The reduced job demands due to automation are expected to reduce the level of exhaustion among decision makers. Engagement is expected to remain the same or decrease slightly, as a result of the change in job resources. Since exhaustion is expected to decrease more than engagement, it is expected that employee well-being will increase. However, the effect is not expected to be strong since the overall changes in exhaustion and engagement are small.

As a result of the above, propositions 16b and 16f are confirmed, proposition 16a is not confirmed nor rejected, and propositions 16c, 16d, and 16e are rejected. These findings result in the confirmation of proposition 16. This is mainly the result of the decrease in work pressure, resulting in a decrease of exhaustion among employees, which leads to an increase in employee well-being. Besides that, the change in job resources is not significant, as well as the change in employee engagement.

Table 20: Confirmed propositions for MVP2 - relationship F

Nr.	Proposition	Conf.
16	The increased availability of information leads to an increase in employee well-being.	✓
16a	The increased availability of information increases role clarity, performance feedback, task significance, and task identity.	?
16b	The increased availability of information decreases task autonomy.	✓
16c	The increased availability of information increases job demands (e.g. work pressure).	×
16d	The overall change in job demands and resources (as described in P_{16a} & P_{16b}) leads to more engaged employees.	×
16e	The overall change in job demands and resources (as described in P_{16a} & P_{16b}) leads to higher exhaustion amongst employees.	×
16f	The changed engagement and exhaustion lead to an increase in employee well-being.	✓

G - Effect of employee well-being on business performance

Since employee well-being is expected to increase as a result of MVP2, and the operators will have more time due to increased automation, in-role as well as extra-role performance are expected to increase. Since operators will have more time to focus on their core tasks, in-role performance increases. On the other hand, the operators can spend this time on tasks which are not part of their job as well, increasing extra-role performance. The final effect of the changed employee well-being on employees depends on the organization's incentives, i.e. if it is rewarded to focus on extra-role tasks, extra-role performance will probably increase more than in-role performance. Because of the limited change in employee well-being, the effects on in-role and extra-role performance are not expected to be strong.

Thus, propositions 17 and 18 are accepted.

Table 21: Confirmed propositions for MVP2 - relationship G

Nr.	Proposition	MVP1
17	The increased employee well-being results in employees exerting increased in-role performance.	✓
18	The increased employee well-being results in employees exerting increased extra-role performance.	✓

Conclusion MVP2

The final model with the confirmed and not confirmed propositions in the case of MVP2 is given in Figure 22. The confirmed propositions are shown in green, the propositions which are not confirmed nor rejected are shown in black, and the propositions which are not confirmed are shown in red.

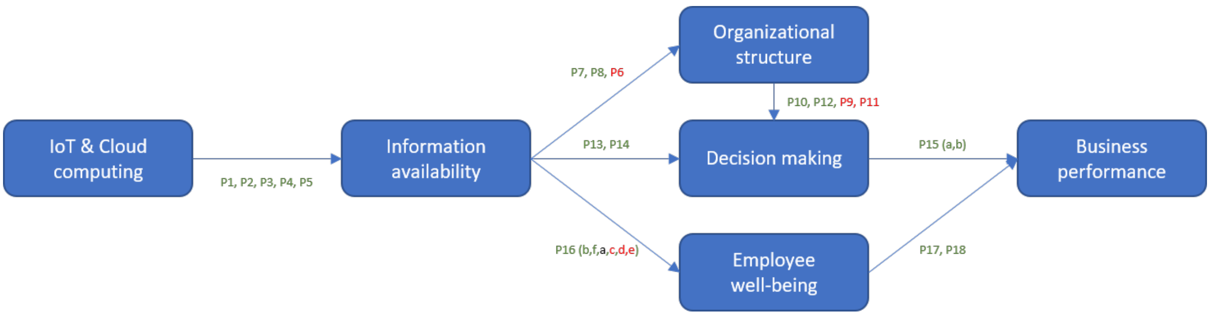

Figure 22: Confirmed propositions in MVP2

Looking at the results presented in this section, the following observations regarding MVP2 are made. As a result of MVP2, the decisions made by the operator are changed. First, the operator had to assess the plant status and then decide to flex. Now, the operator only assesses the plant status and the system decides to flex. As a result, information regarding the plant status becomes more relevant for decision making. With the new dashboard, the operators get additional information which is reliable, accurate, and timely. Furthermore, the timing of the information for the flex system will improve and will move close to real time. The required information for decision making becomes easier to access due to the dashboard, which results in lower controllability of information (i.e. harder to keep information to yourself).

In MVP2, a task will be automated, which is expected to materialize in (small) changes in organizational structure. It is expected there will be a decrease in the number of organizational levels involved in authorizing and making decisions. This is expected to result in faster and more objective decision making. Besides that, because of improvements in the algorithm underlying MVP2, decision making becomes more accurate. The improvements in terms of accuracy, speed, and objectivity are expected to lead to higher quality decisions, which improve business performance.

MVP2 is not expected to affect employee well-being heavily. On one hand, task autonomy will be reduced, which may reduce employee well-being. But on the other hand, work pressure will decrease since the operator does not have to worry about that task any more. It is expected that the decrease in task autonomy and the decrease in work pressure partially cancel each other out in terms of employee well-being. As a result, it is expected that business performance will not be greatly affected by changes in employee well-being due to MVP2.

MVP2 provides undoubtedly technical advantages over MVP1. Decision making becomes more objective, accurate, and fast. However, the results of MVP2 depend heavily on the level of automation of the decision and how this is implemented. For example, if too much of the decision-making process is automated, knowledge possessed by the operator might be missed-out in the new decision-making process. This could potentially negatively affect business performance.

5.5.3 MVP1 vs. MVP2

As can be seen from 22 and the results presented in the preceding sections, there are some differences between MVP1 and MVP2 in terms of information availability, organizational structure, decision making, and employee well-being. These differences are mainly the result of the fact that MVP1 is a decision-support system, whereas MVP2 is an automated system. The differences will be discussed here.

MVP1 gives information about when to flex and the amount to flex with, which is in the current situation the required information for decision making. MVP2 automates the decision to flex, after the operators have determined that it is feasible to flex. Thus, in the two systems, different information is required for decision making by the operators.

Since MVP1 gives an advice, it does not affect the factors regarding organizational structure with the same magnitude as MVP2, which automates a task. From MVP2, it can be seen that the number of organizational levels involved in authorizing organizational actions will decrease. This is not the case for MVP1; the number of organizational levels involved in authorizing organizational actions remains the same. Thus, at first, the results of this proposition regarding MVP1 and MVP2 may seem contradicting, however, this is the result of the nature of the systems.

The impact MVP1 and MVP2 have on employee well-being differ. Where MVP1 (or a decision-support system in general) would not affect employee well-being negatively, it is possible that MVP2 has a negative effect on employee well-being. MVP1 does not affect task autonomy, since it solely gives an advice about a decision. MVP2 automates a decision, and as such, perceived task autonomy is reduced. This may result in less motivation amongst employees, but these effects might be mitigated by a reduction in work pressure. Thus, for MVP2 there might not be a change in employee well-being. If this is the case, in-role and extra-role performance are not affected by employee well-being.

Considering the tension existing between the production department and the project side, with MVP1 the flex potential will probably not be utilized in full. MVP2 already automates a part of the flexing decision, making it more objective. The way MVP2 will be implemented is expected to not affect service levels in a negative way. Therefore, MVP2 performs better in terms of balancing cost savings and service levels. Since the impact of MVP2 on employee well-being is expected to be minor, MVP2 is an improvement over MVP1.

The confirmed, rejected, and not confirmed hypotheses are given in Table 22 on the next page. Here, the column "Nr." refers to the number of the propositions as mentioned in Figure 15. Again, a ✓indicates that the proposition is confirmed, a × indicates that a proposition is rejected, and a ? indicates that a proposition is not rejected nor confirmed. Not confirming nor rejecting a proposition might be the result of not enough data or results which contradict each other.

Table 22: Confirmed and not confirmed propositions for MVP1 & MVP2

Nr.	Proposition	MVP1	MVP2
1	The implementation of IoT and cloud computing increases the amount of relevant information available.	✓	✓
2	The implementation of IoT and cloud computing increases the quality and reliability of information.	✓	✓
3	Use of IoT and cloud computing ensures the required timing of information.	✓	✓
4	The IoT and cloud use case improves the ease of access of information.	✓	✓
5	The use of IoT and cloud computing results in lower controllability of information.	✓	✓
6	The changed information availability leads to more decentralization for highly centralized organizations, and more centralization for highly decentralized organizations.	×	?
7	The changed information availability reduces the number of organizational levels involved in authorizing proposed organizational actions.	×	✓
8	The changed information availability reduces the number of organizational levels involved in processing messages.	✓	✓
9	The changed organizational structure leads to a larger number and variety of people participating as information sources in the making of a decision.	×	×
10	The changed organizational structure leads to a decrease in the number of people in the decision-making unit.	✓	✓
11	The changed organizational structure leads to an increase in the variety of members comprising the decision-making unit.	×	×

12	The changed organizational structure results in less of the organization's time being absorbed by decision-related meetings.	✓	✓
13	The changed information availability leads to more rapid and more accurate identification of problems and opportunities.	✓	✓
14	The changed information availability reduces the time required to authorize proposed organizational actions and make decisions.	✓	✓
15	The changes in decision making lead to improved business performance.	✓	✓
16	The increased availability of information leads to an increase in employee well-being.	✓	✓
17	The increased employee well-being results in employees exerting increased in-role performance.	✓	✓
18	The increased employee well-being results in employees exerting increased extra-role performance.	✓	✓

Chapter 6

Discussion

The aim of this thesis was to determine and test factors influencing successful supply chain integration and information sharing, in the light of current technological developments. Research questions and a research model were developed based on an extensive literature review and expert interviews within Accenture. Using the literature review and expert interviews, propositions were formulated to help in answering the research questions. These propositions were then tested using a comparative case study at a chemical firm. The industrial context is an important factor to take into account, since the firm operates in the process industry, which is characterized by a high degree of automation.

Most promising use cases

The most promising use cases for digitalization were found using the expert interviews within Accenture. There basically were two combinations of technologies which played a role in these use cases, which were IoT and cloud computing, and IoT and blockchain. The technologies in these combinations are complementary, e.g. cloud computing can handle and help to make sense of the big amounts of data generated by IoT sensors.

IoT and blockchain The combination of IoT and blockchain is mainly useful in multi-stakeholder contexts, i.e. where multiple supply chain partners are involved. This is because blockchain technology enables real time reliable information sharing across partners. Besides that, the combination of technologies was identified as being one of the most disruptive ones. The main expected use case obtained from the interviews is asset and order tracking. Asset tracking is mainly useful in contexts where there are a lot of changes in ownership, for example, in transportation cases where pallets or containers are used. IoT plays a role in this use case, since it collects the data to be stored on the blockchain. Not all of the data may be stored on the blockchain, but mainly the relevant data for decision making. Alternatively, data may be concatenated and transformed into information first, before storing it on the blockchain. This reduces the required storage space on the blockchain. For example, order status can be put on a blockchain such that all the involved parties are able to view the order status at any time and can anticipate on this status. This use case is without doubt promising and may affect supply chains significantly. However, the use case mainly exists in theory and has not been applied yet in practice. This makes it difficult to assess the organizational impacts of this use case.

IoT and cloud computing IoT and cloud computing combined form a more mature solution, which has already proven itself in practice. The main applications for IoT and cloud computing were in logistics, optimizing warehouse operations for example. Currently, the resources/process industry is adopting the use of IoT and cloud computing to optimize its processes. This is achieved by using IoT sensors to measure a big amount of variables (e.g. temperature, energy usage, flow rate), storing this data in a cloud and applying analytics to the data in this cloud. These analytics can then be used to implement decision-support systems or fully automate a decision-making process. The IoT and cloud computing use case mainly affects a firm's internal processes, since it does not enforce external information sharing.

Other use cases regarding the use of IoT and cloud computing are improving customer intimacy and new business model generation. Improving customer intimacy is similar to the use case regarding order tracking using IoT and blockchain. New business model generation might be the most advanced application of IoT and cloud computing. However, it was not feasible to analyse this, since organizations regard this information as highly confidential.

Because process optimization using IoT and cloud computing is already in a more mature phase than blockchain technology, this use case was selected as the most promising use case for the study. Consequently, a proof-of-concept with IoT and cloud computing at a leading chemical firm was analysed using a comparative case study approach. There basically were three cases: no automation (the old situation), a decision-support system (the current situation), and full automation (the future situation) .The case study was used to test the propositions formulated before and answer the remainder of the research questions.

Information availability

Type of information The type of information changed in a positive way as a result of increasing digitalization. The main observation regarding the type of information was that - when moving towards full automation - the information became clearer. In the case with no automation, the information was closer to raw data, and had to be transformed first in order to be useful for decision making. In the case of the decision-support system, the system gave a clear advice for decision making, telling the decision maker exactly what he should do. Thus, in this case, more relevant information became available for decision making compared to the old situation. Finally, in the case of full automation of the decision, it is expected the information which was used by decision makers first will become internal to the system. As a result, the old information required for decision making will become unavailable to the decision makers. However, they did not need this information any more, since the decision was automated.

Quality of information The quality of information improved due to an increase in digitalization. This is mainly because a fully automated system is less prone to human errors. Furthermore, automated decisions can be based on more sophisticated algorithms than manual calculations to base decisions on. For example, an operator generally does not have the time or required skill to make an accurate forecast of energy prices.

Timing of information Because of increasing digitalization, timing of information improves. Again, this is the result of (1) removing the human factor (partially) from the decision-making process, and (2) improvements of systems. The closer one moves towards full automation, the faster systems can become since more attention is given to their development.

Ease of access of information From the case study, it was found that the old information necessary for decision making will be harder to access. However, as a result of digitalization, the decision-making process changes and other information will be more relevant for decision making. In the case study it was observed that the relevant information for the new decision-making process is easy to access, and provides an improvement over the ease of access from the old situation. This is the result of (1) the information becoming clearer, as described in "Type of information", and (2) the possibility of displaying the information easily in dashboards, since it is already stored in a central location (the cloud).

Controllability of information Because more information is captured in systems, it is harder for individuals to exert control over information (e.g. to keep information to yourself, to change information). As the level of digitalization increases, the controllability of information decreases. This does not have to be a negative effect, since it leads to an increase in transparency. It depends on an the characteristics of the decision-making process and possibly even on the organizational culture if this effect is regarded as negative or not.

Organizational impacts

Organizational structure In the case study it was observed that organizational structure is not heavily affected by the digitalization project. This was mainly the result of (1) the decision-making unit being of a small size, (2) the size of the task which is being automated, and (3) the short timespan of the project (up until now). Because the decision-making unit consisted of four actors, and the decision they make was just a relatively small task in their set of tasks, it was not observed that, for example, jobs disappeared as a result of digitalization. Furthermore, because the task which was automated had a relatively small size with respect to its effects on the organization, organizational structure was not affected much. For example, if the whole production department's decisions would be automated (e.g. planning, operations), the impact would be much bigger compared to automation of the flexing decision. Finally, if the decision-making unit would be of a larger size and the task would have more impact on the organization, the effects on organizational structure probably would not materialize within the current timespan of the project. This is the result of (1) the project being in a test phase, such that jobs likely will not disappear during the test phase, and (2) because organizations tend to move slowly with respect to changes in organizational structure. It is expected that there will be future impacts on organizational structure as a result of increasing automation, throughout the decision-making process.

Decision making As a result of digitalization, decision making can become more rapid and more accurate. The increase in rapidness of decision making is due to improvements of the timing of information (i.e. information becomes available more quickly), and due to the changed type and ease of access of information. That is, at first the information needed to be interpreted, whereas in the case of the decision-support system a clear advice is given which can be implemented immediately. Furthermore, for the case of full automation of the decision, the rapidness of decision making is maximized. Besides the increase in rapidness of decision making, accuracy increases. This is due to the fact that the information on which the decision is based is becoming more accurate. For example, due to the use of more sophisticated decision-making algorithms. Furthermore, the decision-making process becomes more objective as digitalization increase, leaving less space for subjectivity. As a result, accuracy of decision making increases.

Employee well-being Based on the two solutions seen in the case study, employee well-being is expected to increase as a result of digitalization. The decision-support system mainly increases job resources, increasing engagement. Besides that, the decision-support system gives employees more confidence in their decision making, since they can trust on more reliable facts. Furthermore, job demands decrease, since the decision-support system takes over a task (manual calculation) from the decision maker. For the case of full automation, job demands are again expected to be reduced, since employees will experience less work pressure because the decision is not their responsibility any more. Job resources are expected to stay at the same level or increase compared to the situation without any system. Compared to the situation with the decision-support system, it was found that job resources may decrease slightly. This is particularly the result of a decrease in task autonomy and a decrease in performance feedback. However, the effect of performance feedback on job resources will be negligible, since the performance feedback was focused on a decision the employees do not have to make any more. If job demands and resources are of a sufficiently high level, employee well-being is expected to increase as a result of an increase in digitalization. If job demands and resources generally are low (i.e. below the threshold level), employees might become bored. In this case, their well-being decreases as a result of an increase in digitalization.

Business performance

Decision making The changes in decision making are expected to have a positive effect on business performance. For the decision-support system, business performance will surely improve, given that the system gives the right advice and/or the operator maintains a critical view of the system. That is, the operator does not blindly follow the advice of the system but does a sanity check by himself. However, due to this critical view, the operator may be conservative regarding use of the system, not leveraging the full potential of the system. This can be solved by full automation, where the operator does not have to make the decision himself. Here, it should be taken into account that all relevant real-life factors affecting the decision are included in the system. Alternatively, the (former) decision maker has to give his approval for the decision, such that he takes the real-life factors into account.

Employee well-being In-role performance increases as a result of the decision-support system, since better decision are made when decision makers use the system. For full automation, the decision technically is not part of the decision maker's job any more, so in this case, in-role performance is not affected. However, both a decision-support system as well as a fully automated system reduce the decision maker's workload, giving the decision makers more time to focus on other tasks. This can result in an increase in in-role performance, since due to the increase time they can spend on in-role tasks, they can execute these tasks better.

Extra-role performance may increase for both decision-support systems and the fully automated systems in a similar way. The workload for decision makers is reduced, giving the decision makers more time to focus on extra-role tasks. They can, for example, use this time to think about process improvements.

Thus, changes in employee well-being will have a positive effect on business performance. The increase in business performance can either materialize via an increase in in-role performance or via an increase in extra-role performance. Which of these two mechanism becomes active depends on job characteristics and organizational incentives. For example, if inputs for process improvements are rewarded and this is not part of the employee's job, extra-role performance may increase.

6.1 Limitations

Status of implementation Because of the novelty of the application of IoT and cloud computing in the industry context, this study has some limitations. Only one project was analysed, which results in a low level of generalisability for theory induction purposes. This is mainly the result of the limited attention the use case has received in scientific literature, i.e. a basis for research was not available yet. This thesis provides that basis, by providing a research model with related propositions and performing a first test of the propositions.

Besides that, the status of implementation of the specific project poses a limitation. The full automation case was not implemented yet, which resulted in results which were of a more hypothetical nature. That is, situations were sketched for the interviewees, but they did not have real-life experience with these situations. This resulted in a lower validity and reliability of results compared to the results from the decision-support system phase. Overall it is expected the proposed results will hold, if the project is implemented as planned. However, if there are deviations from the project plan, these results might not hold any more.

Limited time and resources Besides the limitations emerging from the current state of application of the technologies, there are limitations which are the result of limited time and other resources. From the research methods feasible for this study (because of the current state of implementation of technology), the experiment would have been the preferred research strategy. However, an experiment requires lots of resources and takes a big amount of time to set up correctly. Therefore, it was not feasible to conduct an experiment for this thesis. If an experiment would have been used, there would be stronger evidence for causal relationships. Besides that, some propositions could have been accepted or rejected with more confidence. An example of such an expectation is that increasing the size of the decision-making unit is expected to increase the effect digitalization has on organizational structure. On the other hand, the use of a case study provided more insight into real-life variables affecting the relationships, for example, the differences in effect of automating core- and non-core tasks. These insights can be tested in future research.

In addition, to test some relationships, for example, the change in employee well-being and its effect on business performance, a longitudinal case study would have been preferred. However, a longitudinal case study requires a project with a long(er) timespan than was feasible for this thesis. As a consequence, not all of the associated propositions could be tested directly. This was solved by asking how employees would feel in such a situation, that is, ask for their expectation. This decreased the reliability of results.

Furthermore, the case of full automation was not implemented yet, but the stakeholders were aware of it. As a result, expectations had to be asked in the same way as with some of the employee well-being propositions. However, this impacted the reliability of results less, since testing the other propositions (i.e. not related to employee well-being), can be done accurately by sketching a situation and asking the interviewees how they would act in that case. Besides that, documentation helped in improving the validity and reliability of the results.

6.2 Implications

6.2.1 Implications for theory

The research model holds depending on the context of the project under consideration. That is, it is expected to hold for digitalization of a relatively large decision-making process where the human actor plays an important role. If the decision-making process is relatively small (such as for case A), the changes in organizational structure are limited. As a result, the effect of changed organizational structure on decision making is small. If the human actor does not play an important role, changes in employee well-being will not necessarily affect business performance. That is, employees putting in additional effort will not significantly increase business performance. On the other hand, if employees become less motivated and their performance decreases, this may have effects on business performance. Thus, in these cases, employee well-being affects business performance solely on the downside.

The propositions formulated and tested in this thesis should serve as a basis for further research. That is, the propositions should not be seen as 'true', but rather as initially confirmed or rejected, which then requires additional testing. Besides that, some observations were made which were not captured in the propositions. These observations should be treated as if they were propositions, and should be tested in the future too.

Overall, the research model can be accepted as a solid basis for further research. The relationships generally hold, but the mechanisms are not always the same. This depends on several factors, such as the scale of the decision-making process and the scope of the system being implemented. Some propositions were not confirmed due to these factors, but this does not mean the propositions do not hold in general. The propositions are more dependent on the context than the model itself, which was shown to hold for the case of a decision-support system, as well as automated decision making. Thus, the proposed research model is an adequate representation of reality.

6.2.2 Implications for practice

The results from this thesis can be used for three main purposes: (1) Accenture can use the results in digitalization discussions with its clients, (2) Companies can use the results for their own digital transformation, and (3) specific recommendations for the firm at which case A was analysed were formulated, which the firm can use to improve its digitalization process.

Accenture can use the results to discuss with clients about the advantages of IoT and cloud computing specifically, and digitalization in general. The usefulness stems from the fact that usually only the technological capabilities and advantages of digitalization are highlighted. With the results of this thesis, there is the possibility to include organizational advantages as well.

Besides that, the results may be used to contextualize future digitalization projects. In this study, points of attention with respect to digitalization of processes were found. Besides that, benefits of digitalization and effective ways of adoption of new systems were found, from an organizational psychological perspective.

Specific recommendations were given to the chemical organization based on the pilot case study. The firm is developing case A at one plant, but is planning to use the technology in more plants. The formulated recommendations can be used organization wide for the further implementation of the technology.

Finally, general recommendations for digitalization were developed based on the interview results and the pilot case study. These recommendations are useful to take into account for any organization digitalizing its processes. The recommendations are given in the next section.

Managerial recommendations

Based on the findings of this study, a digitalization roadmap for decision-making processes was developed with the intention to aid organizations in their digitalization process. The roadmap is given in Figure 23, and is further explained in this section.

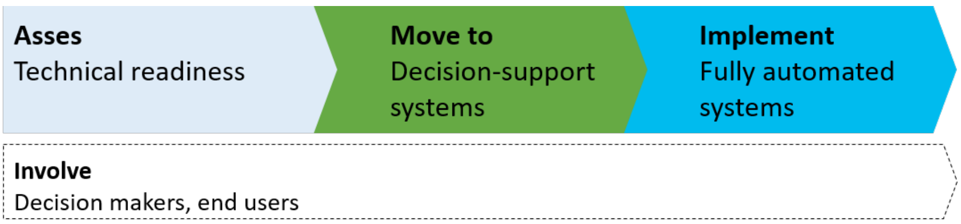

Figure 23: Digital transformation roadmap

Assess technical readiness Before engaging in a digital transformation, the technical readiness of the organization as well as its processes should be assessed. The organization's culture and the stance of its people should be assessed with respect to digitalization. This gives an overview of potential factors of resistance to digitalization, such that they can be addressed beforehand.

Besides that, the technical readiness in terms of processes should be assessed. Since digitalization is a process rather than a 'one-off solution', it happens incrementally on a process-by-process basis. Therefore, the interaction of the digitized process with other processes should be considered. If this is not the case, decisions made by a system could be of a high quality, but if the system is not able to execute and/or implement them correctly, business performance will be negatively affected. For example, a system which only changes the production level of a plant, disturbing the production process but not rebalancing it, can have negative consequences for business performance.

Move to decision-support systems When the technical readiness of the organization is assessed, decision support systems may be put into place. These systems solely have positive impacts on employees and do not require substantial organizational changes. As the name says, decision-support systems help decision makers in making better and quicker decisions, improving business performance.

Since decision-support systems do not fully automate a decision-making process, all relevant real-life factors are still taken into account by the decision maker. They do not have a big impact on an organization in terms of changing the fundamentals of a decision-making process or a decision-making unit. That is, the number of people in the decision-making unit and the way in which decisions are made will largely remain the same. The only difference is that one or more decisions are now supported by a system. Adoption of these systems can be stimulated by including performance feedback mechanisms.

These systems can be used as intermediate systems to obtain information about (factors influencing) the prospective digitized process. The performance of the process will not be affected negatively by these systems, such that the implementation of full automation does not need to be rushed.

Implement fully automated systems Using the decision-support systems as a basis, implementation of fully automated systems may be started. Implementation of fully automated systems is more challenging than for decision-support systems, since all relevant real-life factors should be taken into account and the systems should outperform a human decision maker. If this is not the case, business performance may be affected negatively.

A clear line should be drawn between what the system does, and what is does not do. This way, the human actor knows to what extent s/he can rely on the system. For example, automation of a relatively easy decision can comfortably be relied on. However, more complicated decisions, with a large amount of variables to be taken into account, may not be as reliable when fully automated. This could be the result of wrong specification of the underlying model, or because not all relevant real-life factors are being taken into account.

More complicated calculations and resulting decisions should be tested thoroughly and it is advised to move slowly to full automation. That is, for an appropriate period of time, system performance should be measured and verified to allow necessary improvements to be made.

Relevant real-life factors may be found using historical data analysis, where a model's decision rules are tested against historical data. This way, the model's performance can be assessed. Consequently, the model's performance may be improved by adding variables which are already available in a database. If inclusion of these variables leads to improved model performance, these variables should be included in the final model.

Real-life factors can be obtained from current decision makers as well. That is, 'thinking out loud' protocols may be used to determine which factors the current decision makers take into account. If these factors are already available in a database, they can be easily included in the decision-making model. If this is not the case, the factors should be measured directly. Measuring these factors can be done by the use of, for example, IoT sensors.

Involve decision makers and end users During the digitalization process, current decision makers as well as prospective end users should be incorporated in development of the system. Involvement of current decision makers is important since (1) acceptance of the system will increase, (2) they will adopt the systems more easily, and (3) they can provide valuable inputs for the system. If current decision makers know the rationale behind the new system and the reason for its implementation, they will more likely accept it. Consequently, if decision makers accept the new system and are aware of its benefits, they will more likely adopt it and start using it. Current decision makers can provide valuable inputs spanning from identification of additional variables for the underlying model, to more design-related considerations (e.g. how does a dashboard have to look). Use of intermediate solutions by current decision makers (and prospective end users) is important to obtain data about how the system is used and to identify directions for future improvement.

Often, current decision makers will be the end user of the new system. However, if this is not the case, future end users should be involved to (1) increase their acceptance of the system, (2) increase their adoption rate of the system, and (3) provide them with an initial, basic understanding of the system. If prospective end users already have a basic understanding of the system and the logic behind the system, it will be easier for them to use it in the future.

6.3 Directions for future research

This thesis serves as a basis for research regarding organizational impacts of digitalization in general, and for IoT and cloud computing specifically. Future research should focus on the limitations of the study. Preferably, future research should follow these steps:

1. Conduct an experiment to confirm relationships and test additional propositions
2. Verify the propositions using a quantitative survey
3. Test the results in other contexts

Experiment As already mentioned in the limitations section, conducting an experiment can be useful to test for true causal relationships. The experiment should be used to further verify and confirm the readily tested propositions. This is especially important for the full automation case, since confirming and rejecting these propositions was based on expectations in this study. Additional propositions were found from the interviews, which need testing as well. If it is not possible to test these propositions using an experiment, another case study may be held.

Quantitative survey After testing propositions for true causal relationships in the experiment, additional reliability and validity of results can be achieved by testing the confirmed propositions using a quantitative survey. However, this depends on the availability of cases where IoT and cloud computing are implemented. A quantitative survey improves the validity of results since statistical analysis may be applied on a large number of cases.

Other contexts The results of the quantitative survey can be used for further theory induction. To improve generalisability, the results from the quantitative survey can be tested in other contexts. For example, it can be tested whether the propositions hold for digitalization in general, only for the combination of IoT and cloud computing, or only for the selected use case. Furthermore, the industry context may be changed, to test if the results hold for the process or resources industry in general.

All in all, the specific results obtained in this thesis should be used as a basis for future research. Future research should focus on (1) the limitations of the current research, (2) increasing validity and reliability of results, and (3) generalisability of results.

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Appendix A

General interview format (Dutch)

Momenteel ben ik bezig met een onderzoek naar de invloed van supply chain digitalisatie op informatiedeling en de effecten hiervan op de beslissingsstructuur en de werknemers. Omdat supply chain digitalisatie een erg breed begrip is en dit op zeer veel verschillende manieren kan worden gerealiseerd wil ik een kijken naar de meest veelbelovende use cases van (combinaties van) nieuwe technologieën. Voorbeelden van deze technologieën zijn blockchain, advanced analytics/machine learning, AI, RPA, cloud, IoT. Dit onderzoek is onderdeel van mijn master thesis voor de master Operations Management & Logistics.

1. Use case identificatie
   - Wat denk je dat de meest veelbelovende nieuwe technologie/combinatie van technologieën is voor supply chain digitalisatie?
   - Hoe kan dit worden toegepast in een suppy chain digitalisatie context (wat is de use case)?
   - Wat is het onderscheidende voordeel van deze use case ten opzichte van al bestaande oplossingen?
2. Informatie beschikbaarheid
   - Hoe beïnvloedt deze use case de beschikbaarheid van informatie?
     - Type informatie (voegt het waarde toe)
     - Kwaliteit van de informatie (nauwkeurigheid, betrouwbaarheid)
     - Timing van informatie (op tijd beschikbaar)
     - Snelheid van de informatie (real-time verzending)
     - Toegankelijkheid van de informatie
     - Controle, privacy (wat wordt er gedeeld en met wie)
3. Invloed op organisatie
   - Hoe denk je dat de veranderde informatiebeschikbaarheid de organisatie beïnvloedt (structuur, besluitvorming, werknemers' motivatie)?
4. Afsluiting
   - Heb je voorbeelden van bedrijven die van deze use case een proof-of-concept of een pilot hebben uitgevoerd (bij voorkeur binnen resources)?

Appendix B

Function descriptions

Name in text	Position	Technological/functional specialization	Industry	Speciality	Further remarks
Senior manager 1	Senior manager	Tech architecture science	Resources	Resources industry applications	
Senior manager 2	Senior manager	Program, project & service management	Resources	Industry strategy	
Manager 1	Manager	Functional strategy	Cross-industry	Supply chain & operations	Blockchain expert
Consultant	Consultant	Functional strategy	Cross-industry	Supply chain & operations	Blockchain expert
Manager 2	Manager	Functional strategy	Cross-industry	Supply chain & operations	
Senior principal	Senior principal	Strategy	Cross-industry	Supply chain & operations	
MD	Managing director	Management consulting	Resources	Finance	RPA expert
Manager 3	Manager	Technology consulting	Resources	SAP Financial accounting & operations	AI expert
Manager 4	Manager	Technology consulting	Resources	Business & technology integration	Lead blockchain focus group resources
Senior manager 3	Senior manager	Digital transformation	Resources	Sales	
Manager 5	Manager	Technology consulting	Resources	SAP SCM ERP Planning	
Consultant 2	Consultant	Lean Six Sigma	Cross-industry	Analytics	

Appendix C

Case study interview guide

C.1 General

Thank you for participating in this interview. To provide you with some context: this interview is part of the research for my master thesis for the master Operations Management & Logistics. The goal of this interview is to determine the impact IoT & cloud computing have on decision making and employee well-being. Your answers will remain anonymous and your name will not be mentioned in any kind of report. The interview will take approximately one hour.

C.1.1 Process

1. What does the process affected by the project look like on a high level?
2. Who are involved in this process?
3. What is your role/relationship with the process?
4. In what way do you collaborate with colleagues?
5. How does information usually get shared in your business unit?
6. To what extent are you able to influence the operational performance of the process?
7. What does the decision-making process affected by the project look like?
8. Who are involved in this decision-making process?

C.1.2 Project

The goal of this part is to get a basic overview of the PoC and how it was implemented in the organization.

1. What was the proof-of-concept about?
    - What technologies played a role?
    - How were these technologies used?
2. What was the scope of the PoC?

3. For how long did the PoC run?
4. Who were involved in the PoC (e.g. own firm, consultancy, ...)?
    - How many people were involved in total?
5. Employees from what organizational levels were involved?

C.2 Organizational factors

This part of the interview serves to assess the organizational impact of the PoC. Some questions are comparative, e.g. "How did information availability change?". These questions are compared to the situation without the PoC. If the project is not finished yet, could you give an expectation of these impacts?

C.2.1 Effect on information availability

1. Did the amount of relevant information for decision making change, and if so, in what way?
2. How did the characteristics of the information change?
    - How did the quality of information change (accuracy, ...)?
    - How did the reliability of information change?
3. Was the information available when required (i.e. was the timing of the information good)?
4. How did the accessibility of information change?
    - To you?
    - To people in the decision making process?
    - To other people in the organization?
5. How did the control over the information change (e.g. is it harder to keep information to yourself)?
    - To you?
    - To people in your business unit?
    - To other people in the organization?

C.2.2 Effect of information on organizational structure

Because of the timespan of the PoC, effects on organizational structure will probably not materialize within the duration of the PoC. However, there might be some indicators of these effects. These questions are aimed at finding these indicators to make a prediction for the future.

1. Did people from different hierarchical levels make decisions, compared to the old situation?

2. Did people from different business units make decisions, compared to the old situation?

3. Thus, did decision making shift to other places in the organization?

4. When making a decision based on the information obtained from the PoC, does this decision need to be authorized?

   - If yes, through how many organizational levels does this decision need to go? How does this compare to the situation without the information from the PoC?
   - If no, is this the case without the new information as well?

C.2.3 Effect of organizational structure on decision making

1. Did the amount and variety of (human) information sources used increase or decrease?

2. Did the amount of people in the decision-making unit increase or decrease?

3. Did the variety of the people in the decision-making unit increase or decrease?

4. Did the total amount of time spent on decision-related meetings increase or decrease?

C.2.4 Effect of information on decision making

1. Did problems and opportunities in the process get identified more rapidly and in a more accurate way?

2. How did the time required to authorize and make decisions change?

3. How did the objectivity of decision-making change?

C.2.5 Effect of decision making on business performance

1. How did the quality of the decisions change?

2. How did this affect business performance?

C.2.6 Effect of information on employee well-being

1. Changes in job resources

   - Did role clarity change? How?
   - Was there a change in employee participation in decision making?
   - Was there a change in performance feedback?
   - Was there a change in task significance (i.e. importance of the task to an organization)?
   - Was there a change in task identity (i.e. seeing your work in the end product)?
   - Was there a change in task autonomy (i.e. degree of freedom of a job)?

2. Did employee engagement (i.e. commitment to work, work objects, and/or work content) change?
    - Was this the result of the before-mentioned factors (resources), or was this the result of something else?
3. Did the increased information availability (e.g. performance data, transparency) change employees' perceived job demands?
4. Did the exhaustion among employees change?
    - Was this the result of the changed job demands, or from something else?
5. Did the change in job demands lead to changes in exhaustion among employees?

C.2.7 Effect of employee well-being on business performance

1. Did the employees show changes in performance?
    - In what way was in-role performance affected?
    - In what way was extra-role performance affected?

C.3 Debriefing

Is there anything else you would like to share about your project or your work?

Thank you for your time and participation.

Appendix D

Codebook and descriptions

Code	Description	Proposition nr.
Production process	The production process under consideration, to gain an understanding where the PoC affects the process.	N/A
Decision making (current)	The current or old decision making process (i.e. without the poc), to assess if and how it is going to change.	N/A
Roles	The roles and responsibilities of the people involved in the process affected by the poc.	N/A
Influence on performance	The extent to which the people involved in the process affected by the poc an influence on operational performance.	N/A
Amount of relevant information	The change in the amount of relevant information available for decision making.	1
Quality and reliability of information	The change in the quality and reliability of information available for decision making.	2
Timing of information	The change in speed at which information becomes available, as well as the timing of the decision which can be made (i.e. descriptive, prescriptive, predictive).	3
Ease of access of information	The change in accessability individuals have with respect to the information.	4

Controllability of information	The change in the control individuals have over the information.	5
Centralization of decision making	The change in the extent to which decisions are made by one person or business unit (highly centralized) vs. throughout the whole organization (highly decentralized).	6
Organizational levels authorization	The change in the number of organizational levels a proposed decision has to go through in order to get authorized.	7 & 8
Nr. of human information sources	The change in the amount of (human) information sources used in the decision-making process.	9
Nr. of people in DM unit	The change in the number of people who are part of the decision-making unit, i.e. who gather data, discuss, and make the decision.	10
Variety of members in DM unit	The change in the variety of roles and expertises the people in the decision-making unit have.	11
Time for DM meetings	The change in the amount of time which is spent on decision-related meetings.	12
Rapid and accurate identification of opportunities	The change in rapidness of identification of opportunities, and the change in accuracy of this identification.	13
Time required to make decisions	The change in time required to authorize and make decisions, i.e. the time the whole decision-making process takes.	14
Quality of decisions	The change in the quality of decisions as a result of changed decision making.	15
Business performance	The change in business performance as a result of the changed quality of decision making.	16

Job resources	The change in job resources, i.e. role clarity, participation in decision making, performance feedback, task significance, task identity, and task autonomy.	17 & 18
Job demands	The change in perceived job demands like work pressure.	19.
Engagement	The change in employee engagement.	20
Exhaustion	The change in perceived exhaustion amongst employees.	21
In role performance	The change in in-role performance employees show/will show, i.e. the performance of tasks which are in their job description.	22
Extra role performance	The change in extra-role performance employees show, i.e. performance of tasks which are officially not part of their job description.	23
Remarks	Any further remarks the interviewee has.	N/A