Smart Manufacturing for Dutch SMEs
Why and How?

http://www.localgridtech.com/smart-manufacturing/

Master Thesis

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Preface

This master thesis has been written to fulfil the graduation requirements of the part-time Master of Science in Business Administration programme at Rotterdam School of Management, Erasmus University. It marks the end of a challenging, yet inspiring journey that lasted two years. But it also marks a new beginning, as it opened up new horizons.

I could never have gotten to this point without the help of others. Therefore, I would like to take the opportunity to express my gratitude to the people who have been of great help in the past period.

First of all, I would like to thank my coach Fabian Sting and co-reader Jan van den Ende for their guidance on writing my thesis. I truly appreciate the autonomy you allowed me and the belief you showed in the final result, especially at times of despair. Your concise and constructive feedback have been of great assistance. I also wish to thank the respondents without whose cooperation I would not have been able to conduct this research. You showed that the true strength of Dutch manufacturing lies in the people representing it. A special thanks goes out to Ben van Lier for providing invaluable insight into historic and current developments regarding digitisation of manufacturing.

I would also like to thank my colleagues for their patience and flexibility. At times, I had to rely heavily on you in getting all the work done. A special thanks to Annemarie, Corstiaan, Daan, Desiré, Jules, Peter and Wilfred for kindly reviewing and discussing my thesis.

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Finally, I would like to thank my friends and family for their love, sustenance and encouragement. In striking the balance between a fulltime job, a demanding study and my personal life, the latter has come at the bottom of the list on too many occasions, for which I apologise. Marjon, your love and encouragement have been paramount to the successful completion of my study and your unremitting commitment to our family provided stability to Julia, Tessa and Finn throughout these years. Thank you for that.

Goes, June 2016

Gerben Nieuwenhuize

Contents

Index of figures and tables

Executive summary

The aim of this thesis is to provide insight in the way Small and Medium Enterprises in the Dutch manufacturing industry decide on the application of smart manufacturing technologies and presents the results of an exploratory study of the drivers and barriers to the adoption of smart manufacturing to this end. Smart manufacturing is in the course of this research defined as a family of activities that depend on the use and coordination of information, automation, computation, software, sensing and networking with the aim to improve the performance of an individual firm as well as the performance of the associated value chain, by utilising the data generated in these activities.

The theoretical review revealed that SMEs apply Informations Technology (IT), of which smart manufacturing can be regarded a variety, to improve growth, efficiency and effectiveness. Apart from these expected benefits, the theoretical review showed that the level of automation and the level of collaboration are likely to influence the adoption of smart manufacturing technologies and that the adoption is likely to be preceded by the intention to adopt. Between the intention and the actual adoption some barriers were expected, which current research had not determined yet. Another gap in existing literature is the absence of having a future vision as an influencing factor for the adoption of smart manufacturing, as the benefits of smart manufacturing surpass the "traditional" efficiency and effectivity goals by opening up new business models. Therefore future vision was regarded another driver to the intention to adopt smart manufacturing.

The drivers and barriers have been put together in a conceptual framework, which has been used to guide the exploratory study that was conducted among manufacturing SMEs in the Dutch steel industry. A total of six manufacturing firms have been included in the research by conducting semi-structured interviews with either owners or directors of the respective firms.

The results of the research revealed that the likelihood of adoption is highest upstream the supply chain. Three categories of manufacturers emerged. The dormant who are not intending to adopt smart manufacturing at all, the captives who want to adopt smart manufacturing, but have not managed to do so and the adopters who have applied smart manufacturing technologies to a certain degree. It has become clear that the intention to adopt smart manufacturing always precedes the actual adoption. The research has been aimed at providing an explanation for the fact that some firms have moved from one category to another, while others have not, resulting in the conclusion that the intention is directly influenced by two factors, namely the current level of automation in the production process and the awareness of possible benefits gained from the adoption of smart manufacturing. In turn, the current level of automation is determined by the position of the manufacturer in the supply chain. As the complexity of products and processes increases, the level of automation decreases. This explains the low level of intention to adopt smart manufacturing downstream the supply chain. The awareness of possible benefits is influenced by the level of collaboration, both in diversity and intensity. As manufacturers collaborate more with competitors and organisations outside the supply chain, the awareness of the possible benefits increases, hence raising the likelihood of an increased intention to adopt smart manufacturing.

Having a clear automation strategy has shown to influence the actual adoption, rather than the intention. Once a manufacturer has the intention to adopt smart manufacturing, the presence of a clear vision on the role of automation in the production process increases the likelihood of successful adoption of smart manufacturing.

Furthermore, once the intention to adopt smart manufacturing exists, there are some barriers limiting the actual adoption, namely technology not being ready, a lack of trust and a lack of awareness of smart manufacturing possibilities in the manufacturing industry. The current development level of smart manufacturing technologies is specifically holding back manufacturers from the captive category, as the complexity of their products demands more sophisticated software solutions to reduce the time that is required to calculate products and to robotise the production processes. The lack of trust and the lack of awareness are limiting all categories alike. The lack of trust results in a passive attitude toward smart manufacturing, as manufacturers first want to have clarity about the possible effects on the performance of the firm. The lack of awareness is primarily limiting manufacturers because they have to convince customers and suppliers that smart manufacturing indeed could lead to improving efficiency, effectivity and growth.

This conceptual framework provides a better insight in the way SMEs in Dutch manufacturing decide on the adoption of smart manufacturing by pointing out the primary drivers to the intention and adoption of smart manufacturing and the main barriers manufacturers encounter once they intend to adopt smart manufacturing and hence provides an answer to the main question in the submitted research.

Be not the first by whom the new is try'd, nor yet the last to lay the old aside.
Alexander Pope, An Essay on Criticism (1711)

1. Introduction

1.1. Background and motivation

Dutch manufacturing industry is at the very heart of the recent recovery of the Dutch economy. In general, manufacturing has one of the highest multiplier effects of all industry sectors and this has been recognized by governments around the globe, resulting in several governmental programs and campaigns, aimed at the sustainment and growth of their respective manufacturing sectors. Examples include Industrie 4.0 in Germany, Fabricca Intelligente in Italy, Flanders Make in Belgium and the Smart Manufacturing Leadership Coalition in the USA.

The importance of smart manufacturing for the Dutch industry has recently been recognized by the Dutch government, in large as a result of research conducted by a Dutch consortium consisting of commercial, governmental and research partners (Project Team Smart Industry, 2015). Consequently, Minister Kamp (Economic Affairs) had an action agenda drawn up to address the challenges and opportunities that come with smart manufacturing. Digitisation of manufacturing is, according to the mentioned research and action agenda, one of the cornerstones for increasing the competitive strength of Dutch manufacturing, alongside the application of advanced production techniques and intensive cooperation.

Smart manufacturing, as this digitisation of manufacturing processes is called, is not the unique domain of large enterprises. According to Ineke Dezentjé Hamming-Bluemink, president of the FME and president of the Project Team Smart Industry, this is a persistent misunderstanding. The main mission of the Project Team Smart Industry is therefore to engage Small and Medium sized Enterprises (SMEs) in the digitisation of their manufacturing processes and of the Dutch manufacturing industry as a whole.

The submitted research aims at providing a better understanding of the way SMEs decide on their course of action regarding the digitisation of their production processes. This could be useful for academics as it increases our knowledge about decision making in SMEs regarding digitisation, but it could serve a practical purpose as well as it may provide tools to engage SMEs in the process of digitising Dutch manufacturing, thus enhancing the competitive strength of the sector.

1.2. Research objective

The specific research objective therefore is to provide a contribution to the theory and practice about the application of smart manufacturing by building propositions about why SMEs within Dutch manufacturing consider applying smart manufacturing technologies as a strategic option and how they manage to apply these technologies, despite the obstacles associated with the application.

1.3. Research question

The research question, based on the aforementioned research objective, is as follows:

How do SMEs within Dutch manufacturing decide on the application of smart manufacturing as a strategic option and how do they (expect to) successfully overcome the barriers associated with the application of smart manufacturing technologies.

Research questions associated with the central research question include:

- Why do SMEs apply smart manufacturing at all?
- How does the current level of automation influence the adoption of smart manufacturing?
- What benefits do SMEs expect from the application of smart manufacturing?
- What is the role of collaboration in the decision to adopt smart manufacturing?
- How does the future vision of SMEs influence the adoption of smart manufacturing?
- What are barriers to the adoption of smart manufacturing?

1.4. Reading guide

This paper starts off with the results of an exploratory orientation to the digitisation of manufacturing, including some definitions in chapter two, followed by a theoretical review in chapter three. Chapter four describes the methodology. The results of the research are presented in chapter five and are discussed in chapter six.

2. Orientation

The orientation presented in this chapter aims at providing a better understanding of the relevance of the submitted research and of the theoretical principles it is built upon. It starts with a definition of smart manufacturing and continues with a closer look at the potential impact smart manufacturing has and/or may have on the Dutch industry.

2.1. Smart manufacturing – a definition

The list of terms associated with smart manufacturing is seemingly endless. Smart factories, cloud manufacturing, smart industries, advanced manufacturing, smart production, ubiquitous manufacturing, big data and digital manufacturing are just a few of the terms being used. Rather than trying to start off with an exhaustive definition, as some have tried over the last decade (e.g. (Radziwon, Bilberg, Bogers, & Madsen, 2014) and (Davis J. , et al., 2015), a general description will be provided of what smart manufacturing is considered to be in the submitted research. The basis under this description is the definition of advanced manufacturing systems provided by the United States President's Council of Advisors on Science and Technology (PCAST), as referenced by (Davis J. , Edgar, Porter, Bernaden, & Sarli, 2012):

Advanced manufacturing "refers to a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry and biology. This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies."

Smart manufacturing could be regarded as the first part (a) of this definition and is thus only part of advanced manufacturing. In smart manufacturing systems, sensor data are used to control the flow of materials, products and information. By adding connectivity, smart manufacturing connects production means with each other and with any other device inside or outside the physical boundaries of the production facility. Not only does this enable manufacturers to simulate and control production processes from anywhere, but it also enables them to share information about production processes with other parties both inside and outside the value chain.

In the course of this research, smart manufacturing has been defined as:

A family of activities that depend on the use and coordination of information, automation, computation, software, sensing and networking with the aim to improve the performance of an individual firm as well as the performance of the associated value chain, by utilising the data generated in these activities.

2.2. Relevance and magnitude

The idea of centralised factory control systems based on sensors is not new to the world. In fact, according to The Economist Intelligence Unit (Witchalls, 2013), one out of four manufacturing companies worldwide make use of centralised factory control systems enabling autonomous machine-to machine communication with limited human involvement. The Industrial Internet of Things (IIoT), however, takes these centralised factory control systems one step further by adding decentralised intelligence through extensive connectivity, having an impact far beyond the factory floor. Whereas “traditional” automation solutions aim at increasing productivity and efficiency of physical objects in a single factory, the IIoT enables manufacturers to optimise production across multiple plants by adding connectivity to the physical objects in order to create a digital representation of the physical reality. This representation can be used to simulate change, visualise performance and share information across firms within production chains. The assumption is that this will eventually lead to extensive cooperation between manufacturing firms (Davis et al., 2015). The IIoT in fact brings together two traditionally separated domains, namely, Operational Technology (OT) and Informations Technology (IT) by adding connectivity. The convergence of these domains and the potential benefits for manufacturing firms have been elaborated extensively in recent years, e.g. by (Bloem, et al., 2014), (Xu, 2012) and (Höller, et al., 2014). The convergence of OT and IT enables manufacturing firms to respond effectively to a market developing towards continually and unpredictably changing customer requirements, moving away from the traditional performance measures, such as cost, quality, productivity, flexibility and time, towards more suitable measures, such as adaptability, agility, responsiveness and scalability (Radziwon, Blichfeldt, Bilberg, Madsen, & Bogers, 2015). According to McKinsey Quarterly the opportunities that come with the application of smart manufacturing for individual firms consist of three elements: an increase in sales, an increase in operational excellence and the emergence of new business models (Bughin, Chui, & Manyika, 2015).

Although smart manufacturing is still at an early stage, the World Economic Forum concludes that “the Industrial Internet is indeed transformative. It will change the basis of competition, redraw industry boundaries and create a new wave of disruptive companies, just as the current Internet has given rise to Amazon, Google and Netflix. However, the vast majority of organizations are still struggling to understand the implications of the Industrial Internet on their businesses and industries. For these organizations, the risks of moving too slowly are real.” (World Economic Forum, 2015, p. 3). This view is further supported by the Committee for Economic development of Australia, as referenced by Van Lier: “The existing global industrial ecosystem will change dramatically under pressure of technological developments, and the industrial Infosphere will become increasingly more important than the physical domain as a component of industrial manufacturing” (Van Lier, 2015). It may be no surprise that the speed at which manufacturing environments are being digitised is increasing (Atzori, Iera, & Morabito, 2010).

2.3. Smart manufacturing in The Netherlands

Despite the proposed benefits and the inevitability of smart manufacturing, so far the application of smart manufacturing has seemed to be to be the unique domain of large multinationals, often supported and assisted by large service providers. As a result, research into the application of smart manufacturing has mainly been performed within this context, e.g: (Dutta, Geiger, & Lanvin, 2015), as is shown by (Radziwon, Blichfeldt, Bilberg, Madsen, & Bogers, 2015). The Dutch manufacturing industry, however, consists mainly of Small and Medium sized Enterprises (SMEs). In the light of the structure of the Dutch manufacturing industry, the question arises how SMEs could benefit from the application of smart manufacturing. Davis (2012) concludes that it is almost impossible for a single small or medium manufacturer to apply smart manufacturing to the extent that the manufacturer indeed can benefit from it, due to the high cost involved and the limited value added, at least in the short term. Davis goes as far as to say that: "currently, an investment may be scaled enough to be justified and cost affordable for large companies. Access to the technology by small and medium manufacturers remains essentially prohibited" (p. 149). Bughin et. al. (2015) conclude that the high cost and limited value added mainly stem from problems aligning the organisation, limited interoperability and cybersecurity risks. This explains (at least partly) why some SMEs, also in the Dutch industry, are reluctant to apply advanced manufacturing, despite the clear evidence of the benefits provided above.

On the other hand, The Project Team Smart Industry (2015) identified a number of SMEs where smart manufacturing successfully has been applied, despite the difficulties mentioned by Davis (2012). See, for example, exhibit 1. Smart manufacturing is in fact considered crucial to the further development of the Dutch manufacturing industry as a whole, given the efforts being made to increase awareness of Smart Industry possibilities. Research by the Dutch Chamber of Commerce (KvK Ondernemerspanel, 2014) reveals that this awareness indeed is low; only half of the SME entrepreneurs knows about Smart Industry and an even smaller portion expects their company to be impacted by it. There is no doubt that increasing the awareness will have a positive impact on the assimilation of smart manufacturing within Dutch manufacturing. Yet, an increased awareness will not answer the question as to how or why SMEs should start applying smart manufacturing technologies, especially given the aforementioned problems for SMEs. This gives rise to the assumption that the perceived weight of the advantages of smart manufacturing is higher for some SMEs than it is for other SMEs. It seems obvious that this difference in perceived importance is at least being influenced by the expected benefits from the application of smart manufacturing. Insight into the incentives for SMEs to apply some form of smart manufacturing and into the way they deal with the problems mentioned, may help explain the different attitude towards smart manufacturing and further foster the adoption of smart manufacturing technologies by SMEs within Dutch manufacturing. The explanation of this difference could be of interest to both academics and practitioners.

247 Tailor Steel, founded in 2007, developed a fully automated process for laser cutting metal sheet and tube. At the very heart of this process lies a uniquely designed software suite, named after the founder's daughter Sophia and an acronym for SOPHisticated Intelligent Analyzer. This software enables customers to upload their drawings directly through a web based portal. The software provides the customer in turn with a quotation and expected delivery time. The process of laser cutting is also controlled from Sophia, eliminating the need for a front and back office. The result: lower cost and shorter lead times leading to better market chances.

Source: MT.nl (Peters, 2015)

Exhibit 1 - Smart Manufacturing in practice

2.4. Old wine in new bottles?

A major question to be answered is whether the application of smart manufacturing is nothing but a revival of the efforts made to optimize supply chains in an attempt to finally convince SMEs to participate in supply chain partnerships. Indeed, smart manufacturing seems to refer to the "relational rent as a supernormal profit jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners." (Dyer & Singh, 1998). However, the relational view has mainly been applied by creating partnerships within supply chains for reasons of optimisation. SMEs have been reluctant to participate and for a good reason; recent research has shown that SMEs only benefit from supply chain partnerships when it comes to the R&D function. For other functions of the firm, no significant positive effect of partnerships on the overall performance could be found (Rezaei, Ortt, & Trott, 2015). It may be clear that smart manufacturing needs to bring more to the table than supply chain partnerships have brought.

The cooperation smart manufacturing is aiming at differs from supply chain partnerships since the latter focusses on reduction of transaction costs, regardless of (and sometimes even at the cost of) lower operational efficiency of the individual partners within the partnership. Smart manufacturing aims at a reduction of transaction costs, while at the same time improving the operational efficiency of the firms involved, sometimes at the cost of removing parts of the supply chain that have become redundant. Rather than integrating functions, smart manufacturing has the potential to absorb certain functions in the supply chain, thus reducing transaction costs. At another level, smart manufacturing blurs the boundaries between supply chains, since it provides firms with the ability to share information about their processes with any stakeholder, regardless of their position in or outside the supply chain. Should the possibilities smart manufacturing offers be used to the full extent, this may eventually lead to disintegration and de-verticalisation of supply chains. This could trigger the need for new value stream governance structures, as has been proposed before (Klapwijk P. , 2004), although the speed of recent developments regarding artificial intelligence could eliminate the need for governance structures altogether, as was the tone at the recently organised Smart Industry Event in Apeldoorn (February 4 2016). Either way, smart manufacturing stimulates firms to innovate not only products or processes, but more importantly to innovate their business models, their value propositions and their product/service combinations.

In the next chapter, this orientation will be elaborated by providing a theoretical review related to the application of smart manufacturing within SMEs.

3. Theoretical review

The theoretical review presented in this chapter aims at providing an understanding of the research frame for the submitted research and is structured as follows: it starts with positioning smart manufacturing as a means of process innovation, resulting in drivers and expected outcomes of process innovation in general. Since smart manufacturing is a form of IT application, these drivers and outcomes are expanded to the field of IT application, thus providing a theoretical framework of drivers and expected outcomes of the application of IT in manufacturing environments. Subsequently, the differences between general forms of IT application and smart manufacturing will be elaborated, focused on the emergence of new business models, resulting in a conceptual framework as the source for research questions which will be used for guiding the interviews.

3.1. Process innovation

The application of smart manufacturing is a typical example of a process innovation. Although far less present in literature about innovation (Reichstein & Salter, 2006), process innovation plays an equally important strategic role as product innovation does. The ability to make something no competitor can, or to make something in a way others cannot is a powerful and often underestimated source of competitive advantage (Tidd & Bessant, 2013). Drucker already emphasized this back in 1985 by describing innovation as “the means by which the entrepreneur *either* [emphasis added] creates new wealth-producing resources *or* [emphasis added] endows existing resources with enhanced potential for creating wealth” (Drucker, 1985, p. 67), suggesting that both product and process innovation equally matter to the firm. There is no reason to assume that this would not apply to manufacturing firms. In fact, in a literature review about the antecedents and consequences of firms’ process innovation capability, scholars found that “most products cannot be developed and manufactured without innovation in new process technology” (Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012, p. 519), thus emphasizing the importance of process innovation.

The reasons why companies start innovating their process are manifold and so are the (expected) benefits from process innovation. In order to properly research the drivers for the application of smart manufacturing, it is necessary to firstly understand the drivers for process innovation in general. Rogers (2003) refers to these drivers as influencers of a process in which organisations assess the (expected) advantages and disadvantages of the innovation, the innovation-decision process. Theses drivers influence the decision to implement the innovation, i.c. a process innovation. Rogers describes a model through which the diffusion of innovations can be understood, not only at the level of the individual, but also at the level of the firm, as has been confirmed by scholars (Jeyaraj, Rottman, & Lacity, 2006). The diffusion of innovations, as Rogers argues, can be divided in five stages; knowledge, persuasion, decision, implementation and confirmation. In the knowledge stage, a

> *Everett M. Rogers: Diffusion of innovations (2003)*
>
> *Diffusion was defined by Rogers as the “process through which an innovation is communicated through certain channels over time among the members of a social system” (p. 12).*
>
> *Rogers defined an innovation as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” (p. 5).*

Exhibit 2- Diffusion of innovations

decision-making unit is becoming aware of an innovation's existence and starts to understand how it might be of use. In the persuasion stage, a decision-making unit becomes more involved with the innovation by developing a personal perception of and an attitude toward the innovation. In the decision stage, a decision-making unit engages in activities leading to a decision to adopt or reject the innovation. Implementation is described as the stage in which a decision-making unit puts an innovation to use. Finally, in the confirmation stage, a decision-making unit seeks confirmation for the decision made, sometimes leading to a reversed decision.

However, a problem with this model is that it presupposes a clear view of what the innovation is like, which is certainly not the case with smart manufacturing, given the previously presented definition. There are many ways in which smart manufacturing can be applied and there are major differences between the different possibilities smart manufacturing offers. Setting up a web based portal for instance serves a different purpose than for instance connecting CNC-controlled machines to each other. Yet, both can be seen as smart manufacturing. The different ways in which smart manufacturing can be applied, leaves Rogers' model unsuitable for the submitted research.

A closer look at the antecedents and consequences of process innovation could generate useful insights into the way companies decide more specifically on the application of smart manufacturing.

3.1.1. Antecedents and consequences of process innovation

Frishammar et. al. (2012) divide both the outcomes (consequences) of realized process innovation (consequences) and the key antecedents of potential process innovation (sources) each into three distinct categories, based on an extensive literature review. Efficiency, effectiveness and sustainability are considered as the main outcomes, and strategy, collaboration and culture as the main source from which process innovation stem. The difference between the potential and realised process innovation lies, according to these scholars, in the proficiency in realising innovation solutions, called the process innovation capability. The resulting conceptual model is shown in figure 1.

The process innovation outcomes may be regarded as the ultimate goals companies try to achieve when innovating their processes, thus driving the search for process innovation. The antecedents may in the same way be considered the source, thus enabling process innovation. Simply put, strategy, collaboration and culture trigger the innovation process while the pursuit for efficiency, effectiveness and sustainability drive the innovation process. If a company for instance has not properly aligned the corporate strategy with the operations strategy, the probability that the company will invest in the right process innovation is reduced. Just like that, if a company fails to collaborate with external parties, chances that useful process innovations will be discovered, are diminished.

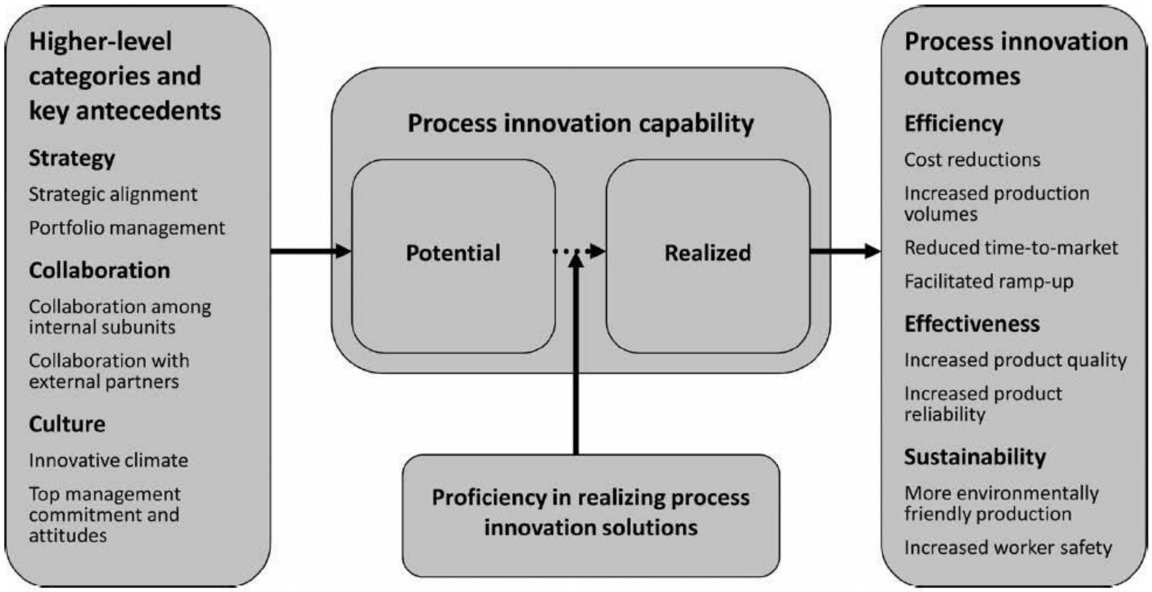

Figure 1- Conceptual framework of firms' process innovation capabilities. Source: Frishammar et. al. (2012).

Since smart manufacturing is considered a variety of process innovation, research into the drivers and barriers of the application of smart manufacturing should at least involve the categories strategy, collaboration and culture. Before turning these topics into research questions, the subject will be narrowed from smart manufacturing as a manner of process innovation to smart manufacturing as a variety of IT adoption, more specifically aimed at SME's as the previously described model is applicable to companies of any size.

3.2. Smart manufacturing and IT adoption

A closer look at the more specific nature of smart manufacturing reveals that the adoption of smart manufacturing is closely related to the adoption of IT and even can be seen as a form of IT adoption. As has been brought forward in the previous chapter, smart manufacturing is in fact about the convergence of IT and OT, which generally is done by adding IT to the existing OT. Since smart manufacturing aims at using sensor data and connectivity to control the flow of materials, products and information, it can be viewed as an application of IT. Therefore it is useful to firstly understand how and why SMEs decide on the application of IT in general. Consoli (2012) classifies the benefits of applying IT in four categories: performance, growth, expansion and new products, all of which are measured at the firm level. Nguyen et. al. (2015) further elaborate on these benefits. Their research shows that customer requirement, business expansion, quality improvement, industry requirement, investment and cost control are the main drivers for the adoption of IT. Since the application of smart manufacturing surely impacts the performance at the firm level, these drivers for IT adoption seem to be useful in guiding the research. It is particularly interesting to see whether the expected benefits from smart manufacturing are different from the drivers for IT adoption in general for it has become clear in the previous chapter that the benefits of smart manufacturing are unsure and lack clear visibility. Yet, the expected benefits will influence the decision to adopt smart manufacturing and should therefore be included in the research.

After making the decision to adopt IT, the actual adoption process starts with the ultimate goal to assimilate the innovation into the existing process. This adoption process itself is also influenced by several factors. A framework containing the drivers influencing the decision to apply IT in SMEs as well as factors influencing the success at which IT is implemented in SMEs has first been provided by Nguyen (2009) and has been slightly devised and confirmed afterwards (Nguyen, Newby, & Macaulay, 2015). The (final) framework is shown in figure 2.

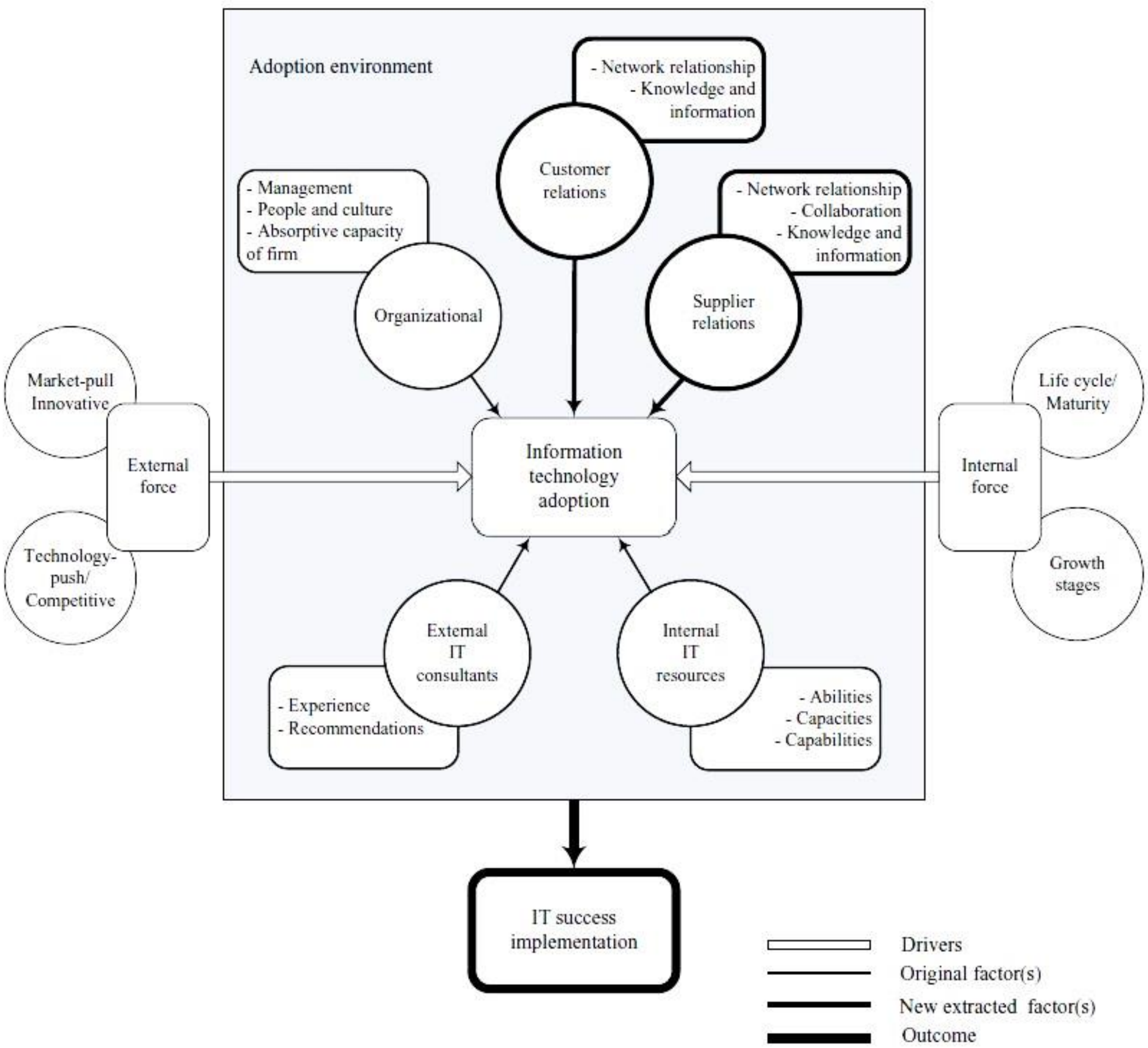

Figure 2 - Framework for SME Information Technology Adoption. Source: Nguyen et. al. (2015).

The framework divides the forces that drive IT adoption into internal and external forces. Externally, the driver could be either the market demanding a company to adopt IT (market-pull) or the availability of new technologies enabling the adoption of IT (technology-push). The first is seen by Nguyen as driven by innovation from within the company itself, positioning the company as a leader, while the latter suggests a more following approach as IT adoption is considered because competitors started doing so, turning certain applications into industry standards.

Besides the drivers influencing the adoption of IT, the framework mentions a number of factors influencing the success with which IT is implemented. These factors fall into five categories, namely organizational, customer relations, supplier relations, external IT resources and internal IT resources and have been put together in what the authors call the “adoption environment”.

Although the framework seems to put all relevant factors together, the model lacks integration between the drivers for adoption on one hand and the environmental factors influencing the rate of success of an adoption on the other. Not only do most of the mentioned environmental factors influence the success, but they also drive the adoption itself. Strong customer relations for instance could lead to IT adoption and not only help successfully implement IT by identifying customer needs in terms of IT, such as B2B e-commerce. The same goes for the availability of highly qualified IT staff; these staff could obviously be of great help in the actual implementation process, but they may just as well drive the adoption by pointing out new opportunities in the use of IT to the management. For each of the five categories it is obvious that the boundaries between drivers and environmental factors is not as rigid as the authors suggest. This also is confirmed when comparing the model presented with the previously described model of Frishammar et. al. They identified collaboration with suppliers and competitors for instance as a source for process optimization, rather than as an influencing factor for success. A combination of both models may therefor provide a more complete conceptual framework for the submitted research.

3.3. Differences between IT application and smart manufacturing

The previously presented framework may seem sufficient for answering the question as to why and how SMEs in Dutch metal industry consider applying smart manufacturing. However, besides the fact that the drivers for adopting smart manufacturing may differ from the drivers for adopting IT in general, as argued before, a major difference between general IT and smart manufacturing is that smart manufacturing holds promise for improving the performance of an entire sector, i.c. manufacturing industry in the Netherlands, rather than only improving the performance of an individual firm. As has been brought forward in chapter two, this could come at the price of the disappearance of some firms, because new business models could emerge. To date, existing literature on the application of IT only has been focused on the effects on the performance of the firm as an entity, namely to enhance organisational survival and/or growth, to remain competitive and to enhance innovative capacity (Nguyen, Newby, & Macaulay, 2015). Furthermore, the framework does not take into account that smart manufacturing could lead to new business models, as it focuses on the performance of the firm in terms of the successful implementation of IT. To get an idea of the possibilities new business models may offer, a further look at the application of smart manufacturing regarding information sharing will be provided hereafter.

3.3.1. Supply chain information sharing and networking

Smart manufacturing is strongly related to the adoption of IT, as was shown in the preceding section. In a broader sense, however, smart manufacturing also relates to theory about supply chain information sharing, particularly within networks. But just as literature on the adoption of IT is primarily focusing on improving the performance of the firm itself, existing theory about supply chain information sharing has a strong orientation towards either the performance of a firm or of a supply chain as a whole (Lotfi, Mukhtar, Sahran, & Zadeh, 2013) and even if horizontal information sharing is considered, this is still done from the perspective of the supply chain (Li, 2002). Brettel et. al. (Brettel, Friederichsen, Keller, & Rosenberg, 2014), however, take information sharing beyond the boundaries of existing supply chains by proposing collaborative networks across a number of supply chains in both manufacturing and design. This may, according to these scholars, be of specific interest to SMEs with (in general) limited resources, because "within a collaborative network, risks can be balanced and combined resources can expand the range perceivable market opportunities. The organisation in networks multiplies the available capacities without the need of further investments" (p. 39). This enables companies to respond to quickly changing customer needs caused by the commoditisation of many industrial products. Since the formation of these networks is one of the promises smart manufacturing holds, as has been shown in chapter two, a further look is required at the way these networks (could) operate and how information sharing between entities in these networks can be utilized, is required. Starting with the latter, the next section describes the possibilities collaborative networks offer.

3.3.2. Monetizing information

As a start, it is useful to firstly take a look at how new business models might emerge from collaborative networks. The new business models created by the application of smart manufacturing stem from the availability of data about processes and capacities of suppliers and customers within ecosystems of firms. Examples of how these data can be monetized are presented by Van 't Spijker in his book The New Oil (Van 't Spijker, 2014). In this book, Van 't Spijker describes five patterns through which data can be monetized. These patterns will be described in brief hereafter, supplemented with possible application in manufacturing.

Pattern 1 – Basic data sales

In basic data sales, companies sell the data that is generated by their core processes to third parties. This can be seen as the simplest pattern for monetizing data. In manufacturing, these data could consist of utilization, capacity, resources, inventory etc.

Pattern 2 – Product innovation

In product innovation, data generated from sales and usage of existing products is being used to generate new products or additional offerings to existing products. In manufacturing, this could be done by using data about the usage of a product to help customers achieve performance improvement by selling a maintenance plan.

Pattern 3 – The commodity swap

In the commodity swap, data generated from sales and usage of existing products is being used to generate additional services alongside products sold. In manufacturing, this could mean providing conditional maintenance services for machines, also known as servitization (Baines & Lightfoot, 2013).

Pattern 4 – Value chain integration

In value chain integration, organisations in the same value chain exchange data in order to reduce costs or improve performance. In manufacturing, this could mean that suppliers have insight in the buying behaviour of the end-consumer with the aim to balance demand and capacity.

Pattern 5 – Value net creation

In value net creation, the aforementioned value chain integration pattern is expanded to the value net, making organisations which are directly or indirectly serving the same end-consumer but are not part of the same value chain, exchange information about each other. In manufacturing, this could mean competitors sharing information about each other's resources and utilization in order to balance capacity and demand.

In describing these patterns, Van 't Spijker confirms the idea that the availability of data as a result of the application of smart manufacturing indeed stimulates the emergence of new business models within an industry. For the submitted research, mainly patterns four and five seem to be of relevance since these patterns can be regarded as process innovations. What becomes clear however, is that closer collaboration between companies in and outside of the same value chain is required.

The term value chain was first coined by Michael Porter in his bestselling book on competitive advantage (Porter, Competitive advantage: Creating and Sustaining Superior Performance, 1985). Initially, Porter described an interlinked chain of events within an organisation in each of which value was added to a product or service. This concept was shortly thereafter expanded to a chain of events spanning an entire industry, called value systems (Porter & Millar, 1985).

Cinzia Parolini developed the idea of a value system further into the concept of a value net (Parolini, 1999). In a value net companies are intertwined in a network (rather than consecutive steps) with at least one common end customer.

Exhibit 3 - Value chain vs value net

3.3.3. Collaborative networks

The idea of collaborative networks has been further elaborated by Van Lier, taking a network centric approach (Van Lier, 2014). The impact of smart manufacturing, as Van Lier argues, should not be merely studied from the viewpoint of the firm, but requires a more network centric approach. Networks have already risen and will keep rising around us, requiring "a fundamental change to the perspective with which we currently organize, produce or regard ourselves as people" (p. 328). Van Lier builds this conclusion on the ideas of biologist Ludwig von Bertalanffy, who has been regarded as one of the founding fathers of a general systems theory (see exhibit 4), stating that, just as in complex biological systems, any interrelated whole is more than the sum of the separate parts, which are interrelated, and should therefore be approached as a an entire system rather than as individual parts of that same system. Van Lier describes our society as one in which we transfer more and more responsibilities to interrelated technological applications, thus reducing direct human responsibilities, provoked by what Van Lier calls "a process of hybridizing man, organization and society with technology" (p. 325). Van Lier claims that, given the complexity of this postmodern network society, parts of a network can only be properly understood when viewed from the perspective of the network (system) as a whole. This view had already been described in the early 1970's by philosopher Arthur Koestler (1972), referring to this parts-whole interaction as holonomy after the Greek word "holos", meaning whole, and the Greek suffix "on", meaning particle or part, as in proton or neutron (Botti & Giret, 2008).

Van Lier takes the network centric approach to describe the challenges ahead when moving into the direction of smart industries, arguing that in an era of ever increasing connectivity and convergence between man and machine, existing approaches to organizing and structuring organisations eventually will fall short. Organisations will have to change their thinking from a hierarchical and functional orientation to a more horizontal approach focusing on relationships between the firm and the external environment. This also requires other types of control and management and will eventually even change existing business models. Van Lier goes so far as to conclude that "this rapidly developing new reality requires a search for the new 'being' in an emerging highly technological environment" (p. 328).

Whereas Van Lier leaves the further details of what the industrial networks of the future may look like to the imagination, Klapwijk (2004) provides a somewhat more detailed vision of what he calls "tomorrow's value chains". He sketches a future "value chain" in which three virtual players have emerged. A visual reproduction of this future value chain is presented in figure 3. In the physical world, there is a broad base of mature suppliers, or 3PO's (Third Party Operators), for virtually anything. In the virtual world, a total of three virtual players have emerged. These are called virtual because they neither not own any assets nor produce any goods. The entire production and delivery of goods has been outsourced to. The first virtual players are the Value Creators. They have a good understanding of what could be of value to society and have a good understanding of what can be made. The solutions they come up with are technology-pushed. The second virtual players are the Fulfillers of Needs. They understand really well what customers in a particular segment of the market require and they know what is available. The solutions they provide are market-pulled. In between the 3PO's in the physical world and the value creators and fulfillers of needs in the virtual world, a third virtual player has emerged, the 4PO (Fourth Party Operator). A 4PO takes care of part of the supply chain, such as transportation and logistics. 4PO's have the value creators and fulfillers of needs as their customers, but do not own or run any assets.

Systems theory

The general systems theory (Allgemeine Systemtheorie) was first described by Austrian biologist Ludwig von Bertalanffy in the early 1950s, based on his previously developed biological theory. The general systems theory gained ground in the United States and Western-Europe through the work of cultural antropologist Gregory Bateson (1956) and psychologists Katz and Kahn (1966) and Watzlawick (1967).

The five major premises of the systems theory are:

1. *The whole is more than the sum of the parts*
2. *Parts within a system depend on each other*
3. *The system determines to a certain degree the behaviour of individuals*
4. *The system will try to adapt to the environment to survive*
5. *A system will try to maintain itself, even when the right for being no longer exists.*

Derived from "Anders kijken" (Willemse, 2012)

Exhibit 4- Systems theory

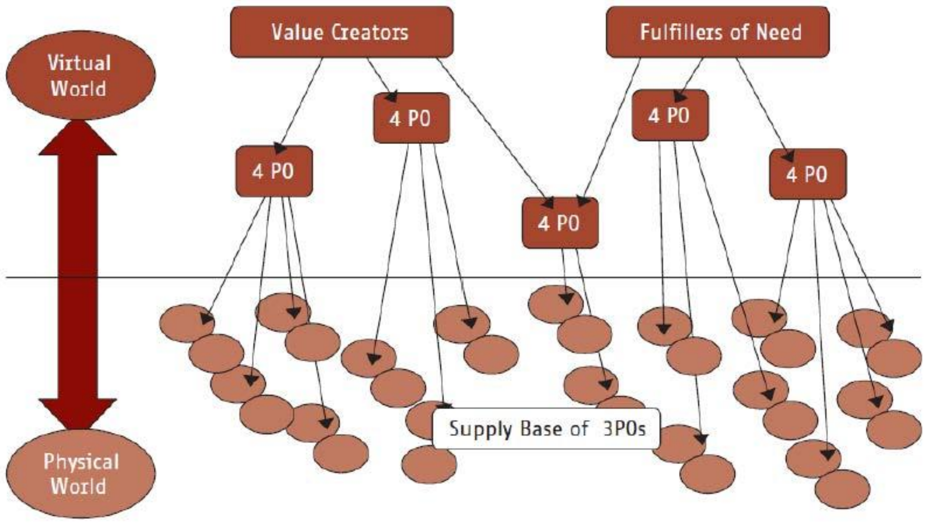

Figure 3 - A future vision of the supply chain. Source: Klapwijk (2004).

Klapwijk, just as Van Lier, emphasises the important role digitization plays in the forming of these networks as it is the availability of data which enables close cooperation between all players involved in the network.

Although this vision may seem futuristic, Klapwijk states that, as early as in 2004, car manufacturing industry already was moving towards this system slowly. Current developments within the Smart Industry platform show that Dutch industry also is slowly embracing this vision, as large manufacturers, like Thales, ASML and Philips Healthcare have recently engaged in a Smart industry field lab with the aim to digitise the supply chain, thus reducing transaction costs (TNO, 2016). However, the question remains how particularly SME's are involved in this process and, of relevance to the submitted research, how they decide on the application of smart manufacturing.

Both Klapwijk and Van Lier stress the inevitability of the convergence of industry networks. If these (future) networks will play such an important role in the development of manufacturing industry, the vision SME's hold on the future must play an important role in deciding on the application of smart manufacturing and should as a result be included in the submitted research.

3.4. Conclusion

The conclusion can be drawn that existing literature about supply chain information sharing and about IT adoption could be useful in shaping a conceptual framework, but is ineffective in answering the research question formulated before, specifically because it does not take into account the impact the decision to adopt smart manufacturing may have across the boundaries of the company. The relevant aspects for the submitted research, resulting from the literature review presented before, have been put together in a conceptual framework which has been used to guide the research into drivers and barriers of smart manufacturing for SMEs.

3.5. A conceptual framework for smart manufacturing adoption

As has been shown before, existing frameworks about the adoption of process innovation in general and about the adoption of IT in particular can only be used in shaping a conceptual framework for a research into the drivers and barriers for the application of smart manufacturing. The resulting framework is shown in figure 4 and will be elaborated hereafter.

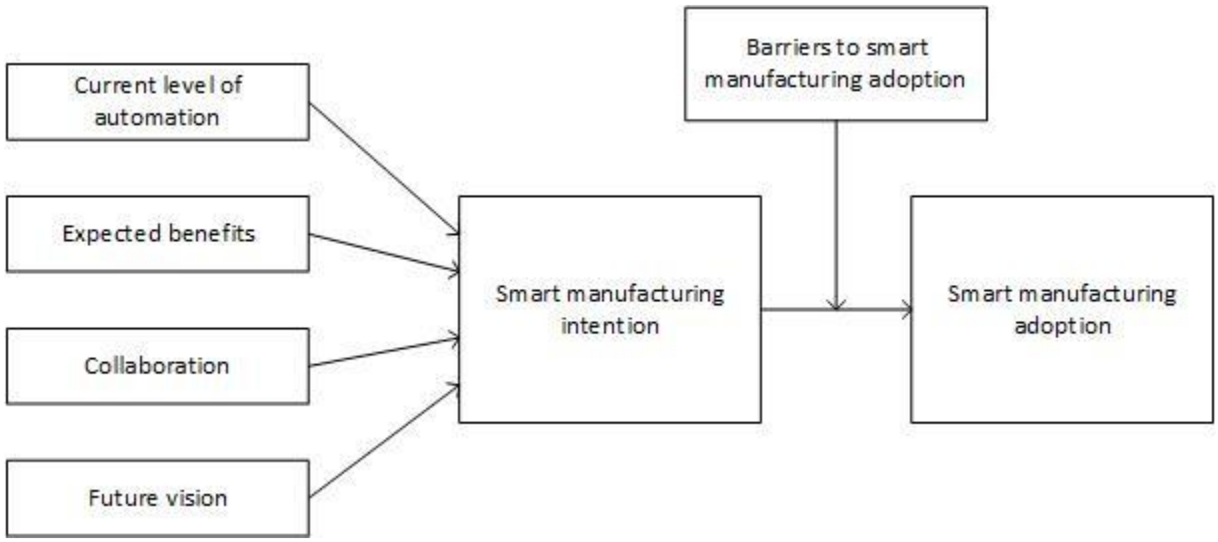

Figure 4 - Conceptual framework drivers and barriers of smart manufacturing adoption

At the heart of the framework lies the intention to adopt smart manufacturing. This intention is supposed to be influenced by at least the current level of automation, the expected benefits gained by smart manufacturing, collaboration with external partners and the future vision on the development of manufacturing industry. The intention may eventually lead to the adoption of smart manufacturing, but this is supposedly influenced by barriers to the adoption of smart manufacturing. In the next section, the variables in the framework will be elaborated and linked to the previously presented theoretical review.

Smart manufacturing intention

Smart manufacturing intention can be described as the motivation to consider applying smart manufacturing. SMEs that have this intention will allocate resources (knowledge, money, time) to consider whether smart manufacturing may be of importance to the firm.

Smart manufacturing adoption

The adoption of smart manufacturing means that the firm will have put smart manufacturing technologies to use, for example by digitizing customer contact or by using process data across the boundaries of the firm.

Current level of automation

The current level of automation as an independent variable combines a number of factors from both the framework provided by Frishammar et. al. (2012) and the framework provided by Nguyen et. al. (2015). The current level of automation is considered to be a result of strategic alignment, top management commitment, innovative climate on one hand and of the life cycle/maturity of assets and growth stages on the other and could therefore be regarded as a driver for the intention to adopt smart manufacturing.

Expected benefits

The expected benefits also play a crucial role in the decision making process. In accordance with Frishammar et. al. the aimed benefits are supposed to be efficiency, effectiveness and sustainability. Nguyen et. al. specify the benefits of IT adoption as business expansion, quality improvement and cost control. A combination of these benefits leads to growth, efficiency and effectiveness as the most important drivers for the adoption of smart manufacturing.

Collaboration

Frishammar et. al. put collaboration with internal and external subunits/partners as a primary driver for the application of process innovation, while Nguyen at. al. regard this as only influencing the success rate of the application of IT as a form of process innovation. As has been brought forward before, it is believed that cooperation indeed primarily drives smart manufacturing and should therefore be included in the research. Since the research is aimed at SMEs rather than at large companies, the role of collaboration with internal subunits seems to be of less relevance than collaboration with external partners. For smart manufacturing, collaboration with competitors, suppliers and customers in particular should be regarded as driving the intention to adopt smart manufacturing.

Future vision

As has been shown by Van Lier and Klapwijk, manufacturing industry is likely to change dramatically over the course of the next decade. It is assumed that SMEs with a clear vision on this future are more likely to intend applying smart manufacturing. How this vision affects the intention is to be researched.

Barriers to smart manufacturing adoption

To move from the intention to the actual adoption of smart manufacturing, SMEs are likely to encounter or foresee barriers. The nature of these barriers is unknown and literature does not provide possible barriers, as smart manufacturing has not been researched in SMEs before. The question what these barriers consist of is as a result approached openly.

3.6. Research questions

The research questions derived from the aforementioned conceptual framework are:

- How does the current level of automation influence the adoption of smart manufacturing?
- What benefits do SMEs expect from the application of smart manufacturing?
- What is the role of collaboration in the decision to adopt smart manufacturing?
- How does the future vision of SMEs influence the adoption of smart manufacturing?
- What are barriers to the adoption of smart manufacturing?

4. Methodology

Given the dearth in the literature about SMEs in general and the application of smart manufacturing in SMEs in particular, no propositions could be generated. What's more, the independent concepts are (at least partially) unknown and will have to be brought forward in the research. As Dul & Hak (2008, p. 182) point out, a theory-building comparative case study would be the most appropriate form of research in this case. This view is supported by Yin, claiming that for "how" and "why" questions that do not require control of behavioural events and focus on contemporary events, an inductive case study is the most appropriate form of research because "...such questions deal with operational links needing to be traced over time, rather than mere frequencies or incidence" (2014, pp. 9-10).

The underlying logic in this research could be described as grounded theory as formulated by Glaser & Strauss (1967), in which theory is being developed "through 'comparative method' which means looking at the same event or process in different settings or situations" (Easterby-Smith, Thorpe, & Jackson, 2012, p. 58). In this research, the event could be defined as the intention to apply smart manufacturing technologies.

4.1. Data gathering

Data will be gathered through semi-structured interviews with representatives of the firms involved in the research. The representatives are to be involved in the decision making process concerning the application of smart manufacturing technologies. The use for semi-structured interviews follows the grounded theory logic since this type of interview leaves the opportunity open to discover new constructs which, in turn, could influence future interviews. The initial set of questions was drawn up around the drivers for adoption of IT in SMEs, as described in the previous chapter. The first case has been used as a pilot case study (Yin, 2014) to refine the data collection plan. The interviews were semi-structured in the sense that a set of questions was drawn up following the research questions, but room was left for interviewees to give their opinion as unrestricted as possible. This was done by including questions, such as: "what do you think about the Smart Industry initiative" rather than merely asking for an answer to the research questions. This method has shown to provide much richer answers to the research questions. All of the interviews have been recorded and the audio files were used to write out the interviews in full. Subsequently, the interviews have been coded using the topics collected during the literature review. The initial set of questions, slightly revised after the first interview, can be found in appendix A. Note: the interviews have been held in Dutch, but the questions have been translated for this paper. The answers have not been translated. A more detailed explanation of the structure of the interviews can be found in chapter 5.

After the interviews were written out in full, the transcripts have been sent to the interviewees with the request to change passages which either had not been transcribed correctly or showed not to reflect the true opinion of the interviewee. Only two of the interviewees felt the need to propose changes, which were mainly textual adaptions that did not alter the quintessence of the transcripts, so the conclusion can be drawn that the interviews are reflecting the true opinion of the interviewees.

4.2. Selection of instances

The unit of analysis is the company. Empirical data was gathered from Dutch manufacturing companies employing between 10 and 250 employees and either a turnover between €2m and €50m or a balance sheet total between €2m and €43m, in accordance with the definition of Small and Medium-sized Enterprises (SME) provided by the European Commission (European Commission). Manufacturing in this particular case means that the companies will have to produce and/or assemble discrete products.

Since the primary objective of this research is to provide insight in the incentives for SMEs to consider applying smart manufacturing technologies, the initial idea was to only select instances for which it is clear that the application of smart manufacturing is considered to be useful to the company. As the secondary objective is to gain insight into the way SMEs expect to overcome the barriers in the application of smart manufacturing, companies in which smart manufacturing has been applied to a certain degree were to be favoured over companies that only intend to apply smart manufacturing. However, a problem arose when companies were contacted. The application of smart manufacturing is far less present within Dutch industry than expected. Only a few companies have applied smart manufacturing to the extent expected. As a result, the focus of the research has shifted from the actual application of smart manufacturing towards the intention companies may have. Still, companies that had already applied smart manufacturing to a certain degree were favoured over others, but companies which had not applied smart manufacturing at all have also been included in the sample, since they could provide useful information about why not to apply smart manufacturing. To make a comparison between companies possible, only companies from a subsection of Dutch manufacturing industry have been selected, namely the steel industry. Steel industry has been selected because most examples of smart manufacturers come from this sector, as became clear from a review of the database of so called ambassadors of Smart Industry, as published on their website (Smart Industry). The first number of cases was selected from this database, since these companies have shown a clear interest in and value Smart Industry. Another part of the cases was selected after visiting Technishow 2016, a trade show in the field of industrial production technology, treatment and processing of metals, plastics, accessories and tools in the Benelux area, held on march 15/16 2016 in Utrecht. At this trade show, exhibitors were asked whether they knew about and intended to apply smart manufacturing. The remainder of the cases were obtained through the researcher's personal network.

All of the companies have been approached by phone to check whether the previously performed screening resulted in the right instances for the research. A phone script was developed to check (a) if the company had applied smart manufacturing already or (b) if the company would be interested in doing so in the near future. This way, the variation in the value of the independent variable (extent of application of smart manufacturing technologies) could be maximized.

Although the case selection strategy resembles theoretical sampling in which cases are selected for theoretical, rather than statistical reasons (Eisenhardt, 1989), the selection strategy is best described as convenience sampling in which maximization of the likelihood that existing relations between the variables in the conceptual framework will be discovered. As Dul & Hak (2008) argue, instances can hardly be selected using theoretical sampling if the concepts are not dichotomous, as is the case with all of the independent variables in the conceptual framework presented before. Convenience sampling is therefore an appropriate strategy for the selection of instances for the submitted research.

All of the interviewees were either owner/director or CEO of the companies that were part of the research, since the research aims at considering smart manufacturing as a strategic option. Because steel industry in the Netherlands is a relatively close community, this also provided a means of cross-checking answers given by the interviewees, thus providing triangulation (Eisenhardt, 1989).

The total number of cases included in the research adds up to six. A total of seven interviews have been held, but the results of one of the interviews proved not to be relevant for the research, since the company involved was still in the start-up phase, expecting to start production in the course of this year. The number of cases is sufficient, as Eisenhardt (1989) argues that, although there is no ideal number of cases, four to ten cases usually provide enough replications to develop theory and analytically generalize from the findings. Eventually, accumulating empirical evidence from the cases supplied "theoretical saturation" (Eisenhardt, 1989), indicating that it is unlikely that new information will be gained by adding more cases.

The results of the research will be presented in the next chapter.

I think the world believes we are further than we actually are. Not just us, but the whole world thinks Smart Industry is further than it is. Like with every revolution, or evolution, it takes time. The speed may be increasing, but it still takes time.

One of the interviewees, May 2016

5. Results

In this chapter, the results of the submitted research will be presented. Some of the interviewees have requested their input to be anonymized for reasons of confidentiality. This request has been granted and the decision was made to anonymize all of the cases. After a description of the interview structure, this chapter starts with a brief description of the cases involved in the research. For the earlier mentioned reasons of confidentiality, the cases are named A through F, followed by a fictitious name for ease of reading. This name is supposed to echo the core activity of the corresponding manufacturer and will be used throughout this report. After the case descriptions, a first attempt will be made to classify the cases in the research, based on their respective levels of intention and adoption, followed by an analysis of both the drivers for and barriers to the adoption of smart manufacturing. Finally, a revised conceptual framework will be proposed, based on the propositions generated during the analysis. The propositions will be numbered as follows: propositions regarding the drivers for the intention to adopt smart manufacturing will be numbered D1 through Dn, and the propositions regarding the barriers to adoption will be numbered B1 through Bn. If a proposition is further explained by another proposition, this will be indicated by adding a lower case letter a through n after the proposition number.

5.1. Interview structure

Based on the research questions posed in the previous chapter, interview questions have been generated to structure the interviews, in such a way that the interviewee will be guided, but still has the opportunity to bring forward anything that might be of interest with regard to the submitted research. To achieve this, besides the questions that were prepared, in all of the interviews the interviewee was asked to give their opinion on the Smart Industry platform in general. If the interviewee was insufficiently familiar with Smart Industry, a brief explanation of the history and objectives of Smart Industry has been provided by the interviewer, accompanied by a more detailed description of the aims of the submitted research. Another way to evoke the interviewee's opinion on the subject was to present the case of 247 Tailor Steel, a well-known company within Dutch industry and ask the interviewee to reflect on differences and resemblance with their own company. Finally, the future vision of Klapwijk and Van Lier was brought forward and the interviewees were asked to respond to this future scenario.

The interview questions that were used to guide the interview can be found in appendix A.

5.2. Description of cases

Case A – Sheet metal

Case A, located in the province of Zuid-Holland, is the sheet metal part of a group of companies providing solutions in precision engineering, mechatronics and sheet metal. The company produces fine sheet metal work using laser cutting, CNC setting and edging, welding, laser hole drilling and rolling techniques. The primary customer base consists of Original Equipment Manufacturers (OEM), of which 35-40% is located abroad, mainly in the United States of America, Germany, China and Singapore. The share of international customers is growing, thus shifting competition from regional to international. The total turnover of the group in 2015 adds up to €14m and the number of employees equals 100 FTE. Turnover is growing over the last five years, but the profitability declined as a result of investments in automation and product development. Turnover is expected to grow further in the next two years, as is the profitability, as a result of these investments. An interview of one hour and 15 minutes was conducted with the Chief Executive officer (CEO) of case A.

Case B – Packaging

Case B is located in the province of Zeeland and serves as an OEM for packaging machines and lines for the food industry, offering solutions for operations such as separation, weighing, filling, distribution, top sealing and lidding. Assembly is at the heart of the production process, but the company also produces its own semi-finished products using CNC-controlled machines for milling and machining. The company has moved away from utilizing these machines to produce for third parties, thus focusing on their core activities. Their main market is The Netherlands, but expansion abroad is one of the targets for the company. Main foreign target markets are Belgium and France in which the company already is gaining foothold. Competitors are mainly located abroad, in particular in Germany. Turnover, just as profitability, is confidential but has grown some 10% over the last two years. The average number of employees equals 50 FTE. The Director/Majority Stakeholder (DMS) of case B has been interviewed for one hour.

Case C – Rail road

Case C is a western province of Noord-Brabant located OEM and parts manufacturer for industry and retail. The company is divided in four separate units, each of which is dedicated to a specific market. The metal division processes metal using conventional and CNC-controlled turning, machining, honing and welding machines and a (recently added) CNC-controlled multitasking machine with a robot. The machine building division delivers turnkey machines and production installations for industrial application. In the rail road division, developing, manufacturing and delivery of unique railway rolling stock takes place. The shop systems division, finally, produces shop furnishings, display units, and point of sale (POS) materials. Their target market is mainly regional, except for the rail road division for which the main market is located abroad. The total turnover in 2015 was approximately €6m, realized with 40 FTE. Production for both shop systems and rail road is done in the machine building division, partly outsourced abroad. Further growth is expected to come from rail road, while the share of shop systems is expected to decline. For case C, an interview of 45 minutes was conducted with the DMS.

Case D – Web based

Case D, located in the eastern part of the province of Noord-Brabant, delivers sized sheet metal, profiles and tubes, using a range of CNC-controlled machines for cutting, setting and edging. The customer base consists of OEMs and of companies serving OEMs in a wide range of industries. The production process is highly automated, enabling customers to upload or design their product specifications via a web based portal from which production is controlled. Traditionally, the market has been mainly regional, but as a result of the high level of automation, customers from outside the region are increasingly requesting products from case D. Turnover and profit are confidential, but have both grown substantially over the last two years, after an initial decline as a result of investments in automation and the initial difficulties encountered with the usage of this automation. A total number of 40 FTE are employed by case D. An interview of one hour and 25 minutes was conducted with the DMS of case D.

Case E – Steel processing

Case E is based in the province of Overijssel and develops and manufactures CNC operated steel processing systems for customers in the steel processing industry, of which 95% is located abroad. Countries in which case E has a broad customer base are the United States of America, Russia, India, France, England and Germany. In each of these countries, a service centre is active. Assembly is the core business of the company, which is mainly performed in The Netherlands. Turnover is confidential, as is profitability, but both are increasing annually through autonomous growth with a strong focus on international expansion. While the machines case E manufactures are highly automated, automation within the production facility is limited. The managing director of case E has been interviewed for 50 minutes.

Case F – Copper separator

Case F is located in the western part of the province of Noord-Brabant and manufactures and installs steel and aluminium constructions, such as stairways, fences and artistic expressions, serving customers within the region, as well as metal parts and constructions for antennae structures and cooling installations nationwide. Customers include project developers in industry, government, utility and housing construction. Recently, the company developed a copper separating machine in close cooperation with another party, for which it serves as an OEM with customers outside the region as main target. Sales of this machine are expected to start this year. The annual turnover is confidential, as is profitability, but is increasing and is realized with 12 FTE. A CNC controlled press brake and flame-cutting machine and an NC controlled punching machine are available to these employees. Further growth is expected to come from high quality products such as frames for medical devices and parts for transmission towers and antennae structures. For case F, an interview of one hour was conducted with the director/owner.

5.3. Categorising manufacturing companies.

The theoretical review in the previous chapter showed that the intention to adopt smart manufacturing is likely to precede the actual adoption, as became clear in the conceptual model presented before. The data from the interviews confirms this, as will be demonstrated below.

When ordering the instances involved in the research on the aspects of intention and adoption, three categories have emerged from the research, based on their level of intention and adoption. In figure 5, a matrix is shown in which the candidate companies have been positioned on these axes. As becomes clear from this matrix, intention seems to be a necessary condition for the adoption of smart manufacturing, since none of the companies in the sample have applied smart manufacturing without a certain intention to do so. It is therefore safe to claim that the likelihood of applying smart manufacturing accidently is very low. This leads to the first proposition:

Proposition D1: The intention to apply smart manufacturing is a necessary condition for the adoption thereof.

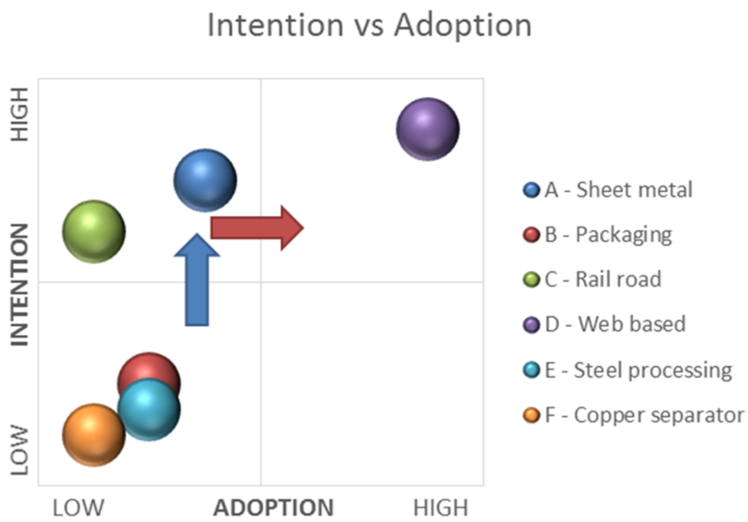

Figure 5 - Intention to adopt vs adoption of smart manufacturing

The categories from the remaining quadrants in the matrix are called the dormant, the captives and the adopters. These categories will be explained hereafter.

Dormant

The dormant are positioned in the lower left corner of the matrix. These companies have shown little or no intention to apply smart manufacturing, neither have they applied smart manufacturing in any form. Cases Packaging, Steel processing and Copper separator are positioned in this quadrant.

Captives

The captives, positioned in the upper left corner of the matrix, are aware of the existence of smart manufacturing and in large of the possibilities smart manufacturing offers, but they have not put this into practice for their own processes because they have not been able to do so for several reasons. These reasons will be elaborated further on. From the candidates, cases Sheet metal and Rail road are found in this quadrant.

Adopters

In the upper right corner of the matrix, the adopters can be found. The adopters have managed to successfully apply smart manufacturing to a certain extent in their own processes, and did such purposefully. The only candidate fitting in this quadrant is case Web based.

In determining the position of the cases on the axes of intention and adoption, the operationalization of these terms provided in chapter 3 has been used. According to these definitions, intention can be described as the motivation to consider applying smart manufacturing. SMEs that have this intention will allocate resources (knowledge, money, time) to consider whether smart manufacturing may be of importance to the firm. If a company has adopted smart manufacturing, it means that the firm will have put smart manufacturing technologies to use, for example by digitizing customer contact or by using process data across the boundaries of the firm. The position on the respective axes has been determined based on the information interviewees have provided during the interviews. The position of the cases on both the intention and adoption axes is elaborated in table 1. Since the reasons for positioning the candidates on the axes in the matrix are manifold, further proof for the positions of the candidates in the matrix will be provided in the subsequent paragraphs, when discussing the drivers and barriers to smart manufacturing adoption in more detail.

Table 1 - Explanation of case position on intention and adoption axes

	Intention	**Adoption**
Case A **"Sheet metal"**	Position: HIGH Explicitly mentioned the desire to connect all of the machines and to make the process data available. They included this consideration in deciding on a new ERP-system.	Position: LOW Have started the implementation of a web portal through which customers can gain insight in the production process, but fail to make effective use of it.
Case B **"Packaging**	Position: LOW Explicitly mentioned that they do not intend to share data with other parties in the supply chain.	Position: LOW The recently purchased ERP-system is aimed at providing process information for internal use only.
Case C **"Rail road"**	Position: HIGH Are aware of the possible benefits and have spent time on considering possibilities.	Position: LOW Started vendor managed inventory, but communication with customers is still done traditionally.
Case D **"Web based"**	Position: HIGH Strongly emphasise the importance of smart manufacturing for the performance of processes. Clearly state that granting customers access to the production data is the way to the future.	Position: HIGH Successfully utilise a web based portal through which customers can communicate their orders. The portal is connected to the shop floor enabling production with as little human effort as possible. Started building interfaces between customer's ERP and the portal.
Case E **"Steel processing"**	Position: LOW Clearly state that digitising production processes and customer contact is not considered relevant. They claim to stay away from initiatives like Smart Industry.	Position: LOW Their core process is mainly operated manually. No effort has been made to digitise this process.
Case F **"Copper separator"**	Position: LOW Emphasise that digitisation is not an option for their products and customers. Expect to invest in automation, rather than digitisation to improve internal efficiency.	Position: LOW The machines on the shop floor are all operating independently, if automated at all.

Table 2 presents some phrases from interviewees to support the position of the cases in the research on the axes of intention and adoption. For reasons of clarity, some of these phrases are combinations of original quotes or paraphrases thereof.

Table 2 - Supporting phrases from interviews for position in the intention-adoption matrix

	Intention	Adoption
Case A "Sheet metal"	"We would like to have all our machines connected and the process data available. That is why we recently bought a new ERP-system, which we gradually expand."	"We've been working on a web portal for the last ten years. I guess you could call it somewhat static. No-one seems to be interested. Bottom line is that we're still sending Excel-sheets back and forth." "There are still a lot of practical issues to be resolved before we could connect with customers."
Case B "Packaging"	"We simply don't want our capacity to be visible to customers and competitors." "We focus on improving the internal processes first."	"We have a new ERP system and we want to attach more processes to this system, but that takes time. We take it step by step."
Case C "Rail road"	"Of course we have been thinking about applying the way 247 Tailor Steel works, but we think it is impossible." "We see the potential, as we're now dealing with a lot of lost time."	"Programming of the machines is digitized, but status information is still recorded in Excel, as is the planning information." "Even communication with a customer for whom we manage their inventory is done using Excel-sheets. Unfortunately."
Case D "Web based"	"We just want to have everything digitised. That is a process which we started 15 years ago and it still drives us."	"We started our web portal around 2008 and we are now at the point that customers can upload their files, get a quotation and, once they confirm the order, it is automatically transferred to the shop floor. The only human intervention is grouping and scheduling the orders. The next step is to automate this as well."
Case E "Steel processing"	"For us, this is not an interesting direction. We focus more on the delivery of technology to our customers."	"Automation of our process is not really possible, let alone digitising it."
Case F "Copper separator"	"For the most operations, customers expect us to work in a traditional way. For our products, a digital process is not an option."	"Our machines are all operating independently and are programmed at the machine itself."

Two main questions arise from the intention-adoption matrix, as a refinement of the initial research question. The first question is: what is influencing the intention of the dormant, indicated by the blue arrow in the matrix. The second question is: what is influencing the actual adoption once the intention is there, turning a captive into an adopter? This question is shown in the matrix as a red arrow.

Before answering these questions by analysing the data in respect of the drivers and barriers for the adoption of smart manufacturing, a closer look is taken at the candidates to find a possible explanation for their different orientation in the matrix. In other words: what distinguishes the categories from each other, apart from the previously defined influential variables, namely their current level of automation, the expected benefits, the level of collaboration and their future vision?

A closer look at the candidates reveals that their position in the supply chain differs, as can be retrieved from the previously provided case description and as is shown in figure 6.

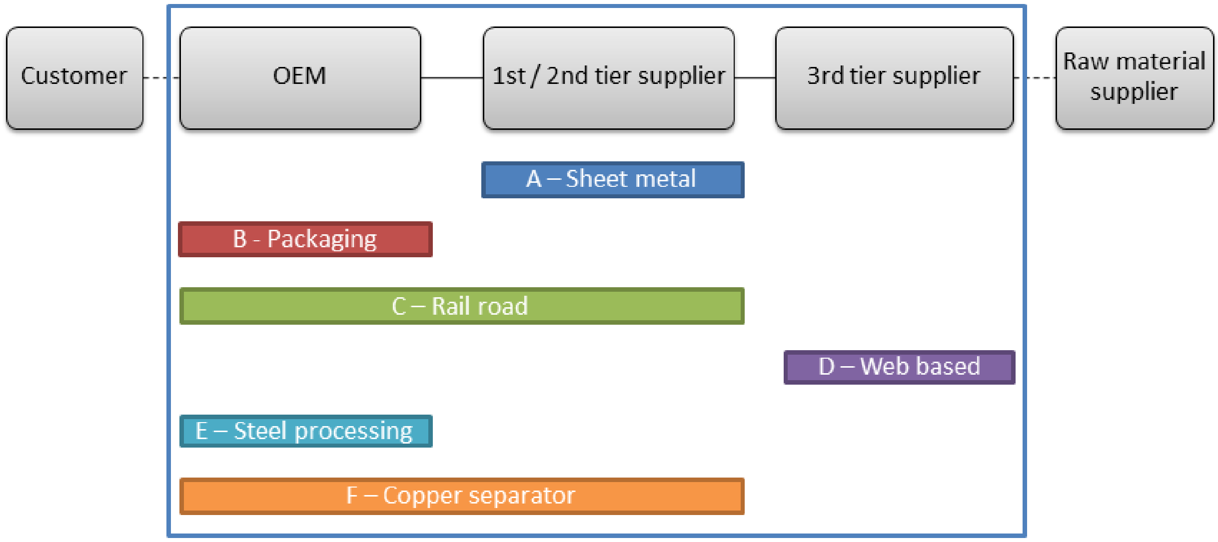

Figure 6 - Case position in the supply chain

Cases from the dormant category are all serving as an OEM, whereas the captives are supplying OEMs. The adopter category is found closest to the raw material suppliers. Cases Rail road and Copper separator are both serving as an OEM and as a supplier, but have a different position in the intention-adoption matrix. This may be explained by the fact that case C started as an OEM, but has added fine metal work to its portfolio some years ago, thus moving downward in the value chain, while Copper separator originally was a supplier of fine metal work (and still is), but recently started serving as an OEM by adding the copper separator to their portfolio, thus moving upward in the value chain. Based on the different direction these manufacturers have taken deliberately, case Rail road could primarily be classified as a supplier and case Copper separator primarily as an OEM. This leaves the proposition standing that the position in the supply chain is related to the intention and adoption of smart manufacturing. This leads to the following proposition:

Proposition D2: The intention to apply smart manufacturing is increasing as manufacturers are moving further away from the final customer in the supply chain.

The position in the supply chain hence seems to influence both the intention and the adoption of smart manufacturing. However, the position in the supply chain is not an explanation in itself, but rather a starting point from where the manufacturers in the research may be analysed. This will be done by first analysing the drivers for the intention to adopt smart manufacturing, followed by a closer look at the barriers SMEs encounter or expect to encounter, thus holding them back from the actual adoption of smart manufacturing.

5.4. Drivers for smart manufacturing intention

In this section, the data from the interviews will be analysed in respect of the drivers for the intention to adopt smart manufacturing. As has been argued before, the intention is a necessary condition for the actual adoption. It is therefore sufficient to research the drivers for the intention only, rather than for the actual adoption. The research has primarily been aimed at the earlier mentioned four drivers for the intention to apply smart manufacturing. These are the current level of automation, the expected benefits, collaboration and future vision, as has been explained in the previous chapter. These factors have been used as a guidance in writing the following paragraphs for ease of reading. Finally, the analysis of the barriers to actual adoption in the next section will reveal what is holding back the captives to move toward the adopter category.

5.4.1. Current level of automation

The current level of automation seems to be of relevance to the adoption of smart manufacturing. Case Web based, the only case in the adopter category, already had their processes automated as a result of a strong orientation toward automation. As the DMS put it: "We started automating our processes some fifteen years ago. We have been taking this further since by adding ICT wherever possible. Everything that can go through the portal will have to go through the portal." Furthermore, the level of automation also seems to influence the intention to adopt, as the cases in the captive category in general have applied more automation to their processes than cases in the dormant category. As both the DMS of Packaging and the general manger of Steel processing claim, this is due to the nature of the processes. For OEMs, the production process mainly consists of manual assembly activities, which can hardly be automated. Copper separator adds to this the financial limitations of a small manufacturer as a reason not to automate its processes further. "I would like to automate the production of simple, standard products, but I do not want to depend on a bank too heavily, so I will have to save some money first", is what the owner/director disclosed.

Scoring the cases on their respective level of automation would be arbitrary, as there are many ways in which manufacturers can automate their processes. However, based on the cases involved in the research, the general level of automation increases as firms are positioned further away from the final customer, regardless of the reasons to apply automation or not, increasingly enabling the intention and adoption of smart manufacturing. This makes sense, as smart manufacturing is the convergence of OT and IT, as has been argued before. Higher developed OT facilitates this integration, allowing smart manufacturing to be adopted.

Proposition D2 could hence be supplemented with proposition D2a as an explication of the relationship between the intention to apply smart manufacturing and the position in the supply chain:

Proposition D2a: The intention to apply smart manufacturing is increasing as the current level of automation increases.

5.4.2. Expected benefits

The expected benefits from the application of smart manufacturing are summarized in table 3, followed by an explanation of how these benefits are thought by the interviewees to stem from smart manufacturing. Note that the interview questions leading to these expected benefits were aimed at the expected benefits of automation in general and at the expected benefits of smart manufacturing in particular. Smart manufacturing is thus considered to be a specific application of automation, as has been argued in the previous chapter. In case the interviewees had no intention to apply smart manufacturing, their answers were more aimed at general benefits of automation. The low awareness of possible benefits of smart manufacturing may in itself be a possible explanation for their low level of intention. This will be elaborated further on. Table 3 presents the expected benefits as indicated by the interviewees. The benefits names by the respective interviewees are marked with the symbol +. Some of the benefits have been explicitly named a disadvantage by some interviewees, in which case the benefit is marked with the symbol -. This is only done if a factor has been named a benefit by at least one interviewee. The benefits have been grouped according to the goals which were expected to be named as the proposed benefits of smart manufacturing, as was explained in the previous chapter. These goals are growth, improved efficiency and increased effectiveness. An explanation of the expected benefits will be provided subsequently.

Table 3 - Expected benefits of smart manufacturing

		Case A	Case B	Case C	Case D	Case E	Case F
Growth	Increased customer base				+		
	Closer relations with customers	+	-	+	+	-	-
	Increased transparency	+					
Efficiency	Reduced costs	+	+	+	+	+	+
	Improved process control	+	+			+	
Effectiveness	Better predictability	+	+	+	+	+	
	Improved quality	+					+
	Shorter lead times		+		+		+
	Higher flexibility	-	+	+	+		+

Growth

Only case Web based named an increased customer base as a direct result of the application of smart manufacturing. “Our portal makes the world a small place” is what their DMS claims. “Growth is currently only limited to costs of transportation associated with customer location, so that is what we’re considering the next step.” Web based also mentions closer relationships with customers, just as Sheet metal and Rail road do. Having access to a customer’s data increases the dependency of that customer, making it more likely that more orders will be requested. On the other hand, the cases from the dormant category expect the relationship with customers to weaken as a result of smart manufacturing. They emphasise the important role customers have in the process of designing a product, which cannot be digitized in their opinion. The owner/director of Copper separator claims that “our customers are different than the ones that may be served digitally. They simply want something other than the standard products”, as is the tone at Steel processing and Packaging. Customers of OEMs demand personal contact which cannot be replaced by digital communication is what they claim.

Transparency is what case Sheet metal mentions as a factor that positively could increase turnover, as increased transparency opens up new markets, such as aerospace or medical devices. In these sectors, a higher level of transparency is required and smart manufacturing could increase this transparency by enabling customers to have real time insight in the processes.

Improved efficiency

All interviewees agree on cost reduction as a primary benefit from the application of smart manufacturing. This cost reduction is expected to be realized by a reduction of information and of errors which occur at the information transfer points, such as status information being transferred to the ERP system automatically instead of using spreadsheets as a medium. Another way cost reduction is thought to stem from smart manufacturing is the freedom it offers to batch orders more efficiently, thus reducing machine idle time and waste material. This is further emphasized by some of the interviewees mentioning improved process control as a possible benefit. Improved process control mainly stems from real time insight in performance of machines and stock levels, as this enables operators to adapt to changing parameters thus reducing possible waste and idle time.

The efficiency interviewees refer to, is limited to internal efficiency, that is to say, the efficiency of the market is not being mentioned, except by Web based and Sheet metal. They foresee that the market will become more efficient as the availability of data, particularly related to capacity, will facilitate the possibility to compare prices among competitors. Although this also poses a threat, since the focus is likely to shift from added value to price, this is just as well being considered a benefit, as it increases the competitiveness of Dutch industry as a whole. As mentioned, this is only recognized by Web based and Sheet metal, the cases with the highest level of intention and adoption.

Increased effectiveness

In respect of effectiveness, shorter lead times and an increase in flexibility are mentioned the most, followed by improved product quality. The latter is mainly related to the previously mentioned improved process control as smart manufacturing enables process operators to detect product deficiencies as early as possible. Shorter lead times are a result of the reduction of time-consuming information transfers within the manufacturing firm as well as between the firm and suppliers and customers outside. Higher flexibility is to be read as an increased reaction speed, enabling a quicker response to changes in customer demand. The proposed benefits related to effectiveness are mentioned by all categories alike. No differences were revealed that were related to the position in the supply chain.

Remarkably, the benefits related to growth are only mentioned by cases from the captive and adopter categories, while the benefits related to efficiency and effectiveness are mentioned by all categories alike. Furthermore, the cases with the highest level of intention and adoption are aware of efficiency benefits across the boundaries of the firm. This implies that, although in all cases the expected benefits influence the intention to adopt smart manufacturing, the awareness firms have of the possible impact of smart manufacturing on both the firm itself and on industry as a whole is primarily influencing the intention. This leads to the following proposition:

Proposition D3: The intention to apply smart manufacturing is increasing as the awareness of possible benefits gained from smart manufacturing increases.

5.4.3. Collaboration

Analysis of the interview data regarding collaboration and the role collaboration plays in the intention to adopt smart manufacturing revealed that the intensity of collaboration and the diversity of collaborating partners is likely to influence the intention to adopt smart manufacturing by increasing the awareness of possible benefits, rather than directly influencing this intention. Table 4 shows for each of the cases their respective level of collaboration, rated high, medium and low, and the diversity thereof by specifying the types of collaboration the cases are involved in. The quotes in the right-hand column support the information in the preceding columns. Again, some of these quotes have been put together using original quotes and paraphrases, thus as closely as possible resembling the true meaning of the interviewees.

Table 4 - Level and diversity of collaboration

	Level of collaboration	Type of collaboration	Quotes
Case A "Sheet metal"	Medium	Competitors Customers	"We invited our competitors over to show them what we are doing." "We developed a process together with our customers."
Case B "Packaging"	Low	Customers	"We do not collaborate with competitors. I don't believe we can benefit from that."
Case C "Rail road"	Low	Customers	"I know there are initiatives for collaboration, but we are not participating. This may come across as a bit presumptuous, but we have learned the hard way."
Case D "Web based"	High	Competitors Customers Universities Research organizations (TNO) Smart Industry field lab	"We are looking for companies with enough synergy to share our knowledge and expertise with." "The solution we developed must be available to competitors as this increases the strength of the market." "We may harvest the first fruits, but it has to be shared."
Case E "Steel processing"	Low	Customers	"Competitors? We don't see them. We rather focus on our internal processes." "We know about the field labs, but each situation is different. So we stay away from it."
Case F "Copper separator"	Low	Customers	"Collaboration in our industry is difficult, because there are too many cowboys."

The classification of the cases in levels of collaboration follows this logic: collaboration with customers is done by all cases, mostly in designing products and in some cases, like in Sheet metal, in designing processes as well. Collaboration with customers is regarded as necessary for doing business and is thus regarded as not relevant for the submitted research. That is why cases that only manifest collaboration with customers have been classified low on the aspect of collaboration. Most cases fall into this category. A medium classification is assigned if a case shows to collaborate with at least one other type of partner, such as competitors in the case of Sheet metal. Collaboration is thought to be high if a case demonstrates collaboration with multiple parties. Only case Web based could be classified high in respect of collaboration. Since there are only two cases which have shown to collaborate with partners other than customers, the available data about what firms expect from collaboration and how collaboration contributes to the intention to adopt smart manufacturing is meagre. Web based, ranked highest in collaboration, mainly seems to collaborate to share their knowledge and expertise regarding smart manufacturing, rather than gathering information form others. Says their DMS: “We are looking for companies with enough synergy to share our knowledge and expertise with” and “the solution we developed must be available to competitors as this increases the strength of the market.” In fact, collaboration can increase awareness within the market as the DMS of Web base says: “For us, it (smart industry platform [added GN]) doesn’t change anything, because we’ve been doing this for years. But for companies thinking there is no other way than the traditional way, this increases their awareness.” Web based built their system on their own, with little to no involvement of others, except for a software partner. This implies that collaboration is not directly influencing the intention to apply smart manufacturing, like awareness does. However, closer collaboration with competitors and other parties increases awareness of the possible benefits, which in turn influence the intention to adopt smart manufacturing. This leads to the following proposition, closely related to proposition 3:

Proposition D3a: Awareness of the possible benefits gained from smart manufacturing is increasing as the level of collaboration increases.

5.4.4. Future vision

Future vision is considered to be another variable influencing the intention to adopt smart manufacturing, as has been argued in the previous chapter. In order to determine how a future vision influences the intention, the data from the interviews has been analysed in respect of the vision interviewees hold on the future regarding the development toward a more connected industry. This vision is reflected in the interviewee’s quotes regarding the vision they hold on the future as presented in table 5.

Table 5 - Quotes on future vision

Case A **“Sheet metal”**	“Frankly, we don’t see it that much.” “It is basically nothing but connecting what we already have. We already did that, but we’re simply taking this further.” “Smart industry is not a revolution, it is rather evolution.”
Case B **“Packaging”**	“They suggest that there is an organisation that will arrange everything for you to achieve shorter lead times, lower costs and a better competitive position. That I don’t believe.” “Then you will lose your own identity and no entrepreneur would want that. At least I don’t.”
Case C **“Rail road”**	“Digitising of the production is the farthest away from now, compared to the other aims of Smart Industry.” “Our customers will demand connectivity in the future. It’s just a matter of time.”
Case D **“Web based”**	“You should not try to think about what is available to you in 15 years. You need to have a vision on the direction you are taking.” “We want everything digital, that is in the DNA of the directors and this conviction trickles to the shop floor gradually.” “I believe a lot is going to happen regarding collaboration in the value chain in the next couple of years. People will play a less significant role.”
Case E **“Steel processing”**	“One thing is sure; digitisation is coming. It actually is already there. But that is about the only thing we know. We have no clue whether we are heading the right direction.”

	"I think the world believes we are further than we actually are. Not just us, but the whole world thinks Smart Industry is further than it is. Like with every revolution, or evolution, it takes time. The speed may be increasing, but it still takes time."
Case F **"Copper separator"**	"I like the way we are working now. To me, automation is not a magic formula." "I think in the future we need to specialise more. You can't keep doing everything. Digitisation will play a role in that process"

Despite the clear vision some of the interviewees have on the future, this does not seem to influence the intention to adopt smart manufacturing. This is surprising, since one would expect the vision on the future to be of importance for the decision to consider smart manufacturing as a strategic option. However, the available data from the interviews does not reveal any suggestions as to how future vision affects the intention to adopt smart manufacturing. All interviewees agree on the inevitability of industrial digitisation, yet only Web based managed to turn this into practice already. The vision on the future is the same for cases from the dormant and captive categories alike.

The only difference that can be found is that, unlike all the other cases, Web based moved beyond the uncertainty by deliberately choosing to automate and digitise whatever is possible. As their DMS put it: "10 years ago we would've never thought to have the possibilities we currently have. You should not try to think about what is available to you in 15 years. You need to have a vision on the direction you are taking." This vision in the case of Web based is clear: automate through the portal whatever can be. Rather than influencing the intention, having a clear automation strategy directly influences the adoption of smart manufacturing itself. This leads to the following proposition:

Proposition D4: The adoption of smart manufacturing is increasing as companies have a clearer automation strategy.

5.4.5. Passion for technology

A factor that has previously been overlooked in theory about the adoption of process innovation and IT in manufacturing, but which emerged from half of the interviews, is the passion for technology in decision-makers as a driver for technical process innovations, such as smart manufacturing. The DMS of Packaging, for instance, showed this by saying: "Basically, we are a technical company. We are a bit crazy about technology. We simply have too. And automation is something we very much like. That is how we started machining back in time." As did the DMS of Rail road, claiming "Of course costs are important when deciding about automation. But also the technical challenge. We like to do it. Passion for technology." The DMS of Web based, finally, put it like this: "You need to have a close affinity with what you are doing. I personally am not too much interested in machining and that is probably why we never moved in that direction." Since passion for technology was not a previously defined variable influencing the intention to adopt smart manufacturing, this factor has not been asked for in particular. The unrequested upbringing of this factor at least suggests that it does play a role in the decision-making. Since this has been brought up by manufacturers from the dormant, captive and adopter categories alike, no proposition can be generated related to the specific intention to adopt smart manufacturing, but the influence it has may be investigated in future research.

5.4.6. Smart Industry platform

The Smart Industry platform is aiming at increasing awareness for the inevitability and possibilities of smart manufacturing within Dutch industry. Since this is closely related to the previously mentioned awareness of the benefits of smart manufacturing as influencing the intention to adopt it, it seems relevant to take a closer look at how the Smart Industry platform is perceived by the SMEs involved in the research.

To put it mildly, SMEs are not over-enthusiastic about the role of the Smart Industry platform. To support this statement, table 6 presents some quotes of interviewees regarding Smart Industry.

Table 6 - Quotes regarding Smart Industry

Case A **"Sheet metal"**	"Well, isn't that what we call old wine in new bottles?" "The story sounds great, but practice is different."
Case B **"Packaging"**	"They suggest that there is an organisation that will arrange everything for you to achieve shorter lead times, lower costs and a better competitive position. That I don't believe."
Case C **"Rail road"**	"I don't think they are that important. They should take the lead, but these kinds of initiatives don't appeal to me personally."
Case D **"Web based"**	"They have done quite a good job in increasing awareness, but there is still too much bullshitting going on." "For us, it doesn't change that much, as we've been doing it like this for years now. But other companies discover through Smart Industry what it could offer them. Awareness is the main yield from Smart industry."
Case E **"Steel processing"**	"We prefer doing it ourselves, because we know the agenda of FME. It is all too specific for each case." "It is good that the field labs are there to promote things, to make it visible. But I don't believe in concrete solutions from it." "On the other hand they trigger us to take steps to make better use of our data. That is what they achieved."
Case F **"Copper separator"**	"I have no idea what Smart Industry is about, although I can imagine several things." "Naturally, theory always sounds great."

From these quotes it becomes clear that, in the perception of the interviewees, Smart Industry mainly contributes to the adoption of smart manufacturing by increasing awareness. The role of the field labs is considered low. Interestingly enough, the role Smart Industry is trying to play, namely stimulating collaboration in the field labs and increasing awareness in sketching a future vision, supports the previously posed propositions 3, 3a and 4. After all, these propositions claim that awareness increases the intention to adopt smart manufacturing, that awareness in turn is influenced by collaboration and that having a clear automation strategy, based on a future vision, increases the likelihood of applying smart manufacturing. Smart Industry should thus not be regarded as an independent influencing factor, but rather as working on collaboration and future vision, among other stimuli. The rather negative sentiment of interviewees regarding Smart Industry may be studied in future research.

5.5. Barriers to smart manufacturing adoption

After having analysed the factors that influence the intention to adopt smart manufacturing and the adoption itself, this section will provide a closer look at the barriers to the adoption of smart manufacturing, starting with listing the barriers as encountered or expected to encounter by the interviewees. The barriers mentioned are listed in table 7. If a barrier was mentioned at least once, the respective barrier was marked with the symbol +. If a barrier was named more than once or if the respective barrier was brought up without asking for it, the symbol ++ has been used. By summing the + symbols, the barriers were ranked according to the number of times they were mentioned and their relative importance. The perceived barriers will be elaborated subsequently.

Table 7 - Perceived barriers to smart manufacturing adoption

	Case A	Case B	Case C	Case D	Case E	Case F	Sum
Technology not ready	++	+	++	++	++	++	11
Lack of trust	++	+	+	++	++	+	9
Lack of awareness in industry	+		++	+	+	+	6
Lack of standards	++	+		+	+		5

5.5.1. Technology not ready

The technological barrier is considered the most important barrier, as all interviewees point this out as a barrier, regardless of the level of intention and/or adoption. Smart manufacturing technology, despite the general optimistic tone at conferences, trade fairs and alike, is not ready for complex products. That is to say, according to the interviewees.

Table 8 - Quotes on smart manufacturing technology

Case A **"Sheet metal"**	"At this moment it is simply impossible to buy a software suite in which all of our tools fit." "For flat sheet metal work it all is pretty simple, but as soon as the product becomes more complex, or if you want to assemble it, the number of parameters is just too high to automate it completely."
Case B **"Packaging"**	"People often think it is really easy, but in practice it is always more difficult. Welding stainless steel for instance, requires quite some experience which cannot be replaced by automation."
Case C **"Rail road"**	"We think it is still impossible for us. Our process is dealing with a lot more variables than taking a piece of sheet metal and laser cut it in 2D." "Calculating a laser cut is easy. There are no tools in a laser cutter, while for an average product in our shop some 20 different tools are required. Calculating in our case is basically a guesstimate." "Maybe in five years technology will be able to assist us in calculating more complex products. Today, it is simply impossible. The products are too complex."
Case D **"Web based"**	"We deliberately stay away from more complex processes, such as welding, as these complex processes can hardly be automated through our portal." "We would like to apply the technology we are using for our machines to robots, but that is not that easy. Programming a robot for an average product takes between one and three hours. That has to be improved." "The difficulty is mainly in the diversity of the design with so many variables that it can hardly be automated."
Case E **"Steel processing"**	"The type of operations determine the applicability of smart manufacturing. A drilling process is quite different from reading engine data." "Our assembly process is fully manual, as these processes are too complex to automate." "Compared to 247 Tailor Steel; what they are making is not that exciting. It is cut sheet metal. We build machines with electrical and mechanical parts and software."
Case F **"Copper separator"**	"For our product, that is not an option. Our customers want something different and the flexibility that is required cannot come from automation."

The difficulties regarding smart manufacturing technology mainly seem to stem from the complexity of products and processes, according to the quotes presented in table 8. While the current level of technology is sufficient for less complex products and processes handling only a few parameters, technology is not developed far enough to offer the same options for more complex products. Given the number of times this barrier was mentioned and the logic explanation for it being a barrier, technology not being ready is a serious threat to the actual adoption of smart manufacturing. This leads to the following proposition regarding barriers to the adoption of smart manufacturing:

Proposition B1: The current level of smart manufacturing technologies is limiting the adoption of smart manufacturing.

5.5.2. Lack of trust

Lack of trust within Dutch metal industry also was mentioned by all of the interviewees. As becomes clear from the quotes about the role of trust, presented in table 9, lack of trust is holding back captives from moving toward the adopter category and dormant from moving toward the captive category.

Table 9 - Quotes on lack of trust

Case A "Sheet metal"	"There are not many companies willing to share their data." "Some process information I am not even allowed to share. That is for protection of our customers of course." "We too are reluctant to share our data, as people will make misuse of it." "Opening our systems is unknown and a larger risk. There are no standards, no governance."
Case B "Packaging"	"There is always the fear that one competitor will run away with the other's property."
Case C "Rail road"	"Our customers are protecting their data. They don't want us to access their stock levels directly. They are not ready yet." "The real problem is the mind-set. People must be open to the idea, but they are not yet." "We are not taking the lead in these developments. I want to see first how it all develops. I don't want to take all the risks."
Case D "Web based"	"It is all a matter of trust. We already know for a long time that we know more about each other than we think. But the forced attitude of not wanting to be open to others is only holding back progression."
Case E "Steel processing"	"I know about these portals through which you can share all your information with suppliers. We stay away from that. Before you know it, all the information is on the street."
Case F "Copper separator"	"It would indeed be nice if we could trust each other, which is a real problem in metal industry. We are all farmers, but there are too many cowboys around."

Even Web based acknowledges that trust plays an important role in the further adoption of smart manufacturing, albeit that they primarily notice this lack of trust in other companies, whereas the other interviewees frankly admit that they have insufficient trust in smart manufacturing as a promising development. Uncertainty about outcomes of smart manufacturing might contribute to this, but this could not be retrieved from the data directly. Some companies simply want to protect their property and demand some form of governance before they may consider disclose their data, while others blame customers for not letting them share data about processes. Either way, lack of trust hampers the adoption of smart manufacturing. The conservative nature of Dutch metal industry, as mentioned by some of the interviewees, may contribute to this. This should be considered when generalising the results of the submitted research. Regardless of the reasons for the lack of trust, the conclusion can be drawn that it without a doubt influences the adoption of smart manufacturing. This is reflected in the following proposition:

Proposition B2: Lack of trust is limiting the adoption of smart manufacturing.

5.5.1. Lack of awareness in industry

Five out of the six interviewees mention the low level of awareness with other parties as limiting the adoption of smart manufacturing. This low level of awareness mainly stems from the conservative nature of metal industry, according to the interviewees. In table 10 some quotes can be found to support this.

Table 10 - Quotes on lack of awareness

Case A **"Sheet metal"**	"You can share information as much as you like, but no one is interested." "Externally there also are benefits from smart manufacturing, but is that what is asked for? Or is cost price the only relevant factor?"
Case B **"Packaging"**	-
Case C **"Rail road"**	"The real problem is the mind-set. People must be open to the idea, but they are not yet." "Metal industry is not a very progressive industry, which may also not be very helpful."
Case D **"Web based"**	"Awareness is slowly increasing in the sector." "Smart Industry mainly helps in creating awareness, which is what is needed." "Being conservative, a typical characteristic of metal industry, I think is the main limitation."
Case E **"Steel processing"**	"Our market is very conservative and awareness is minimal. We are not that far ourselves even."
Case F **"Copper separator"**	"Is our sector ready for this? I doubt it."

As may become clear from these quotes, lack of awareness indeed seems to limit the adoption of smart manufacturing. This makes sense, as awareness of the benefits of smart manufacturing has been named a primary driver for the intention to adopt smart manufacturing. Lack of awareness thus limits the intention rather than the adoption itself. There is no use in claiming that lack of awareness is a barrier to adoption if that same awareness is a driver for the intention. Intention is after all a necessary condition for the adoption of smart manufacturing. Hence no proposition has been formulated regarding the lack of awareness.

5.5.2. Lack of standards

A lack of standards is brought up by four out of the six cases involved. Table 11 presents interviewee's quotes to support the idea that a lack of standards is considered to be of relevance to the adoption of smart manufacturing.

Table 11 - Quotes on lack of standards

Case A **"Sheet metal"**	"It all comes down to open standards. They are not there yet. To connect using all these different standards is way too expensive." "Being a small company, we have machines from different manufacturers, which all have their own standards. It is not like in automotive where a complete line from one manufacturer is installed." "If everything is connected, how are you going to control quality? There are no standards regarding quality." "No standards, no governance. It is going to take a long time."

Case B "Packaging"	"Not everyone delivers the same quality. How are you going to measure that?"
Case C "Rail road"	-
Case D "Web based"	"Connecting different ERP systems is a challenge."
Case E "Steel processing"	"We can connect our machines to machines from another manufacturer. But then we're using our own software otherwise it won't work. There are no real standards."
Case F "Copper separator"	-

The standards interviewees refer to, are twofold. Firstly, they mention a lack of standards in respect of the connectivity of machines and systems, so called interoperability. According to the interviewees, the dearth of standards leads to high costs because interfaces will have to be built which have to be adapted every time a new machine or system is to be connected. This makes connecting customers only interesting if enough turnover is being realised through this customer, whereas smart manufacturing holds the promise of expanding the customer base quite easily. The lack of standards is prohibiting the latter. The diversity in machines in Dutch metal industry also inhibits smooth connectivity between machines, as each manufacturer has its own protocol.

The second standard interviewees refer to is a lack of quality standards. As some of them argue, if capacity is known to customers, price is more likely to be the discriminant factor, but there has to be agreement on basic quality levels, which is not the case yet. This makes comparison between competitors impossible, leaving the eventual investments in machines and systems related to smart manufacturing useless.

The development of shared standards, whether or not being open, could thus indeed foster the adoption of smart manufacturing. Argued from the other side, this leads to the following proposition:

Proposition B3: Lack of standards is limiting the adoption of smart manufacturing.

5.6. Conclusion

In the preceding paragraphs the drivers and barriers to the intention and adoption of smart manufacturing respectively have been analysed, resulting in a number of propositions. These propositions, in order of appearance, are:

Proposition D1: The intention to apply smart manufacturing is a necessary condition for the adoption thereof.

Proposition D2: The intention to apply smart manufacturing is increasing as manufacturers are moving further away from the final customer in the supply chain.

Proposition D2a: The intention to apply smart manufacturing is increasing as the current level of automation increases.

Proposition D3: The intention to apply smart manufacturing is increasing as the awareness of possible benefits gained from smart manufacturing increases.

Proposition D3a: Awareness of the possible benefits gained from smart manufacturing is increasing as the level of collaboration increases.

Proposition D4: The adoption of smart manufacturing is increasing as companies have a clearer automation strategy.

Proposition B1: The current level of smart manufacturing technologies is limiting the adoption of smart manufacturing.

Proposition B2: Lack of trust is limiting the adoption of smart manufacturing.

Proposition B3: Lack of standards is limiting the adoption of smart manufacturing.

These propositions have been incorporated in the conceptual framework which has been presented in chapter 3. This leads to a revision of this conceptual framework, as is shown in figure 7.

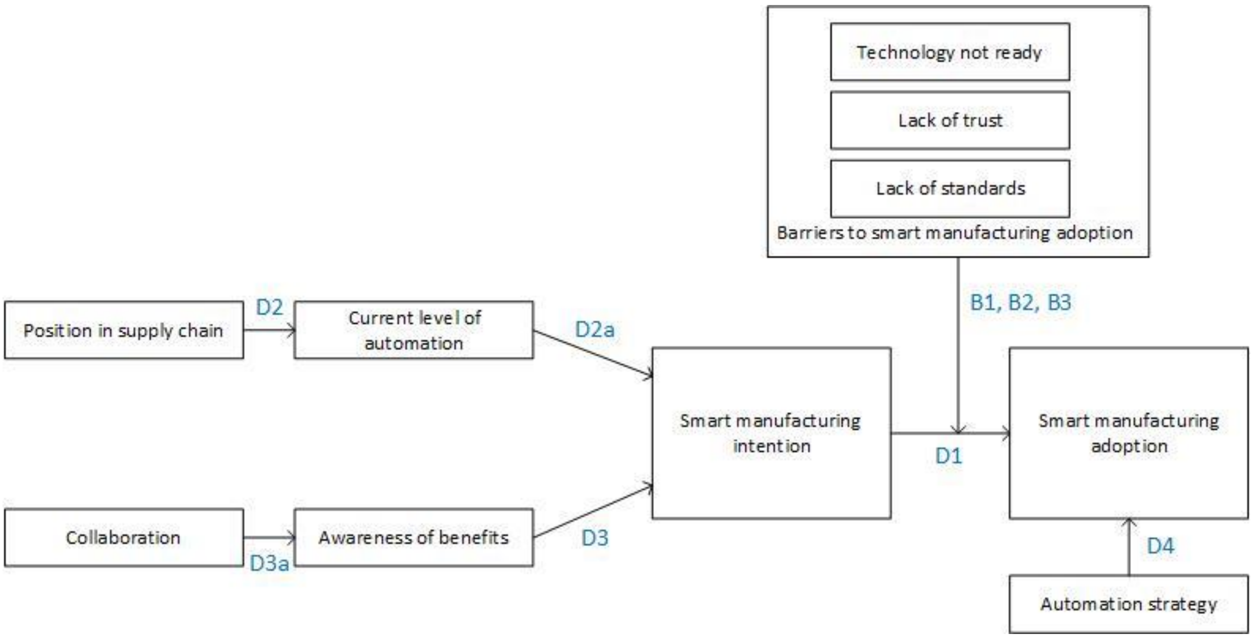

Figure 7 - Conceptual framework revised

The labels in the conceptual framework represent the respective propositions generated in this chapter. It has become clear that the intention to adopt smart manufacturing always precedes the actual adoption, as is indicated by proposition D1. The intention is directly influenced by two factors, namely the current level of automation in the production process (D2a) and the awareness of possible benefits gained from the adoption of smart manufacturing (D3). In turn, the current level of automation is determined by the position of the manufacturer in the supply chain (D2). As the complexity of products and processes increases, the level of automation decreases. This explains the low level of intention to adopt smart manufacturing downstream the supply chain. The awareness of possible benefits is influenced by the level of collaboration, both in diversity and intensity (D3a). As manufacturers collaborate more with competitors and organisations outside the supply chain, the awareness of the possible benefits increases, hence raising the likelihood of an increased intention to adopt smart manufacturing.

Having a clear automation strategy has shown to influence the actual adoption, rather than the intention (D4). Once a manufacturer has the intention to adopt smart manufacturing, the presence of a clear vision on the role of automation in the production process increases the likelihood of successful adoption of smart manufacturing.

Furthermore, once the intention to adopt smart manufacturing exists, there are some barriers limiting the actual adoption, namely technology not being ready (B1), a lack of trust (B2) and a lack of awareness of smart manufacturing possibilities in the manufacturing industry (B3). The current development level of smart manufacturing technologies is specifically holding back manufacturers from the captive category, as the complexity of their products demands more sophisticated software solutions to reduce the time that is required to calculate products and to robotise the production processes. The lack of trust and the lack of awareness are limiting all categories alike. The lack of trust results in a passive attitude toward smart manufacturing, as manufacturers first want to have clarity about the possible effects on the performance of the firm. The lack of awareness is primarily limiting manufacturers because they have to convince customers and suppliers that smart manufacturing indeed could lead to improving efficiency, effectivity and growth.

This conceptual framework provides a better insight in the way SMEs in Dutch manufacturing decide on the adoption of smart manufacturing by pointing out the primary drivers to the intention and adoption of smart manufacturing and the main barriers manufacturers encounter once they intend to adopt smart manufacturing and hence provides an answer to the main question in the submitted research.

In the next chapter, the implications of the results presented in this chapter will be elaborated.

6. Discussion

In this chapter the implications of the previously described results for academics and practitioners will be described, followed by a description of the limitations of the submitted research and some suggestions for further research.

6.1. Implications for practice

Since the submitted research is aimed at SMEs within Dutch manufacturing industry, the implications for them will be described first. First and for all, this research offers SMEs the opportunity to assess themselves regarding intention and adoption of smart manufacturing. Given the inevitability of the digital future, SMEs should consider whether smart manufacturing might be of relevance to them. The identified drivers for the intention, level of automation and awareness of the benefits could guide them in this process. This research calls on SMEs to invest in diverse and extensive collaboration to become aware of the possible benefits of smart manufacturing. Furthermore, especially manufacturers positioned close to the end-customer in the supply chain, should consider whether processes could be (further) automated, as a higher level of automation increases the chances that smart manufacturing may be beneficial to a manufacturer.

For the Smart Industry platform, and for consultants alike, the submitted research offers valuable insight into the way SMEs decide on the adoption of smart industry. The research confirms that Smart Industry is aiming at the right spot by stimulating collaboration and by focusing on the inevitability of a digital manufacturing industry. However, particularly regarding the inevitability, Smart Industry should rather prepare SMEs for a digital future by stimulating the development of a clear automation strategy as this has shown to be of important influence in the actual process of adopting smart manufacturing. The future vision Smart Industry is trying to get across, should at least be accompanied by advice on how to develop such an automation strategy.

Smart Industry should further focus on a faster development of smart manufacturing technologies, especially aimed at companies further upstream in the value chain, as the research reveals that it is increasingly becoming difficult to automate and subsequently digitise production when moving further away from the final customer. This may foster both the intention (by enabling assembly to be automated) and the actual adoption (by reducing information transfer problems). The creation of standards, both in information sharing and in quality, may speed up the adoption even further.

In taking this route, Smart Industry might be able to get rid of the rather negative sentiment toward the platform.

6.2. Implications for theory

The conceptual framework presented in the previous chapter is a further refinement of the model by Frishammar et. al. and of Nguyen et. al. and provides specific patterns in the adoption of smart manufacturing as a means of IT process optimisation. The framework explains how the adoption of smart manufacturing can be fostered and provides an explanation for the reluctance to adopt smart manufacturing by SMEs in Dutch manufacturing industry.

The research confirms the difference Frishammar et. al. identified between potential and realised process innovation capabilities and the complementary roles they have by distinguishing intention and adoption and proposing that intention is a necessary condition for the successful adoption of smart manufacturing as a means of process innovation. A major difference between the model proposed by Frishammar et. al. and the submitted research is the role of strategy. Frishammar et. al. propose that strategic alignment influences the potential process innovation capability. This research shows that strategy, in particular automation strategy, mainly affects the actual adoption, or realised innovation capabilities as Frishammar et. al. call it, rather than the intention.

Nguyen et. al. claim that, given the risk adverse nature of SMEs, they should have a clear understanding of why they adopt IT in the first place, rather than improving their processes just for the desire to change. While this may be true, the submitted research revealed that this understanding starts with awareness of the benefits. This is in particular true for smart manufacturing, as the benefits are considered unclear. As a result, growth is not considered a possible benefit of smart manufacturing, except by firms which already have adopted it. This conflicts with the view of Nguyen et. al. claiming that customers are the main driving force behind IT adoption. As customers are unaware of the possible benefits of smart manufacturing, they are unable to drive IT adoption in the specific case of smart manufacturing. The same goes for growth being considered the second most important driver for IT adoption. The role awareness plays in the decision-making process within SMEs which has been identified in the submitted research thus complements the model of Nguyen et. al.

What the submitted research also shows, is that the distinction between the drivers to adoption on one hand and the adoption environment on the other hand is not as strict as Nguyen et. al. propose. In fact, the adoption environment also plays a significant role in the decision to adopt smart manufacturing, mainly through collaboration. Rather than only influencing the level of success in adopting smart manufacturing, collaboration also influences the intention to adopt it, through an increase of awareness of the possible benefits.

Both Frishammar et. al. and Nguyen et. al. did not mention the position in the supply chain as influencing the decision to start process innovation, although Nguyen et. al. did so indirectly by identifying the maturity of a firm as a factor. The submitted research contributes to this by proposing that the level of automation influences the intention to adopt smart manufacturing. As the level of automation is related to the position in the supply chain, this position in the supply chain is considered influential as well. Again, the differences between smart manufacturing and general IT adoption may explain this factor being overlooked.

The conclusion can be drawn that, although smart manufacturing can be seen as a form of process innovation by adopting IT, it is in fact different because of the uncertainty of outcomes and the low awareness thereof, both at the level of the firm and at the level of the manufacturing industry. The submitted research provides an explanation of these differences by identifying two patterns; one from low intention to high intention (dormant-captive) and one from low adoption to high adoption (captive-adopter). The first pattern is mainly influenced by the current level if automation and awareness of the possible benefits, whereas the latter is mainly influenced by the presence of a clear automation strategy and limited by the current level of technology, lack of trust and lack of awareness within manufacturing industry. The proposed conceptual framework thus provides an explanation for the differences between the adoption of smart manufacturing and general IT adoption and should therefore be seen as a completion of previously described antecedents of IT adoption. Smart manufacturing should not be regarded a general form of IT adoption when it comes to the factors influencing adoption.

Another contribution to theory is the discovery of passion for technology as driving process innovation. In the submitted research there was insufficient evidence to fully specify how passion for technology does influence the intention, but it was concluded that it does somehow. This has been overlooked in literature until now and should be explored by academics as it could provide useful additional insights in the way SMEs decide on process innovation in general.

6.3. Limitations

The first limitation stems from the choice to only include cases from the steel processing industry, albeit that this decision has been explained and defended in the methodology section. However, this industry is rather conservative, as has become clear through the research. Contributing to this is the structure of steel industry as a factor, being fragmented with little trust between parties in the supply chain. Yet, it is this industry that has shown interest in the topic, justifying the reduction of the population to steel processing industry. The question remains whether the results can be generalised to other sectors, such as paper or plastics industry.

Another limitation is the fact that only few companies have applied smart manufacturing at this moment, making it hard to find enough suitable cases involved in the research. Future adoption should lead to more available cases, specifically from the "adopter" category, although theoretical saturation eventually was reached.

Finally, related to the low level of adoption within the industry, a low awareness of smart manufacturing within the industry is another limitation. As the awareness of the possible benefits of smart manufacturing was low, a certain amount of time in each of the interviews has been dedicated to clarifying what smart manufacturing is about. As a result, the research had elements of action research in it, while this was not foreseen or thought about before. With the benefit of hindsight, other methods of data gathering might have been used, such as focus groups. This would also increase the validity of the research as it would provide a means of triangulation.

6.4. Suggestion for further research

A few suggestions for further research emerged during the submitted research. First of all, the influence of nationwide action agendas (like Smart Industry) on decision-making in SMEs in general may be studied. This may help explain the rather negative sentiment from SMEs toward Smart Industry.

What has shown to be missing in theory about smart manufacturing or about IT adoption in general is research into the benefits of smart manufacturing, related to the type of technologies being used. A classification of smart manufacturing technologies could not be found and could be the starting point for such a study. The research should reveal how smart manufacturing is to be categorised and what the benefits are for each category?

The propositions generated in the submitted research should be tested in a quantitative study. Since the adoption rate of smart manufacturing in the Netherlands is rather low, this study should preferably be done in countries where smart manufacturing already has gained a foothold, such as Germany or Australia.

Replication of this study is, despite the previously mentioned theoretical saturation, suggested as this is expected to provide further support for the conceptual framework. Replication should be done in other industries, like in paper of plastics industry and, preferably, in other regions as well to determine whether there are specific Dutch characteristics influencing the research.

Finally, further research on the role of passion for technology in decision-making within technical SMEs in general may provide better insight into the motives for SMEs to adopt technical innovations of any kind.

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Appendix A – Interview questions

Introduction on the research by interviewer. Agree on level of confidentially/public nature.

General information

What are the main activities of the company?

What is the position in the supply chain?

What type of customers does the company serve?

Who are competitors?

What was the annual turnover in 2015?

How many FTE does the company employ?

How successful is the company? Are turnover and profitability over the last two years growing or declining?

Smart Industry

What do you know about the Smart Industry platform?

What is your initial reaction to Smart Industry? (Explain Smart Industry if interviewee is unfamiliar with it.)

How important is Smart Industry to your company? What role does the platform play?

Smart manufacturing

Visie op automatisering/digitalisering?

Is automation/digitisation part of the company's strategy?

How could the current level of automation best be described? And the current level of digitisation?

What goals is the company trying to achieve by automation/digitisation?

Present the case of 247 Tailor Steel. How far is this case different from your company? What are similarities? Could the way 247 Tailor Steel acts be copied to your processes?

To what extent could smart manufacturing be applied within the company?

What are limiting factors in the application? And what would foster the adoption?

Under what circumstances could smart manufacturing be of relevance?

Collaboration

What role does collaboration with customers and suppliers play in making decisions related to smart manufacturing?

How are competitors involved in the decision-making process?

What other parties do play a role in the decision-making process regarding smart manufacturing?

Future vision

Present the future scenario according to Van Lier/Klapwijk. What is your intitial reaction to this scenario?

What would be necessary to achieve this?

What is holding back the constitution of such a future?

What position would your company like to take in this scenario?

Where is initiative toward this scenario likely to come from? (OEM, supplier, raw material, software supplier, etc.)

Which new business models are likely to emerge and how could your company benefit from these?