Universiteit Utrecht

Barriers to digitalisation in the SME manufacturing industry: a guideline to a solution

Master thesis innovation sciences

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Table of Contents

Abstract

The Fourth Industrial Revolution, also known as Industry 4.0 has emerged and it is forcing companies to re-examine the way they do business. Numerous companies barely finished catching up with the third revolution that dealt with digitising their company. The Dutch government recognised the problems in taking the next step towards digitalisation especially within the SME manufacturing industry. As digitalisation is an intricate process, the mechanisms and characteristics that enable digitalisation needed to be researched. A comprehensive model to identify barriers and offer potential solutions to lagging digitalisation in the SME manufacturing industry is currently missing in the literature. This gap in the literature led this research to the following research question: "What strategies can SMEs in the manufacturing industry use to overcome barriers to digitalisation, creating a digital enterprise and thus increasing their competitiveness?". To visualise how all conceptual elements coexist together, a conceptual model was created after an extensive literature study. This model was tested by conducting qualitative interviews with a wide range of companies in the Dutch SME manufacturing industry. The respondents shared the same pronounced views on what barriers were most troublesome. At a micro level, compatibility challenges prevent linking the factory floor with ERP software. The barrier at meso level is the fact that the digitalisation level of companies within a supply chain can differ immensely, so the degree of possible collaboration is limited. The macro level barrier concerns the lack of standardisation in the industry. This last barrier is the solution in itself. When all companies in a supply chain can use the same database structure or are able to link it easily with their own software, sharing data will become effortless. Using standardisation for machinery software will also prevent the resource investment of custom software development. Policy makers, education institutes and company executives and managers must keep this conceptual model as their guideline as they aim towards optimising digitalisation. Using this conceptual model can identify weak points within a company's digitalisation efforts. Companies can actively cope with these weak points and thus become a more digital enterprise. Future research can test the impact of using the conceptual model and its subsequent effect on digitalisation across the supply chain within SMEs in the manufacturing industry. Applying the model in other industries or company sizes might also offer different results and solutions that could help advance the discussion and creation of theory.

Introduction

The Dutch ministry of economic affairs has started a subsidy program in late 2016 to improve digitalisation of industry in the Netherlands. Accelerating this digitalisation will aim to improve the competitive power of the Netherlands and try to make it more appealing as a place of business for production activities (Ministerie van Economische Zaken, 2016). Smart Industry that was created for this very subsidy program, is an organisation that is founded by the ministry of economic affairs in November 2014 that strives to enable companies to use smart technology and digitalisation to create new business opportunities. Their main drive is a plan made in February 2018 that aims to make The Netherlands the frontrunner in flexible and digitally connected production networks in Europe. The plan that is implemented from 2018 till 2021 intends to result in more economic growth by increasing productivity, creating more appealing employment opportunities, and solving societal issues e.g., using less raw materials and energy. The Smart Industry team envisions to achieve this through capitalizing on existing knowledge, accelerating it in field labs and strengthening its foundation (Smart Industry, 2020). There are currently 45 of these Smart Industry fieldlabs active. Fieldlabs are environments where companies and knowledge institutes develop, test, and implement smart industry solutions. These environments are not solely used for development, but also allows employees to learn using these solutions.

As digitalisation within businesses is an important goal of the Dutch government and thus Smart Industry, a closer look is needed at the mechanisms and characteristics that enable digitalisation. To understand the Dutch government's emphasis on digitalization, this thesis begins by identifying its underlying causes. Lasi et al. (2014), believe that a new fundamental paradigm shift has marked the fourth industrial revolution. Industrial revolutions have been the cause of technological leaps that have caused paradigm shifts. Digitalisation is an important part of the last two industrial revolutions, first widespread and then advanced factory digitalisation respectively formed the third and fourth revolution. The Dutch government has acknowledged this trend and thus has taken policy measures to ensure its industry stays competitive. The relevance of this thesis is due to this very decision, which gave the inspiration to take a closer look into digitalisation literature and how this relates to Smart Industry and the Dutch industry.
Because of the increased global interest in digitalisation, the subject has gotten more attention in the literature. But as this area of research is still relatively new, there are a lot of uncharted territories within this body of literature. Digitalisation takes place in many different shapes, sizes, and circumstances. The differences that can be identified in these various applications are important for a better understanding of the subject. This is due to the fact that new or improved knowledge about this subject can improve application in practice and will enrich the literature for further research. In this certain scenario it will also offer the Dutch government information about their mission to improve digitalisation in the industry. Besides this, the results will also be generalised to show possible applicability to other countries and scenarios.

This thesis therefore focuses on the difference between firms and their adoption of digitalisation. A significant contribution in this growing body of literature is a paper by Sorbe et al. (2019), who argue that high productivity firms are more likely to benefit from digitalisation. This is because productive firms are more likely to adopt new technologies opposed to less productive ones. The processes of these firms need to be reorganised for digitalisation and productive firms tend to have better management and digital skills to cope with this. This is supported by Berlingieri et al. (2020, p.55), who argue that:

“Laggards are catching up at a lower speed in industries characterised by more intensive use of digital technologies and digital skills, as well as in industries characterised by higher average levels of (general) skills, suggesting obstacles to the transfer of technology and knowledge”.

So, low productivity firms might not necessarily benefit from extensive digitalisation. Then what are exactly the firms that benefit the most? Gal et al. (2019), share the same reasoning as Sorbe et al. (2019) on the fact that digitalisation is associated with substantially higher firm-level productivity. Apart from this, Gal et al. (2019) argue that these firms are often seen in manufacturing industries and in industries

that have a lot of routine tasks. For these firms, digitalisation can streamline production processes and thus create a more efficient production process. To some extent, digitalisation might even cause some processes to act as a substitute as they could replace routine tasks.

The reason these lower productivity firms are lagging might be because of the fact that productive firms gained much more productivity in contrast and thus exacerbating the problem (Gal et al., 2019). Gruber (2019) shares the reasoning of Gal et al. (2019) but argues there are more reasons for smaller firms to lag behind. Gruber (2019, p.121) finds that "smaller companies are often more concentrated in industries that are less exposed to the need for rapid digitalisation". Gruber (2019) also argues that small and medium enterprises (SMEs) ease a little slower into a full digital transition. This is because SMEs are not as driven by market forces and are therefore not pressured to quickly adopt new transformative processes. Researching these digitalisation differences and how they can be handled with through policy making is especially useful for the Dutch government.

Numerous previously cited papers in this article state that digitalisation changes the whole concept of innovation modelling. Being able to digitally collaborate changes the possibilities that lie within an innovation method. This thesis researches what methods a company can use when aiming for digitalisation and/or increased use of digital technologies that will influence their implementation success. As earlier paragraphs stated, companies all have different business types, sizes and needs, this makes a clear-cut path to implementation of digitalisation quite difficult. So, as not all companies have similar circumstances, the barriers they encounter might also differ. For this reason, the scope needs to be demarcated. As Gruber (2019) states that SMEs struggle the most with digitalisation efforts, the most interesting and vital research could emerge from these companies. Kroll et al. (2018) state:

"As a result of strong price competition, in particular due to substantially lower production costs in emerging economies, manufacturing companies have invested heavily into an upgrading of their production processes, including robotics, advanced automation and further digital technologies."

This is only a relatively new development and digitalisation projects can take several years before being completed. As it will take several of these projects to become a substantially more digital enterprise, numerous manufacturing firms might still be in the early or intermediate stages of digitalisation. This makes them an interesting case for research as they still have a great deal of barriers and challenges that they encounter.

The aforementioned gaps/shortcomings in the literature leads this research to the following research question:

"What strategies can SMEs in the manufacturing industry use to overcome barriers to digitalisation, creating a digital enterprise and thus increasing their competitiveness?"

The sub-questions that will help to answer this research question are:

- What cultural barriers do companies encounter when implementing digitalisation?
- How do companies acquire the skills and human capital to support their digitalisation efforts?
- What role do suppliers and customers play in digitalisation?
- Are there technological barriers that hinder a company in digitalisation?

Answering these questions will help to identify barriers and offer potential solutions to lagging digitalisation. This information can help policy makers and managers make more educated decisions and thus spend their budget and time more effectively. As digitalisation is a central part of the industrial revolution, it is crucial for firms to avoid becoming laggards in digitalisation and thus losing their competitiveness.

To answer these questions more research was needed. A theory section was formed which serves as a foundation for this thesis. While searching for theory it was clear that no model or framework encompasses the problems this thesis outlined in the introduction, so a conceptual model was created. This conceptual model needed to be evaluated. Several SME manufacturing firms were interviewed, whose responses were outlined in the results chapter. This was consequently related back to the conceptual model. These findings were summed up in relation to the research question in the conclusion and finally the discussion offers some limitations and future research possibilities.

Theory

Industry 4.0 is the industrial revolution we find ourselves in currently. Once started as a German governmental policy piece rapidly turned into an established term in literature. Schwab (2016) was the first to introduce the term into literature by writing about the challenges and opportunities that industry 4.0 will uncover. Schwab (2016, p.4) states the following about the impact on business:

"The inexorable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing companies to re-examine the way they do business. The bottom line, however, is the same: business leaders and senior executives need to understand their changing environment, challenge the assumptions of their operating teams, and relentlessly and continuously innovate."

So, companies cannot sit idly by while competitors might seize all the new opportunities this fourth revolution has to offer. Using this revolution to its full extent might not be so simple as incorporating a few new business processes. "Disruption is also flowing from agile, innovative competitors who, thanks to access to global digital platforms for research, development, marketing, sales, and distribution, can oust well-established incumbents faster than ever by improving the quality, speed, or price at which value is delivered." (Schwab, 2016, p.4). Continuously innovating using digital platforms seems to be the takeaway, but not all companies might be equipped to deal with this. As stated in the introduction especially SMEs are not up to par with their digitalisation progress. First a clear definition for digitalisation needs to be established. This thesis will use Gartner's (2020) definition as the main interpretation for the term digitalisation:

"Digitalisation is the use of digital technologies to change a business model and provide new revenue and value- producing opportunities, it is the process of moving to a digital business".

Changing a business model might not be easy for companies with limited resources. Transforming a company through digitalisation will fundamentally change its business model (Osterwalder & Pigneur, 2010). Companies that offer infrastructure service technology software often have applications that can scale according to the size of the company. However, SMEs do not always have the skills to fully benefit all opportunities this software can offer. Plekhanov & Netland (2019, p.2) support this stating: "small and medium enterprises generally have lower capabilities in integrating advanced digital technologies into organisational settings to extract a commercial value. Therefore, company size may be a path-dependent force defining frameworks for a digital transformation." Flexibility of the firm could however also play a part. Levy & Powell (1998) argue that SMEs might be more flexible opposed to their larger counterpart. When a large firm significantly changes one of their company processes during their digitalisation efforts, a lot of bureaucracy and organisational systems could slow down the speed of the change. Whereas SMEs work on a smaller scale and presumably have less 'bridges to cross' when implementing new systems.

The industry in which a company operates can significantly impact the pace and status of its digitalization progress. "Small and medium enterprises and large firms from technology-intensive sectors show high levels of use of digital technologies and data-driven approaches to improve productivity and operational efficiency. There are significant changes in levels of technology absorption across industrial sectors. Industries that used to show rather low levels of technology adoption are increasingly becoming technology intensive" (Plekhanov & Netland, 2019, p.28). That last sentence is particularly interesting as some sectors might have several firms that are frontiers in digitalisation causing the need for laggards to accelerate their progress. So even if a sector is quite poor in their technology adoption, some players can force other companies to adapt quickly.

Adoption of digitalisation is heavily dependent on the knowledge and skill a company has to its disposal. This is however inadvertently linked to the culture within a company. A company needs employees that are willing to test and implement new technologies to improve its processes. Employees that seem to

get the most attention are those that belong to the somewhat older demographic. They can sometimes struggle to see the opportunities and are reluctant to change. It is also possible that they have seen so many projects related to digitalisation that they have grown wary of changing so often (Fitzgerald et al., 2013). This reluctancy to change can however present itself throughout the entire company. IT departments might be too occupied with keeping the existing systems up and running opposed to being able to make time for innovative projects. This is also linked to the lack of talent in these professions, as supply and demand are skewed, the competition for such staff is extreme resulting in high salaries or demands (Pflaum & Gölzer, 2018). These expensive employees can also result in management deeming investments in digitalisation too costly due to smaller budgets. Some projects may have an overly complex calculation of the return-on-investment analysis, resulting in them never being initiated. Management can also be risk adverse and prefer short-term projects with quicker returns (Pflaum & Gölzer, 2018). This can be linked to a lack of urgency that resides within the company, companies that have existed for many years might not see the need for change. The vision that stems from the management of the company will need to support continuous change. When this is not embedded into the culture, starting projects might become progressively difficult as older systems can lose support or updates. These legacy systems can become increasingly complex to convert into new systems. Employees can also purposefully impede digitalisation efforts as their business units shrink due to the need of less personnel or because of their decreased power within the organisation (Fitzgerald et al., 2013).

The location of a company also plays a significant role in the digitalisation of a company. Silicon Valley is a shining example: "The capital investment and location advantage of Silicon Valley are of great importance. Effective path dependencies from earlier technological success, intensively trained technical capabilities, the appeal to potential employees from other countries and extensive business experiences play important roles, and connect these Internet companies to the location in a unique manner." (Hüther, 2016, p.10) In a more theoretical standpoint, Keenan et al. (2020, p.114) also supports this: "Digital transformation also seems to favour further concentration of innovation activities in innovation hotspots (often urban areas). This calls for policies favouring territorial inclusiveness. "Excellence-based policies", even if blind to location, tend to favour geographical concentration, since excellence is concentrated. These indirectly widen the gap between leading and lagging regions." So, the location where company is based can have major influence on the ability and need a company has, to strive for increased digitalisation. The location is also linked to the government a company must cope with. Lammers et al. (2019, p.4) argue what impact that has on digitalisation:

"The regulatory environment can represent an important external obstacle at meta-level in some cases. The lack of standards and frameworks as well as regulatory limitations due to hindering policies and regulations can be a consistent external barrier. On the other hand, governments' actions can also be a driver for digital transformation in the form of support to the deployment of innovation through incentives that facilitate the adoption of digital technologies for different purposes."

So, the adoption of these technologies varies significantly across sectors, sizes, and locations of companies. But even if these three parameters match, it might not mean the adoption rate is also equal. Even then the model of Rogers (1995, figure 1) can still be used. Laggards and innovators will occur not only among competitors but also in supply chains. This poses a problem for collaborative innovation which is essential to industry 4.0. Schwab (2016, p.4) argues: "A world of customer experiences, data-based services, and asset performance through analytics, meanwhile, requires new forms of collaboration, particularly given the speed at which innovation and disruption are taking place. And the emergence of global platforms and other new business models, finally, means that talent, culture, and organisational forms will have to be rethought." A company might not be able to utilise the full extent of all possibilities that industry 4.0 has to offer when a supplier or customer is operating on the opposite side of the digitalisation adoption spectrum. Being the innovator in a supply chain might be a curse in this sense as innovating outside of the bounds of your own company could

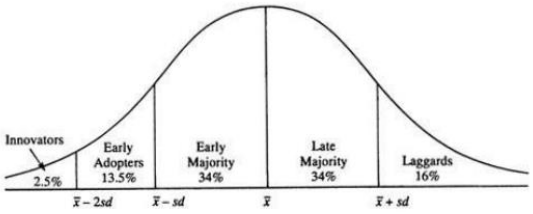

Figure 1; Rogers's Adopter categorization on the basis of innovativeness

present numerous barriers. When comparing competitors these high production firms encounter the same situation. Andrews et al. (2015, p.30) state:

"The rising productivity gap between firms at the global frontier and other firms raises more central questions about why seemingly non-rival technologies and knowledge do not diffuse to all firms. In fact, the evidence gathered in this paper is consistent with a model whereby new global frontier technologies do not immediately diffuse to all firms but instead are first successfully adopted by national frontier firms, and only diffuse to laggards once they are tested and adapted to country-specific circumstances by national leaders."

This might be logical as companies often do not have sufficient resources to take on more radical innovations that frontier firms can. In supply chains however, the frontier firms can collaborate with the rest of the supply chain to ensure a streamlined process with more room for trialability. "Higher R&D collaboration is associated with a faster catch-up process of laggards firms very far from the national frontier, while firms close to this frontier keep pace with it." (Andrews et al., 2015, p.30). When a frontier firm uses its resources to assist suppliers and customers to improve its digitalisation it is an investment in the success of the entire supply chain.

A comprehensive model is currently lacking in the literature, da Silva et al. (2019) present a model that includes all the aspects that come into play when considering the supply chain elements. This model is focused on the technological aspects of industry 4.0, it does not include the practical part of supply chain management. It includes the theoretical benefits of supply chain collaboration, the internal digitalisation processes and initialisation of collaboration are not discussed. Creating a digital supply chain starts at each individual firm, a chain is as strong as its weakest link so this micro aspect must be included in the model for a holistic view. Other articles contain the same shortcoming, Stoldt et al. (2018) and Doyle & Cosgrove (2019) only deal with tools that can be used for digitalisation. Schönfuß et al. (2021) include the possible solutions a firm can implement when entertaining digitalisation efforts. This does not include the cultural and organisational changes that are inherent to digitalisation projects. So, these articles are not exhaustive enough to encompass all elements that make up the digitalisation of companies in the SME manufacturing industry.

To visualise how all conceptual elements coexist together, a conceptual model was created (figure 2). A distinction of four different categories creates a holistic yet uncluttered model. The categories are technological, cultural, financial & knowledge and industrial. Digitalisation efforts are not only dependant on how a company itself tries to implement it on an organisational level but also on its environment. Thus, the conceptual model includes multiple levels to emphasise the elements that come into play. The micro, meso and macro levels separate the concepts in the model. The micro level includes the internal organisational policies where a company almost has complete control over. A moderate amount of influence on an external level is the meso category. This will encompass entities like suppliers, competitors, and customers. Finally, the macro level deals with the concepts a company has very marginal control over. This will be in terms of the technological, political, cultural, and economic state of a country or region. This conceptual model will show the different elements that come into play when digitalisation efforts are being pursued.

The cultural elements at a micro level relate to the policy that a company has on its internal organisational digitalisation efforts. This includes the willingness and capability of employees to change and subsequently the way management deals with this change in terms of change management (Lammers et al., 2019). The amount of risk a company is willing to take and engage in radical innovation in pursuit of digitalisation also has significant impact on a company's progress (Blichfeldt & Faullant, 2021). At a meso level the culture refers to the relationship a company has with its direct environment. If a company is very dynamic and progressive in an otherwise rigid environment, change can be difficult to realise (Lammers et al., 2019). Collaboration is key when digitalisation efforts along a supply chain need to be implemented. When there is a culture of fierce competition within a sector, collaborations might be ignored that could make the entire sector more robust (Gnyawali & Park, 2009). The culture at a macro level involves the nature of people within a country. Different approaches might be needed

when dealing with other cultures. If a country generally has risk averse people, business cases need to be more explicit, and it could take some more intensive persuasion (Rubino et al., 2020). Flexibility is also a key factor; digitalisation efforts are often associated with frequent change. Analysing how flexible employees are, will help to create more effective change management strategies (Stoldt et al., 2018).

On the technological side, the micro level challenges exist on the factory floor. Manufacturing firms deal with machines that often have long returns on investment, so not all machines might be compatible with the newest technologies (Lammers et al., 2019). Connecting these older machines to the new software that resulted from digitalisation efforts presents itself with new challenges (Angerer et al., 2010). Custom coding will often be the solution to link machines to each other and the overarching factory management software. Companies often lack in-house knowledge of this type of coding. (Waszkowski, 2019). Digitalisation efforts are thus often delayed until new machines are procured that will be compatible. This train of thought can be continued to the meso level. Where compatibility of machines is not per se the problem, but rather the linking of company software across a supply chain. Linking this software can offer numerous benefits (Lammers et al., 2019). Customers and suppliers can monitor information like the progress of their order and amount of stock. This will create a much more dynamic and efficient supply chain unfortunately this will not be an easy path (Aamer et al., 2022). Large investments need to be made to link these different software modules together, an investment that companies will not be eager to make. That is where the macro level can offer some support, governmental help in the form of a neutral standardised supply chain software. When governmental investments offer a standard that all companies can use, the only investment a company needs to make is the link to that particular software (Stolwijk & Butter, 2015). TNO in collaboration with Brainport already started a project called Smart Connected Supplier Network (SCSN) that offers this in a smaller scale, where companies can see each other's stock information and handle automatic order confirmations. When expanded to offer more information, the supply chain can work more efficiently due to optimalisations like more accurate delivery dates, faster procurement processes because of stock information and even automated reoccurring orders (van Lonkhuyzen, 2021). The level of digitalisation is also linked to the technological limitations that exist in the world. When innovations enter the market that facilitate a more effective path to digitalisation, the factors in the rest of this conceptual model can be impacted significantly.

The next category is finance & talent. As explained in an earlier paragraph, these can be allotted to the same category as they are quite dependent on each other. At the micro scale, tacit and explicit knowledge that exists in a company can greatly assist in the rate of digitalisation. When employees can develop new internal systems themselves, no costly outside help need to be brought in. If necessary, new talent can be created by training existing employees (Brunetti et al., 2020). This will create a more knowledgeable employee base, but this will come at a cost. Education will come in the form of college, universities, or courses. These are significant investments where companies will need to set apart specific budgets for. As a result, companies oftentimes set up a contractual clause that employees need to stay at the company for a specific time to reap the benefits of their investment. If these investments are deemed too costly or if knowledge must be brought in immediately, outside help can be brought in. At a meso level, there are several options. A company can choose to hire new employees, this will present its difficulties as talent and especially IT skills might be scarce (Waszkowski, 2019). When the balance of supply and demand tips the wrong way, employees can demand substantial salaries or secondary conditions. Additionally, contracts and commitments must be established, which can be costly if the employee is not suitable for the job in the long run. Consultancy firms can offer help in a more flexible project-based way, this will however come at a high price. Running projects along the supply chain can also help with the creation of new knowledge (Aamer et al., 2022). Collaborating with suppliers and/or customers to increase innovation can certainly be viable as costs are being shared (Huo et al., 2015). Collaboration with competitors can improve the competitiveness of the entire industry. As stated earlier, increasing knowledge and skill in a company can drain resources. Governmental help can offer companies the stimulus they need at a macro scale. Regulatory benefits as tax breaks or patent laws can be beneficial to companies in need. Governments can also assist in grants and subsidies to promote aspects like environmentally friendly investments or help with funding start-ups or spinoffs

(Kalpaka et al., 2020). Educational institutes can also offer help with internships, projects, and testing grounds. It is not an uncommon scenario to see internships turn into full time employments when students graduate.

Lastly is the type of industry in which company operates. Industries where rapid adaption and technological savviness are key characteristics, digitalisation efforts will be easier to implement (Aaldering & Song, 2021). The knowledge of software might already be in-house and working with paper might be a phenomenon of the last decade. The progress of digitalisation will differ greatly between industries and the level of competitiveness that exists within that industry. Less technological intense industries that avoid change and are overly bureaucratic will have a harder time to indulge digitalisation efforts (Berlingieri et al., 2020). When working with a very talent competitive industry, keeping your current employees can even be a challenge (Brunetti et al., 2020). That can be a significant barrier within companies that try to implement digitalisation efforts, as employees might not agree with certain changes and thus easily move to a different company. Keeping employees contended can result in the very downfall of a company as new projects and innovation are being shunned. The amount of digitalisation can also vary significantly within a supply chain. Industries that have an overly complex or lengthy supply chain may encounter companies that sell raw materials at the very start of the supply chain that do not have the urgency to exert digitalisation. At a macro level, the technological state of a country also plays a large role. If a country is very technologically advanced, industries are inherently further along in their digitalisation efforts. Apart from this, a well-educated population creates a workforce that can affordably help digitalisation without resorting to expats or expansive external consultancy.

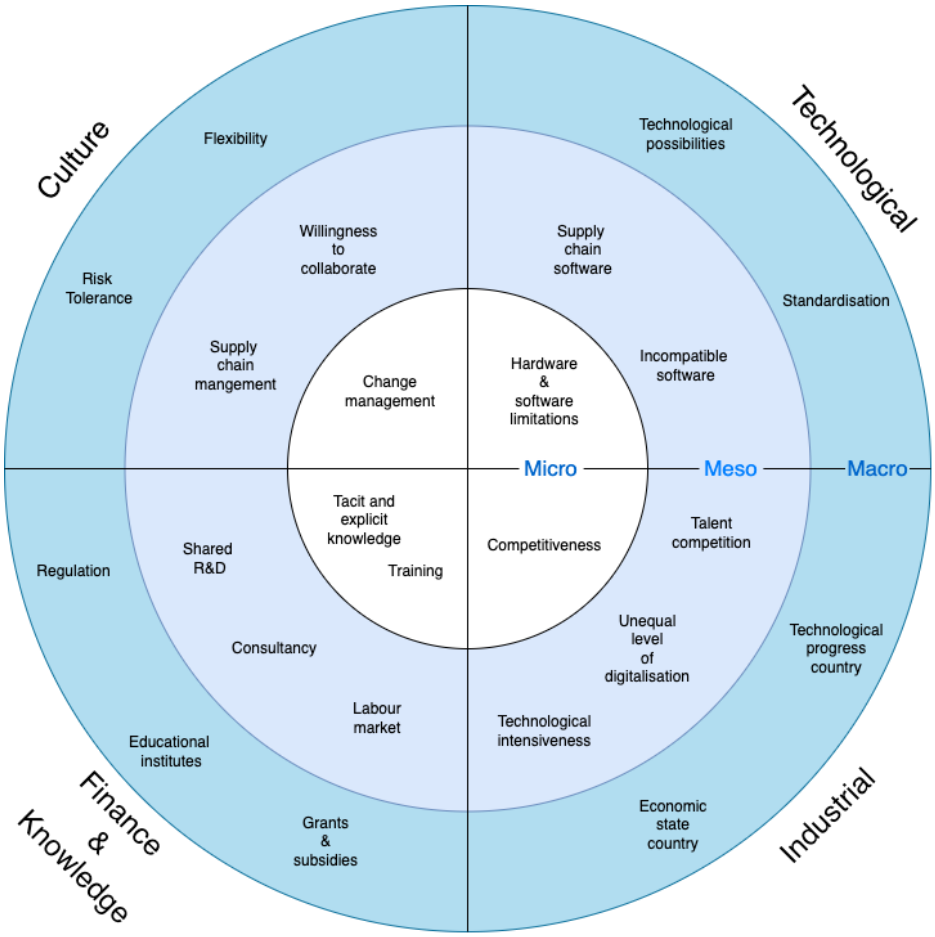

Figure 2: Conceptual model digitalisation SMEs in Dutch manufacturing industry

Method

For the writing of the theory section a specific literature search strategy, the method of Bryman, was used as shown in figure 3. Extensive tracking kept this literature search clear and retraceable. Specific search queries (with operators), keywords, core papers and relevant papers were all documented to ensure that the search was as organised as possible. Mendeley was used to manage all papers collected through various article databases. Folders were created to sort all the different areas of research that came into play. Besides this, a mind map had been created to keep an overview of how all subjects relate with each other. This mind map was the mainstay of this thesis and aided in brainstorming e.g., about possible search queries and structure of the theory section.

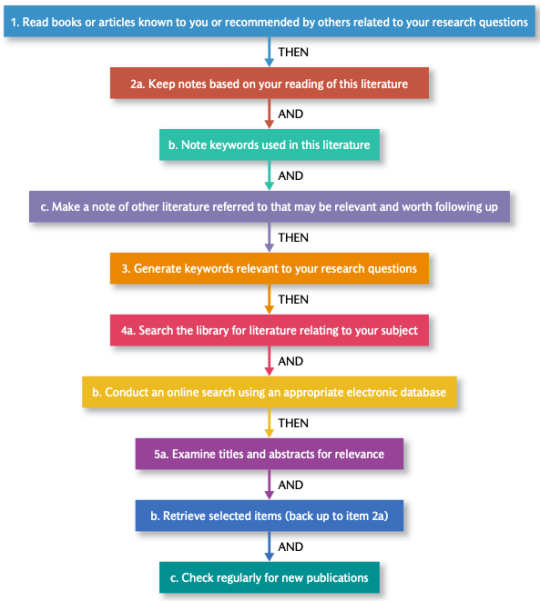

Figure 3: Literature search strategy, Bryman (2016)

As the writing of the theory section resulted in a thorough understanding of the literature, it was clear that there was not a model or theory that encompasses the challenges that this thesis's research question was confronted with. As knowledge needed to be generated and not tested, an inductive approach between theory and research was best suited to this thesis and thus a qualitative research method was used (Bryman, 2016). As this research was qualitative, the data gathering method that was used were interviews. A self-completion questionnaire or structured interviews were too rigid for this research and were better suited for a quantitative approach. The interview questions were constructed in a way that all aspects of the conceptual model were tested. Every element that was part of the conceptual model was separated into a different section in the interview. These sections consisted of several questions that focused on the parts of the conceptual model that needed to be tested. The result of these interviews was then used to test the conceptual model that was created as a result of the theory section. The conceptual model offers a wide range of elements that impact a company's digitalisation efforts.

The interviews were conducted in a semi-structured way. As this part of the research was qualitative, the interviews need the opportunity to be flexible. Bryman (2016) argues that a semi-structured interview allows the interviewer to move the interview in the desired direction without losing too much room for the interviewee to note potentially essential information. These interviews were recorded and then transcribed to allow for the analysis to be as concise as possible. The interviews were processed as soon as possible after they were conducted to ensure correct transcription. When possible, the transcribed interviews were also coded immediately to sharpen the focus of questioning and understanding of the data in the subsequent interviews. All data collected in interviews were stored on encrypted devices and consent for recording and documenting the conversations with interviewees were handled with the informed consent form and verbal agreement.

Purposive sampling was used to choose the interviewees. In collaboration with Smart Industry, the participants were chosen in a strategic way. A preliminary meeting with a contact at Smart Industry was used to discuss which Smart Industry members best fitted to ensure variety and helped to answer the research question. As this was a non-probability sampling method, the sample was not truly random. As this research was not quantitative, there was only time for a limited number of interviews. So, this method fitted best to ensure a sample that was relevant and diverse.

The largest risk of error in the interviews was the data-collection error. The coding of questions in the interview were therefore categorised, this means that people's answers were examined and grouped into distinct categories (Bryman, 2016). The theory used behind this was the method of Corbin & Strauss (1990). Open, axial and then selective coding were used to organise the transcripts of the interviews. First, open coding was used to divide the data into discrete parts and these parts were then labelled. Next, connections were drawn between these codes and placed into categories in the axial coding phase. Lastly, these categories were combined into one core category through selective coding.

Results

This result section is separated into four types of barriers that companies encountered while digitalising their company. These results consist of quotes derived from the interviews which are then linked to theory.

Cultural barriers

Culture in the manufacturing industry can sometimes be described as somewhat rigid. Some companies produce the same product for decades and the employees are cautious with change. 'If it isn't broke don't try to fix it' seems to be a striking phrase within this industry. Interviewee C has an example for this:

"Well, at some point the average age within a company gets too high and then you must deal with dinosaurs. I've also been working here for 25 years, what you see is that people who sometimes work here even longer, think that things actually went quite well in the past. That's one of the biggest barriers, so you really must show internally what the benefits are for the people who work on it. We had a project where we received a bill of material from a customer, which we had to normalise to your own internal bill of materials in our ERP system. Pretty tricky, you could easily automate this, if you start talking about this then you will be quickly rebuked, as the whole process is someone's job and they really see it as a threat."

He elaborates on this by linking this problem to the structure of the company:

"One of our biggest problems is that structures in a company are usually hierarchical. A department head is actually valued by how many people he has. He wants to have as many people as possible under him, and a good department head has no one under him because he has automated everyone away. You can't, but that should be the point. It is not in a department head's interest that he no longer has any staff, because then he has a smaller department that doesn't seem important."

Almost all interviewees stated that changing processes within the company can be very challenging. A lot of varying solutions were offered though. Interviewee A argued re-education is crucial in this changing environment. He stated that the employees that control the machine know it inside out. Learning these employees to control the machine and the robots that supply it would be the ideal solution. He also argues that breaking habits can help immensely. Explaining his own process about the fact that the company removed a lot of printers and that he now must walk further to one which caused him to work more digitally as a result.

Interviewee B argues that the resistance is often due to incomprehension. He then links that to a lack of explanation and/or information given by management. Employees often know their job is going to change drastically and keeping clear lines of communication and discussion helps a lot.

Interviewee D shares the same opinion by saying that employees know they need to help because they know if they do not, their company might not exist in 10 years as the competition will have superseded them. He also stresses the aspect of creating a group feeling when implementing changes. Surprising employees with a new machine or process without informing them as opposed to seeking their input and assistance in a test run over a long period can make a significant difference. This will also demonstrate to them that their opinions are valued.

Interviewee E marks removing barriers in communication as one of its most important changes:

"By removing those barriers, I do see a behavioural change that makes people take more responsibility. That is a crucial point in our development. You are actually going to give that shop floor access to digitalisation that they have not had until now."

Creating ownership among the factory workers changed the whole dynamic within company E. Allowing all hierarchies of a company to communicate with each other created an environment for easier feedback and process improvement. When an email chain across 4 employees can be reduced to a one-on-one conversation, the amount of redundant work is greatly decreased. These employees can also be more susceptible to change as their ownership might causes them to collaborate with the process of change.

Interviewee G argues that implementation of change needs to be flawless. Employees first need to see the benefits of the change before using it:

"When you implement something, you expect that they are going to use it, but what you often see is that a few months later they don't use it at all, a few hundred euros is simply not used…
...You must tackle all exceptions in advance, because if you don't, you get people who start to mistrust the system. Because then they actually experience much more trouble because they have to correct their work every time"

This company uses more of a top-down approach and figures that offering thorough information and using a first-time right implementation is essential.

Technological barriers

The second category is the technological barriers that companies encounter. As the interviews were conducted with manufacturing firms, the most encountered barriers are linked to machines on the factory floor. The technology behind digitalisation is nothing new, the challenges seem to lie in implementing them opposed to relying on R&D. The only problem was linking the machines to any administration software or connecting machines to each other.

Interviewee C stated:

"We ran a project to be able to link machines and we couldn't do that. Getting machines to talk to each other is very difficult. We have about 15 machines, and if you're lucky, they all speak their own language. So normalising information is a difficult process. There is certainly not 1 operator per machine. You actually want 1 dashboard for the entire line, where everything an operator has to do is listed to solve the problems. Nobody is working on that, that's really amazing, I've been doing this work for 25 years, and I've been working on this for 24 years to get that done. So, we are increasingly doing that ourselves, we need APIs (application programming interface) for that or link directly to the database of the machines."

Streamlining a factory floor introduces new challenges that are hard to overcome. Investing in linking several machines together might not be as profitable either as these machines are replaced periodically. This will change the entire process and subsequently machines will need to be relinked to work again.

Interviewee G have the same issue and linking software is something that they want to implement in the future. This will mean investing in custom software or waiting until new machines come in that support linking with other machines. He explains it with an example:

"What we have now, we have a plate laser of brand X with nesting software from X that then goes to the press brake, but that is from supplier Y and that does not match. It is currently possible that if you cut a plate with software X, it immediately makes a program for machine Y. And that takes into account the Z differences. That ingenuity creates an all-in-one software, now we have to solve all that manually. A generic control of the machines in terms of software would really help."

Interviewee B stated that current limitations are primarily related to linking within the supply chain:

“I also see that suppliers want to move more towards standard solutions. In particular, standard solutions because they actually want to run it in the cloud, so you see that in our industry a lot of packages have grown as they are now. But turning that back into a standard product is going to be complex. And what impact that will have as a company, yes that is not yet clear, for many it is not yet possible to foresee. You need that standardisation to properly link to each other. I think that's the biggest challenge for the industry.”

Financial & knowledge barriers

The financial and knowledge barriers are combined as they are quite intertwined. Increasing salaries in markets that experience a shortage of talent results in an environment where companies might struggle to find or afford new employees. Interviewee C supports this statement:

“It is already very difficult to find people, that is the big problem with us. Technical educations like MTS and HTS do not really exist anymore. But it is very difficult to get people. Whether they are good or not, that remains to be seen. You can also see that; a lot of technicians get offers from other companies.”

Interviewee F proposed a solution, but acknowledged that it would not completely eliminate the problem:

“It’s the problem of labour shortage. Technical people who are hard to find. Yes, if you can have a robot do it, at least you’ve got that. That spares me from finding engineers, but you still need people to program that robot.”

Bringing in consultancy firms may be a viable option, as it provides access to skills that may be otherwise unavailable. Interviewee G argues that it can help but it is not a permanent solution. It can take a lot of time to explain the whole situation to the consultancy agency and it can take weeks before they offer a solution. And when it is all finished and done you receive a bill that makes you rethink if you should have started the entire project at all.

Interviewee A went a different route and started looking for interns through educational facilities. He argued that bringing in young and eager people helped their organisation tremendously. He also mentioned it helps significantly if you make the company appealing to them:

“But we have also invested heavily in our machine factory in the past year, especially. We have replaced the fluorescent lighting with LED lighting in all our branches. And, in addition, we’ve had a coated floor installed in our machine factory. We have invested heavily in a new machine, but also in the air quality in our factory and all this has ensured that in the… well, I think two months ago, 3 young guys applied to us, open application and all 3 have been hired.”

Interviewee B talks about a shortage of people with the real expertise to make a difference. He also introduces the next industry barrier alongside this:

“If money isn't an issue, then you could have built it (a smart factory) a long time ago. well, that doesn't happen. A supplier offers a solution for something, and it must first run its payback period before they start on the next thing. You can already fix it now by making certain choices that one supplier has that solution while the other supplier has a solution for that. This way you can gradually put down dots that you can connect them in the long run and make complete it, but that must take time. And that time is needed on the one hand for the financial side, on the other hand; there are just people with real knowledge who end up doing it, there aren't that many of them. So, all those developments often rest on a few people. A product must be developed and that must be put in the market. There must be feedback on this and then the people who have real knowledge can translate that into a better or new product. And that loop just takes time, I don't yet see any possibilities on how we can speed it up.”

Industry barriers

The largest overall response in the interviews was on industry barriers. Every interview was filled with examples how customers or suppliers halt the progress of innovation and digitalisation. The need for standardisation was a reoccurring factor during most of these conversations. First some examples of small step solutions are explained by interviewee A:

"With supplier X we conducted a pilot for them called smart bin. They look at our stock by using scales, it is then processed at night and forwarded to supplier X and they see, for example, the amount we produced this day or week. And when that goes below a certain level, then they automatically send parts to us."

Interviewee B digitalised a process towards the customer:

"We have already arranged that you can use a web portal, the customer can then upload his files and automatically receive a quote there. Because a quotation process simply takes a lot of time. The customer knows he has his quote within minutes and that is experienced as something positive."

The problems seem to arise especially when linking software across companies. Interviewee C argues that API's might offer some solution:

"We lacked the ability to put technical information somewhere and that we could share more data and that we could also get information from suppliers/manufacturers with APIs. We are now working on APIs for technical information, but also price information and things like that, stock levels at suppliers that we can put directly into our system."

Interviewee G puts some perspective into this by clarifying that not all companies are ready for this yet:

"You can see all those young companies that are already using plenty of APIs and I think that is the future, only unfortunately our systems are not that far yet and that makes it difficult. So at the moment we are still doing a lot of manual linking."

Helping companies with their transition to digitalisation might also be a solution. Interviewee G runs into limitations when implementing their digital system on pricing agreements and bill of materials with his customers. It is now being used with a couple of customers, but he would like to see it expanded to almost all customers by even sharing in the costs:

"They must purchase a supply chain module worth two thousand euros. Well, they already refuse to do that. So, I increasingly feel that we need to lend a hand and develop a kind of standard for ourselves that we can offer and bring the customer in. And then we can even say we cover half of the implementation costs to convince them, because the more we do with it, the more benefit we will get from it."

Interviewee E has a more dramatic method. They experienced a customer that was causing a lot of trouble because of their issues with forecasting. So, they decided it took less effort to take over their customers forecasting for them opposed to dealing with the issues it caused.

Interviewee C argued that collaboration is key. Even meeting with competitors to discuss if systems with suppliers can be optimised. But he also argues that a lot of companies do not even want to standardise. He blames the mindset that when one wants to change something in the system you must convince a lot more parties involved. In this sense it can halter innovation. He then quickly shows the other side of the coin by explaining that if everybody worked together the industry could have been miles ahead in contrast to where they are now.

A perfect solution would be a piece of software that could link the entire supply chain together. Interviewee B is already exploring the possibilities:

“I think one of the nicer things of recent times is the increased attention for linking the supply chain. This is called Gatewise, they use a certain standard that has been developed by TNO. Companies in the industry have contributed to this. And what they actually want to achieve with that is a standard with which we can exchange data with each other. So, you can communicate directly from factory to factory, so that there is no retyping work and so on. So, you can see in real time what is my supplier's stock, what is his planning. That's what we're pursuing with that, you see that's starting to take flight now. There are many parties that commit themselves to this. Then things can go pretty fast, in my eyes that is really industry 4.0.”

This last statement offers a solution to the entire problem. As companies struggle to keep up the pace in digitalisation efforts, the industry must progress together through collaboration. Even frontier firms struggle with this as they might implement a very costly automation system which in turn cannot even be used because of lagging parts in a supply chain. An investment in the standardisation of the supply chain can seem like a choice that hampers innovation and progress when it might be the opposite. Fine tuning systems with suppliers and customers might create optimalisations in administrative processes like quotations and billing. It also offers a lot more data in terms of stock, delivery dates and so on. Digitalisation might be a challenging subject for companies that have tight budgets, a lack of knowledge or problems with their outdated company culture. When a supply chain works together to create a system that is used by all, profitability will most certainly improve. The process might be accelerated when the frontier firm in that chain starts the discussion and investment.

When linking this acquired knowledge back to the conceptual model, some interesting observations can be made. On the cultural side, change management is deemed very important. This is clearly separated between the management and employee side. Management claims that convincing and educating the employees is a difficult task. Employees just want to be kept in the loop and be able to have some say or offer feedback concerning the digitalisation efforts. Monitoring these aspects is crucial for a successful implementation of any changes in company processes. A reoccurring statement in these interviews is also the cultural aspect compared to other companies in the supply chain. The management of said supply chain and the willingness of these companies to collaborate can seriously hamper the digitalisation progress of a firm. The interviews emphasised that this part in the conceptual model is essential to keep track of. When collaboration with another company is initiated, clear lines of communication, sharing the planning from an early stage and even financial compensation will streamline the digitalisation process.

Hardware and software limitations are a large part of the technological barriers with many interviewees complaining about this conundrum. Without absurdly large investments for custom software development or new machinery, rapid change cannot be easily realised. Even when investments are made to link old machines together, these return on investments might not be positive. When procuring new machines with new software, all this effort could be in vain. As the lifecycle of machinery will variate significantly, these investments are deemed risky, and the process will often coincide with machinery downtime. Two possible solutions are offered, collaboration with other companies could help to make linking machines an easier task. When companies have similar machines, development efforts can be combined. Another solution is where the manufacturers of this machinery include software that can export information or even include API’s. This will enable companies to use and link machinery without large investments and replacing machinery will not be accompanied with extensive software development efforts. An interviewee argued that collaborating with machine manufacturing companies can help to accelerate this process. Singing up for beta software and giving feedback or suggesting new features can improve the machinery without large investments.

As for the finance and knowledge side, interviews are filled with statements about labour shortage. It is obviously difficult to pursue digitalisation efforts when there is no inhouse knowledge about it. Training employees to learn new skills is certainly a possibility but is deemed a sizeable investment and risky if

the employee chooses to leave the firm. Using consultancy firms can offer some short-term solutions but due to pricing is not deemed a permanent solution. Sharing R&D is mentioned a few times and is often successful but can only be implemented in specific scenarios. So, it certainly has its part in the conceptual model, but companies spend more effort looking into macro factors. Gaining knowledge through internships or projects linked to educational facilities is certainly beneficial and can be a point of interest if not utilised fully yet. Governmental grants and subsidies should not be forgotten either, a large number of possible financial benefits could be available without a company ever knowing. Periodically checking governmental initiatives or regulations can offer that bit of knowledge or financial influx a company might need to continuously improve their processes.

Lastly, the industry barriers, which present the largest response. Every industry has its own level of competitiveness, and this can be linked to the level of digitalisation. If a firm is not threatened by other competitors, they will not invest in digitalisation efforts when the urgency is absent. If there is a healthy competitiveness in an industry, companies will want to improve their processes if financially possible. If companies struggle to attain or allot a budget for these funds, other possibilities must be explored. Collaboration can offer a solution for this problem. As a lot of interviewees struggled with this aspect, it is a complicated issue. These collaborations will run into limitations when some prerequisites are not met. The interviewees argue that companies must have the same level of digitalisation and commitment in the form of funds and skill. When the level of digitalisation differs too much, demands of supply chain software can differentiate so significantly that the desired functions might not align. When a firm wants to monitor inventory numbers and the other firm still has an analogue administration, collaboration of creating a supply chain system will not reap its intended benefits for the more digital firm. The investment of funds is also a difficult part for firms to agree on. Available budgets might not be equal, which will be unacceptable for the firm investing the larger part. These collaborations are seen as too intricate and thus take a long time before it can even be set up. Acknowledging these disparities beforehand can help create more constructive collaboration efforts and consequently a higher success rate.

A summary table at the end of this results chapter (Table 1) provides a concise overview of the key findings from this study. All elements of the conceptual model are included in the summary table. Elements are divided by colour coding to indicate the level of environment.

Micro	Meso	Macro

Cultural	**Technological**	**Industrial**	**Finance & knowledge**
Change management: Old values are extremely hard to change, but with the right change management strategies, ownership and urgency can be created. Show what benefits arise from the changes and communicate clearly and thoroughly.	*Hardware & software limitations:* Linking machinery to ERP or other software can be challenging, due to machines with a long lifespan that do not support the newest technologies. The skill to create custom software for this link is often not present in a company.	*Competitiveness:* When an industry does not have an intense competition, companies within it become complacent. When requests for modernisation from suppliers and customers is low, need for optimalisation will be equally sparce.	*Tacit and explicit knowledge:* Digitally documenting in-house knowledge and processes is deemed very beneficial to companies who implement this but requires investments and needs to be done right or it will not be used.
			Training: Training employees is deemed expensive and risky as they might leave with their new skills. But pays off when they stay and improve.

Supply chain management: Creating a good relationship with companies in the supply chain is essential for its efficiency. Visiting the suppliers and starting up a conversation on how to improve processes is a crucial foundation for advanced future projects like linking software.	*Supply chain software:* When companies have the same software with the same functionalities (often an extra expensive module need to be bought) software can link up quite easily. In other scenario's it needs significant investments.	*Talent competition:* Bringing in and retaining employees is deemed very difficult. Improving the attractiveness of a company can help with hiring young and skilful talent. Running a organised and modern company that implements and shows interest in the newest technologies, will attract the best talent.	*Shared R&D:* Oftentimes not an equal effort, stems out of frustration. Frustrated party tries to cope by running trails and thus gradually integrate wanted improvements.
Willingness to collaborate: Almost all respondents see the need for collaborating with companies across the supply chain, this does not seem to happen though. Employees believe that they need to focus on their own company and obtaining extra resources for collaboration is difficult. Creating urgency for this collaboration can help to convince managers but will be a challenging process.	*Incompatible software:* Collaborations with machinery manufacturers can help create functionality without large investments. Conducting pilots and returning feedback will help the manufacturer create machines that are more in tune with the needs of the customer. Using API's also helps when linking software together, but this can become quite resource intensive.	*Unequal level of digitalisation:* Dealing with suppliers or customers that do not have the same digital capabilities is frustrating. Proposed solutions are helping with finances or providing knowledge to make up for this inequality.	*Consultancy:* Often avoided when possible. Excessive costs and long project times are significant downsides. To truly get them informed in all the processes a lot of time and effort is needed. But their outside view can help greatly when successful.
		Technological intensiveness: When a whole industry has a low technological intensiveness its need for digitalisation will be lower. Companies in the supply chain will sooner be angered by requests for digitalisation than welcome it.	*Labour market:* Knowing the state of the labour market is essential for a long-term plan. Setting up an inhouse training program or a systematic collaboration with educational institutes can help cope with a difficult labour market.
Flexibility: Acknowledging the flexibility of employees in a certain country and coping with this can help tremendously with allowing employees to tolerate testing and implementation of new technologies.	*Technological possibilities:* Some technologies are not available just yet. The only effect a company can have on this is collaborating with software or hardware manufacturers to push the boundaries of technology. Helping with or conducting your own	*Economic state country:* Being aware of the business cycle or developments in the economy can help act on problems before they become insurmountable. Coping with the coronavirus was easier for companies who took precautions.	*Regulation:* Always being aware of regulations is crucial. When collaborations reach an advanced state, internal company processes can become chaotic. Its important to avoid mistakes with taxes, laws, and standards like ISO.
Risk tolerance:			

Companies that work with small budgets are very careful where they spend their money. Being aware of the risk tolerance can help significantly. When clearly explaining the benefits and backing it up with data, even the more risk averse managers can be convinced.	radical R&D and testing cutting edge technology is the only impact a company can make. *Standardisation:* Examples like SCSN show that with a neutral outside party, remarkable things can be accomplished. But companies across the supply chain will have to invest resources to make this successful. Convincing the entire supply chain will be a difficult process that needs to be meticulously coordinated.	*Technological progress country:* Some processes just take time. Expecting every company to have completely automated forklifts controlling the warehouse is not realistic. Development of hardware and software will take a while and become affordable only over some time.	*Educational institutes:* Using students to run projects or opening up for internships gives new and refreshing outside views. Apart from having little to no costs, interns could be offered a job after their studies. *Grant & subsidies:* The Dutch government offers a wide range of financial and practical support for innovation, digitalisation & sustainability. Fieldlabs are an example of practical support where companies can collaborate without prior investments.

Table 1: Results summary

Conclusion

The goal of this thesis was to provide a comprehensive overview for policymakers and managers addressing the challenges of digitalisation in the SMEs manufacturing industry. The research question introduced at the start of this thesis was:

"What strategies can SMEs in the manufacturing industry use to overcome barriers to digitalisation, creating a digital enterprise and thus increasing their competitiveness?"

Through an extensive literature study, a conceptual model was created to show all aspects of digitalisation. This model was tested by conducting interviews with a wide range of companies in the Dutch SME manufacturing industry. These companies ranged from operating in the advanced stages of digitalisation to analogue firms that are only starting to discover its possibilities. These interviews were transcribed and coded to derive the most important data for the result section of this thesis. Finally, a summary table of the results was added to give a clear and concise overview of the data.

The interviews sketched a clear view of the current state in the Dutch SME manufacturing industry. At a macro level, a lot of barriers still originate from the fact that employees might not even have gotten used to the third industrial revolution. Manufacturing firms might not have changed drastically in decades which reflects on the employees. A shortage in the labour market in this industry will also not have contributed to their flexibility. Company demands might not have the same effectiveness when compared to other industries as employees can easily find another company when they do not agree with any changes within the firm. This also highlights the financial restrictions that occur, when companies are not able to pay the salaries that are associated with experienced workers, they might be forced to use younger talent. This inexperienced work force might not have the true technical expertise but offer a lot of fresh enthusiasm and ideas that can create a more dynamic organisation. The technical boundaries in becoming a more digital business does not seem to be a bottleneck, rather it is the lack of resources to blame. Software often needs to be custom made to connect the factory floor and a company's digital systems. So, employees with that knowledge need to be brought in, educated internally or outside help needs to be hired. All can be a resource draining option, so a company might want to look further than its own boundaries.

At the meso level, one of the largest problems in the industry seems to be digitalisation across a supply chain. As the digitalisation level of companies within a supply chain can differ immensely, the degree of possible collaboration is limited. Digitisation of processes seem to have caught on during the last industrial revolution and its repercussions can be seen clearly. Companies often have numerous digital systems, ranging from only using Microsoft 365 to comprehensive ERP systems. The next step would be linking this software to a supplier or customer to ensure even further optimalisations. This seems to be the problem almost all companies struggle with. As the digital systems these companies have implemented in recent decades were developed by various companies or were custom-made, linking them has become an entirely new and separate business.

The macro results were prominently filled with statements about standardisation. The number of resources required for custom software development generally deters companies from engaging in digitalisation efforts. This results in a wish for standardisation consequently reducing custom development and thus being less reliant on specialised skills of employees. When all companies in a supply chain can use the same database structure or are able to easily link it with their own software, sharing data will become effortless. Examples like SCSN show that with a neutral outside party, great things can be accomplished. But companies across the supply chain will have to invest resources to make this successful. Convincing the entire supply chain will be a complicated process that needs to be meticulously coordinated.

Policy makers, education institutes, and company executives and managers must keep this conceptual model as their guideline as they aim towards optimising digitalisation. Using this conceptual model can

identify weak points within a company's digitalisation efforts. Companies can actively cope with these weak points and thus become a more digital enterprise.

Discussion

This research aimed to identify the barriers that companies face when realising digitalisation efforts. As this research focused on the Dutch SME manufacturing industry, the case selection had three requirements it needed to adhere to. The companies needed to be SMEs, so large companies were not included. The second requirement was that they conduct their business in the manufacturing industry. This was because of the statements made in earlier parts of this thesis that argued SMEs in the manufacturing industry are more interesting to research due to lower levels of digitalisation. And lastly, they were located in the Netherlands which was due to this research being based on Smart Industry, which only includes Dutch companies.

In terms of external reliability, as the sample of interviews was small but diverse the results are quite robust. The sample offered companies in all stages of digitalisation, they differed in size (within SMEs) and place in their supply chain. This should have strengthened this thesis in terms of reliability. The sample was not truly random, so conducting this research outside of the Smart Industry network can present different results. The companies in the sample already have some form of interest in digitalisation due to them being a member of Smart Industry. The sample could be above the average rate of digitalisation. During the interviews however, some companies admitted that joining this initiative was their first step to exploring the possibilities for digitalisation. As the interviews were semi-structured, internal reliability was quite challenging. When another researcher will try to replicate this research, the interviewees will be offered the same possibilities to share their findings that are not directly linked to the interview questions because of this semi-structured method. Keeping in mind this qualitative method thus offers plenty variability, results can differ significantly. The response from the interviews was quite clear on the most important aspects, so the mainstay of this thesis would largely remain the same.

As for the external validity, the interviews were conducted with members of Smart industry that operate in the SME manufacturing industry, but the resulting conceptual model could certainly be relevant for other industries that are concerned with digitalisation. Internal validity can be ensured with the help of the first part of this research. Researching exactly what factors and mechanisms characterise digitalisation, helped to eliminate mistakes during the interview section of this thesis. The interviews were conducted digitally by using Microsoft Teams. The increased difficulty to detect non-verbal communication might make face-to-face interviews better for reading the respondents reactions (Bryman, 2016). Due to the coronavirus the interviews were forced into this format. The interviews might be more relaxed however, as the interviewee is probably most comfortable at his own desk. All interviews were conducted using both the interviewer and interviewees native language. This helps with small misunderstandings that might occur due to certain expressions or linguistic incomprehension.

The results do not present findings that contradict the earlier amassed theory (Pflaum & Gölzer, 2018; Lammers et al., 2019; Plekhanov & Netland, 2019). The theory in the numerous papers quoted in the theory section were confirmed in the interviews. One of the examples is: "Employees can also purposefully impede digitalisation efforts as their business units shrink due to the need of less personnel or because of their decreased power within the organisation (Fitzgerald et al., 2013)." Which was exactly confirmed by the statement of interviewee C:

"One of our biggest problems is that structures in a company are usually hierarchical. A department head is actually valued by how many people he has. He wants to have as many people as possible under him, and a good department head has no one under him because he has automated everyone away. You can't, but that should be the point. It is not in a department head's interest that he no longer has any staff, because then he has a smaller department that doesn't seem important."

The knowledge created in this thesis can be used to accelerate the discussion of digitalisation in both literature and industry. This model needs to be tested in companies and may need to be improved after feedback. If companies increasingly start using this refined model, collaboration in digitalisation across the supply chain will become standard practice. Normal rollout through word of mouth or encounters with the model might not be enough to spread the increased focus on digitalisation. A governmental influx might be the factor that is needed for an accelerated digitalisation. Governmental agency like Smart Industry already have the infrastructure to spread such awareness. Using this network to spread this model accompanied with the message to focus on supply chain collaboration and standardisation in digitalisation will change the industry's way of doing business radically. Smart Industry can also offer explanation and guide the application of this model to ensure its success. Another collaboration with Brainport and TNO's SCSN and the use of this model can be the perfect combination to ensure an successful implementation. The model created in this thesis can be used as an required onboarding procedure to increase collaboration success. Companies can use the model to form awareness of its shortcomings and address them. After the company has its processes in order, they can join this supplier network with a reliable and well organised foundation.

This thesis resulted in a conceptual model which can be used in a wide array of situations. The model is developed with a particular case in mind, it can however be used in many other scenario's. The industry or size of a company might not matter as the model is set up in a comprehensive way. Tweaking the model after some practical research might even make it suitable for the service industry. Applying the model in other industries might offer different results and solutions that could help advance the discussion and creation of theory. Future research can test the impact of using the conceptual model and its subsequent effect on digitalisation across the supply chain within SMEs in the manufacturing industry. Future research can also limit the case to even more specific characteristics like SME revenue limitations or expand the case to even include large companies.

An additional part of the discussion that also has its statements for future research is an encountered bias. A very large part of this research is focused on linking supply chain software. This is a part that keeps reoccurring because the interviewees argue they cannot collaborate and blame their lacking digitalisation efforts on their adjacent companies. An attributional bias in the form of an attribution error may be at play here, as companies blame their failure to external factors (Franco & Haase, 2010). These companies might not be able to analyse the true nature of their barriers because they are too intertwined in the company or they may simply choose to wilfully ignore internal problems. Future research can try to recognise signals of this bias and attempt to uncover the underlying reasoning at play through especially designed interview questions or tactics that test this bias.

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Appendix: Interview questions

• Does the company innovate or conduct/track their innovation in a digital environment? • Has digitalisation helped to increase and/or improve innovative efforts? • Are digitalisation efforts often custom made or are they slightly changed pre-existing systems? • Did digitalisation change the distribution of radical/incremental innovation? • Are digitalisation efforts progressing at the desired rate or is there missing knowledge/funds? • Is the company willing to invest in risky/not proven technologies or are they more risk averse? • In what department is the amount of digitalisation efforts the highest? (Sales, manufacturing, warehousing etc.)
• It seems that high technology intensive sectors have more technology capable employees, but are they really used for digitalisation efforts? • What part does the level of productivity play in the usefulness of digitalisation? • Does the competition 'force' you to keep up digitalisation? • Do customers 'force' you to keep up digitalisation? • Did digitalisation help to discover the market better and find new business opportunities?
• Do companies that have less in-house capabilities hire new employees, collaborate with other companies, hire consultancy firms or do they use a combination of these methods? • Is/was there resistance to change when implementing digitalisation? • Is flexibility towards digitalisation a focus when hiring new employees?
• In what ways has the company used digitalisation to improve their forecasting? • Has the company changed their product line because of insights through digitalisation? • In what ways has the company used digitalisation to improve their stock management? • In what ways does the company focus on turning tacit knowledge into explicit knowledge through digitalisation? • Does the company rely more on data driven decision making through digitalisation efforts?

Table 2: Interview questions