Master thesis – Towards a Smart Industry

The Adoption Process of Smart Technologies in the Dutch Manufacturing Industry

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Preface

Dear reader,

First of all, I hope you will enjoy reading this thesis. Writing this thesis has been a long journey, but I am content with the result. During the process of writing I was lucky to have many people standing by my side helping me in their own unique way, on a professional and on a personal level. Without them, finishing this thesis would have been way more difficult. Therefore, I would like to thank some people in particular for their help and support. First, thanks a lot to my supervisor, Paul Ligthart. His feedback and support helped me greatly. Also, I thank my friends and family for their help. A special thanks to Eva Hekman and Jan Hazeleger, good friends of mine with whom I have spent so many days working on my thesis. Without them, this process would have been a lot more difficult. Thanks to Kevin van Huet Lindeman and Leon Smit as well for their support, advice and peer reviews. Other friends and family that remain unnamed, also a big thanks to you all. I appreciate all your help, support and friendship. It meant, and means, a great deal to me. Last but not least, I want to thank the interviewees for their time and effort. Thanks for inviting me and thank you for your enthusiasm about the topic of this thesis. Your enthusiasm helped to keep me going and finishing my thesis in the end. Thanks a lot for sharing so much about the internal processes of your firms. I have learned a great deal of your personal stories and experiences. I hope you appreciate this thesis and again, I hope you enjoy reading it.

Abstract

This thesis concerns the limited use of smart technologies in Dutch manufacturing firms and how this limited use is explained by the adoption process of smart technologies. Thereby, the way in which technological attributes of smart technologies contribute to the adoption process of smart technologies is explained. Existing literature on smart technologies lack consensus and definitions and therefore the goal of this study is to explore the topic by means of qualitative research. In this research, eight semi structured interviews were conducted with respondents of firms that are involved in the adoption of smart technologies. The interview guide was based on the three constructs: smart technologies, the adoption process of smart technologies and their technological attributes. The interviews were analyzed by mean of a combination of open and closed coding. The results, sorted by category, shed light on the relations between the constructs and provide insights into the importance, usefulness and value of these relations. The insights into the role of technological attributes in the adoption process of smart technologies will help both researchers and managers to accelerate the progress of the Dutch manufacturing industry towards a smart industry.

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Nomenclature

3D = Three Dimensional

AGV = Automated Guided Vehicles

AI = Artificial Intelligence

BU = Business Unit

CEO = Chief Executive Officer

CPS = Cyber Physical Systems

Cobot = Cooperative robot

DOI = Diffusion of Innovation (theory)

ERP = Enterprise Resource Planning

Fte = Fulltime-equivalent

GUI = Graphical User Interface

HR = Human Resources

I4.0 = Industrie 4.0

ICT = Information- and Communication Technology

IoT = Internet of Things

IoS = Internet of Services

IT = Information Technology

M2M = Machine to Machine

PLC = Programmable Logic Controller

R&D = Research and Development

SI = Smart Industry

TAM = Technology Acceptance Model

TPB = Theory of Planned Behavior

TRA = Theory of Reasoned Action

TOE = Technological, Organizational and Environmental (framework)

1. Introduction

Firms in the Dutch manufacturing industry are being challenged due to disruptive changes in the environment and in order to survive, firms need to innovate (Crossan & Apaydin, 2010; Ligthart, Vaessen, & Dankbaar, 2008; Pereira & Romero, 2013). One can assume that the greatest opportunities for firms to become and/or stay distinctive and competitive, lies in the fourth industrial revolution that has already started. This revolution is called ‘Smart Industry’ (Huizinga, Walison, & Bouws, 2014). Academics and practitioners largely agree that global importance of smart industry offers great opportunities and has a great impact on today’s markets, business models, supply chains and work in general (Schneider, 2018, p. 2). Since this industrial revolution is the first that is predicted a-priori instead of observed ex-post, research institutions and companies can actively shape the future. Besides, the economic impact of smart industry and its impact on production processes is believed to be huge (Hermann, Tobias, & Boris, 2015; Huizinga et al., 2014). The most important opportunity that comes with smart industry is that machines, installations and products will become ‘smart’ by means of the connection to the internet. This enables these ‘Smart Technologies’ to communicate with each other. Together smart technologies will form a smart network. In a smart network, technologies are able to alter/adapt the production process themselves. This will change the production process drastically and leads to a great potential for companies because it enables cost-efficient, flexible and individualized mass production (van Helmond et al., 2018b; Hofmann & Rüsch, 2017).

However, Dutch manufacturing firms struggles with the ‘Adoption of Smart Technologies’. Due to this struggle, only a single or a few self-contained smart technology/technologies are adopted in most firms. On top of that, these smart technologies do not form an integrated network (van Helmond, Kok, Ligthart, & Vaessen, 2018b; Hermann et al., 2015).

Thus, manufacturing firms in the Netherlands are missing out on the opportunities that smart industry provides. In addition, it appears that Dutch firms only adopt a small selection of smart technologies, while others are left out (van Helmond et al., 2018b).

In this study, an explanation for these phenomena is found in the various views upon the way firms shape the ‘Adoption Process of Smart Technologies’. This process entails multiple phases from initiation to implementation, in which different activities take place. The creation of an adoption process like this is influenced by ‘Technological Attributes of Smart Technologies’. These attributes are basicly factors or features that specifically belong to a certain smart technology and play a role in a certain phase of the adoption process. The research model of this study on adoption process of smart technologies is based on two prominent innovation adoption models, namely the theory of Hameed, Counsell and Swift (2012) and the stage-gate model of Cooper (1990). The reason for the combination of these two models is that they complement each other. The model of Hameed et al. (2012) describe certain stages and technological attributes. These attributes are technology specific features/factors that are taken into consideration during the adoption process. The stage-gate model of Cooper (1990) incorporates gates between the stages and feedback loops between these stages and gates. This combination leads to an all-encompassing adoption process with stages, gates, associated activities and feedback loops, affected by technological attributes. The goal of this explorative research is to shed light upon the adoption process, its' influence on the actual adoption of smart technologies and how technological attributes influence the adoption process. In order to do so, the similarities and differences between Cooper (1990) and Hameed et al. (2012) will be assessed leading to propositions which will be tested by means of results coming from coded interviews.

This results in the following research question:
'To what extent do the technological attributes contribute to the existence of stages and gates and progress across stages in the explanation of the adoption process of smart technologies of Dutch manufacturing firms?'

Outline study

Overall, this study provides other scholars with a clear overview of smart technologies, the views on the design of the adoption process of smart technologies and the relation between the existence of an adoption process and the actual adoption of smart technologies. In addition, this study provides manufacturing firms with an overview of existing smart technologies and possibilities and the means to design the adoption process of smart technologies in a way that the chance of a successful adoption increases. This will help firms to speed up their innovation pace to create a network of smart technologies in the end and thereby make use of the possibilities that come with smart industry. These possibilities will enable them to improve their competitive position.
The study is structured as follows. In the second chapter, smart technologies and smart industries will be defined and explained. Thereby, related terms for smart industry will be explained in order to prevent ambiguity since terms are often confused in the literature.

Furthermore, the most important smart technologies and the ones that are adopted most often so far are described in order to provide an overview of the current state regarding smart technology adoption. In chapter three, the adoption theory of Hameed et al. (2012), the stage-gate model of Cooper (1990, 2006) and their similarities and their differences will be explained. Together they form the foundation of the research model, which is presented at the end of chapter three. In the methodology chapter, the research method is assessed. The methodology chapter is followed by the analysis chapter. In this chapter the results regarding the multiple constructs and the propositions about expected relations between them will be presented and analyzed. The study is concluded by a discussion. In this chapter the study will be summarized first. Secondly, implications and contributions of this research are described, and recommendations will be made for both managers and researchers. Recommendations for managers entail advice to optimize adoption processes and recommendations for researchers are about possibilities for further research. Thirdly and finally, strengths and limitations of this study will be discussed, closed with an ethical reflection.

2. Smart technologies in the Dutch manufacturing industry

In this chapter smart technologies and smart industry (SI) will be explained and defined. Furthermore, attention will be paid to terms related to smart industry and their similarities and differences. This is important since a few terms related to smart industry are often confused. After that, the most important smart technologies and their application possibilities are discussed. Finally, the smart technologies and their application that are adopted most often are assessed as well.

2.1 Smart Industry

Smart industry is the fourth industrial revolution that takes place right now. This revolution is preceded by three other industrial revolutions. These revolutions are respectively about mechanics and the use of steam, the technological revolution characterized by mass production and third industrial revolution, which is known as the digital revolution. Smart industry builds on the digital revolution. The core concept of SI is linking the digital world with the physical world in the industrial sector (Schneider, 2018) by means of smart technologies. In order to be able to explain what SI means, a definition of smart technologies is provided first. Because of the lack of consensus on definitions of smart technologies (Hermann et al., 2015), a definition has been formulated based on Huizinga et al. (2014). Smart Technologies are defined as:

"*Technologies made smart by means of a connection to the internet and the combination and convergence with technologies like sensor technology and robotics*".

In other words, smart technologies are characterized the connection to the internet and connectivity with other technologies. In SI, a network of smart technologies provides the ability to bridge the gap between the digital and physical world on different levels, namely on a technology and application level between people and machines, on a firm level across systems and on an industry level across factories and companies (Schneider, 2018). The adoption of smart technologies and their integration into a smart network leads to an automatic, intelligent and highly flexible manufacturing process with real-time interactions between people, products and devices during the production process (Hermann et al., 2015; Huizinga et al., 2014). A network of smart technologies enables the ability to predict, control and plan for better business outcomes (Hermann et al., 2015). Due to SI, the focus in the manufacturing sector has shifted from a centralized production of popular products to a decentralized production of personalized products and services. In this decentralized production, the participation of the user of the products and services is increased in order to maximize added value by a firm (Lu, 2017; Zhou, Liu, & Zhou, 2015). In short, SI concerns the increase in intelligence and decision making autonomy of production process technologies and their intra-company cross-linking and cross-company integration which leads to decentralized value creation networks (Hofmann & Rüsch, 2017, p. 25; Schneider, 2018, p. 1).

Despite existing literature on SI providing the means to formulate a detailed description of SI, no generally accepted definition of SI has been published so far (Hermann et al., 2015; Schneider, 2018). A literature study revealed numerous different definitions and descriptions of smart industry which are assembled in appendix 1. However, one clear and complete definition of SI is needed as the lack of a clear definition of SI is one of the reasons companies struggle at identifying and implementing smart technologies (Hermann et al., 2015). In order to provide a new, complete and all-encompassing definition of SI, all the assembled definitions in appendix 1 are compared and combined. Based on this comparison and combination of different definitions, Smart Industry is defined as follows:

"*Smart Industry is the connection of products, services and all manufacturing equipment via the internet or other network applications into an integrated network of complex machinery and devices with sensors (technologies) used to predict, control and improve the production process in a decentralized value chain organization*".

The exact way in which this definition is created is presented in appendix 2. In short, this definition is characterized by a holistic perspective with a technological focus on smart industry in which the connection of smart technologies in a decentralized value network forms the central element. This definition is believed to be complete, but in order to gain a more clear and detailed insight into smart industry it is important to distinguish between terms that are associated with smart industry and that are used as synonyms while they are not.

2.2 Terms associated with Smart Industry

Manifold contributions of both academics and practitioners have made the meaning of smart industry blurry (Hermann et al., 2015). In this section the consensus and the inconsistencies in the literature on smart industry are described.

Firstly, an important remark is that the terms SI and 'Industrie 4.0' are often used in the theory as synonyms, but they are not. Industrie 4.0 is defined as: "*A part of Germany's high-tech strategy so as to prepare and strengthen the industrial sector with regard to future production requirements which was publicly introduced at the Hanover Trade Fair in 2011*" (Hofmann & Rüsch, 2017, p. 24). So, SI is a broad industrial development, where I4.0 is the German national innovation strategy formulated to exploit possibilities that comes with SI.

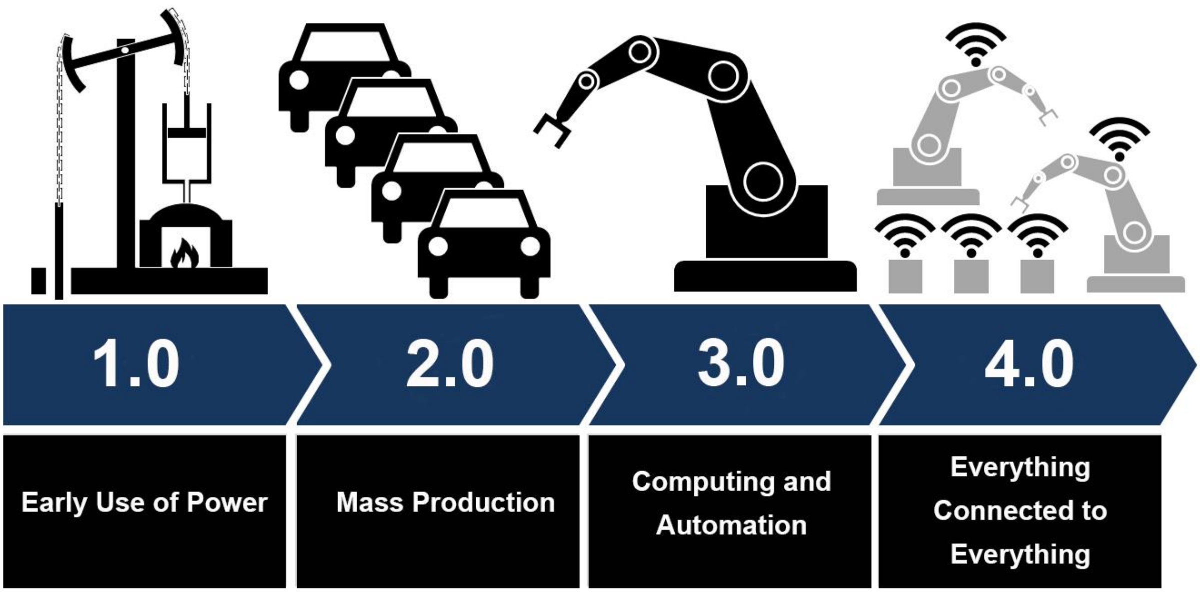
Secondly, SI and 'Digitization' are also often used as synonyms, but they are not. SI is the term used for the fourth industrial revolution and digitization of information and communication is one the key enablers of the third industrial revolution (Hermann et al., 2015). Digitization is defined as "*The conversion of analogue data (esp. in later use images, video, and text) in digital form*" *(*"Digitization", 2020). In SI, the digitization of manufacturing is brought to another level by the creation of a smart network in which the human and digital world are connected (Huizinga et al., 2014; Lu, 2017). Schneider (2018) emphasizes that "*digitization is a technological prerequisite for such networking, but does not constitute the distinctive feature of SI in itself*" (Schneider, 2018, p. 5). However, Schneider claims that "*in several descriptions and definitions, digitization is mistakenly indicated as such*" (Schneider, 2018, p. 5).

Thirdly, both digitization and SI are often confused with 'Digitalization' (Schneider, 2018). Digitalization is "*The adoption or increase in use of digital or computer technology by an organization, industry, country, etc.*" ("Digitalization", 2020).

Fourth, the term 'Automation' needs some explanation as well. Automation began in the third revolution, often in the form of programmable logic controllers (PLCs) and is defined as: "*The action or process of introducing automatic equipment or devices into a manufacturing or other process or facility; (also) the fact of making something (as a system, device, etc.) automatic*" ("Automation", 2020). In SI, automation is made smart by means of sensors and the connection to internet (Hermann et al., 2015; Huizinga et al., 2014). Finally, the term 'Robotization' is an unique aspect of SI (Huizinga et al., 2014) and is defined as: "*The action or process of robotizing a person or thing*" ("Robotization", 2020). To robotize is in turn defined as: "*To automate (a process, factory, or industry); to mechanize. Also: to turn (a person) into a robot*" ("Robotize", 2020).

To conclude, digitalization, digitization and automation are associated with the third industrial revolution/digital revolution and the connectivity of technologies in the smart industry is associated with the fourth industrial revolution. Digital technologies are a prerequisite for smart technologies, so digitization and digitalization are prerequisites of SI. In other words, SI builds upon the third revolution. Automation plays a role in both revolutions, but the role it plays is different in each revolution. Automation technology is made smart in SI. SI gained attention due to the introduction of the prominent German innovation strategy Industry 4.0. The figure below shows how the industrial revolution builds upon each other.

Figure 1. The four industrial revolutions.



Source: BIM learning center (2020), retrieved from: *https://bimlearningcenter.com/look-leap-industry-4-0-building-construction/industry-1-0-to-4-0/*

As mentioned before, smart industry is characterized by four levels of analysis: industry, firm, technology and application level. Technologies associated with SI are called smart technologies. Their connectivity leads to a smart factory, which is characterized by a decentralized production system, and ultimately to a smart network with partners in the supply chain (Hermann et al., 2015; Kagermann, Wahlster, & Helbig, 2013; Schneider, 2018). SI is a smart value network with partners in the supply chain on an industry level and the smart factory is on firm level. The smart factory is one of the four key components of SI (Hermann et al., 2015). The other three key components SI represent the three key smart technologies and are therefore about SI on a technological level. These three key smart technologies are: Cyber-Physical Systems (CPS), Internet of Things (IoT) and Internet of Services (IoS) (Hofmann & Rüsch, 2017). Together they form the Smart Factory, which is defined as:

"*A factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks*" (Hermann et al., 2015, p. 10).

2.3 Smart technologies and their applications

The definitions of the other three key components of SI on a technology level are presented in the table below. The definition of CPS is composed of multiple definitions.

Figure 2. Definitions of the three key smart technologies.

Term	**Definition**
CPS	"*The integration of computed systems with physical processes by means of actuators, sensors, control processing units and communication devices in which embedded computers and networks monitor, coordinate and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa.*" (Hofmann & Rüsch, 2017; Lee, 2008, p. 1; Parvin, Thein , Park, Hussain, & Hussain, 2013, p. 928).
IoT	"*A world where basically all (physical) things can turn into so-called 'smart things' by featuring small computers that are connected to the internet.*" (Hofmann & Rüsch, 2017, p. 25).
IoS	"*A world in which services are made available through web technologies, allowing companies and private users to combine, create and offer new kind of value added services.*" (Hofmann & Rüsch, 2017, p. 25).

Cyber-Physical Systems (CPS), Internet of Things (IoT) and Internet of Services (IoS) are described as follows. CPS are systems that connect and combine physical and cyber networks in one smart network. Therefore, it is an upgrade of the production process in terms of control, surveillance, transparency and efficiency (Hofmann & Rüsch, 2017). The integration of these networks is realized by means of the use of actuators, sensors, control processing units and communication devices (Parvin et al., 2013, p. 928). IoT is an initiator of SI and

enables the collection of useful, low-cost, high resolution data about the real world (Fleisch, 2007; Hofmann & Rüsch, 2017). The IoS enables service vendors to offer their services via the internet (Hermann et al., 2015). IoS will be playing a key role in future industries in the form of marketplaces of service on the internet (Hofmann & Rüsch, 2017).
In short, in a smart factory, CPS communicate over IoT so products can find their way through the production process in an independent way. By doing so, products are always easily identifiable and locatable (Kagermann et al., 2013, p. 19). However, there is much more to say about Smart Industry on an application level.

Application of smart technologies

In a smart factory, smart technologies enable new applications including human-machine interaction technologies and advanced analytics of (big) data for example. There are a lot of applications of smart technologies. Different overviews of smart technologies and their applications have been published. These are presented in appendix 3. The technology applications described in these studies are considered being smart for two reasons: they are described either as smart technology applications related to productionprocesses or as processtechnology applications that are considered to be related to SI (Agostini & Filippini, 2017; van Helmond et al., 2018a; van Helmond, 2018b; Hermann et al., 2015; Hofmann & Rüsch, 2017; Lu, 2017; Rüβmann et al., 2015; Saucedo Martinez et al., 2018; Wee et al., 2015; Zhou et al., 2015). However, in literature of smart technology terms are often confused. In addition, not all technologies and their applications that are associated with SI in the literature are in fact smart. Based on the overlap between multiple studies, the most important smart technology applications are described. These are presented in appendix 4 as the bottom layer of the pyramid in which the four different levels of SI are displayed.
A few remarks regarding the application of smart technologies are important. Big data, intelligence and advanced analytics are combined since these technologies are often linked (Agostini & Filippini, 2018; Rüβmann et al., 2015; Saucedo Martinez et al., 2018; Zhou et al., 2015; Wee et al., 2015). Technologies as digital production planning and digital exchange of data with the shop floor technologies are associated with SI (van Helmond, 2018b), but in the light of the given definition of SI, they are rather a digital technology then a smart technology. Therefore, they are left out in this study.

Literature reveals that there is a difference between (applications of) smart technologies regarding how often they are adopted by firms in the Dutch manufacturing sector (van

Helmond et al., 2018a, 2018b). The two technologies most adopted (digital technologies) are the technologies that fall in the grey area as mentioned before. The five that follow are the first convincing smart technologies: realtime production control systems, additive manufacturing, etc. The next is PLCs, which are associated with digitalization as mentioned before. Key smart technologies like IoT and CPS technologies close the list (van Helmond et al., 2018b). The sectors buildingmaterials, machinery and electronics are leading with an average of four adopted smart technologies. The food sector lags behind with an average of two (van Helmond et al., 2018b). Striking is the fact that "*smart technologies do not seem to form a integrated configuration*" (van Helmond et al., 2018b, p. 2), while this network is the distinctive feature of SI (van Helmond et al., 2018b).

To conclude, in the smart industry, smart factories are connected in a value network of supply chain partners. Within the smart factory, the connectivity of smart technologies like IoT and CPS leads to a lot of different applications. Firms in the Dutch manufacturing industry are just beginning to adopt smart technologies and applications and networks of smart technologies that lead to a smart factory are absent. Besides, smart technologies and their applications differ in the extent to which they have been adopted by these firms. An explanation for this difference lies in two different views upon the adoption process of smart technologies: the models of Cooper (1990) and Hameed et al. (2012). These views will be assessed in the next chapter.

3. The adoption process of smart technologies.

In this study, the analysis of the adoption process of smart technologies in Dutch manufacturing firms on a firm level is based on the IT adoption theory of Hameed et al. (2012) and the Stage-Gate model of Cooper (1990). These models have clear similarities and differences in their view upon adoption processes and complement each other in multiple ways. Hameed et al. (2012) describe multiple stages, which are supplemented and specified in this study by the stage-gate model of Cooper (1990) in the form of the formulation of stages, gates, specific activities and feedback loops between the stages and gates. Besides, Hameed et al. (2012) describes attributes that influence the design and the execution of the adoption process. Attributes are believed to be associated with certain stages and gates by Cooper (1990). The comparison between and combination of these models yields useful insights into the relation between the design of the adoption process and the actual adoption of smart technologies. In this chapter, a definition of adoption of smart technologies will be formulated first. After that, the different views on the adoption process will be assessed shortly before the adoption theories of Hameed et al. (2012) and Cooper (1990) are assessed. Thereby, both the adoption process and the technological attributes of smart technologies are discussed. Finally, the propositions and the research model will be presented and explained.

3.1 Technology adoption

In this section, a description of technology adoption by firms in general is provided. There are many different views upon adoption processes, however, literature lacks clear definitions leading to a lack of overview in both literature and practice on this topic (Hermann et al., 2015). Therefore, the formulation of a clear definition of the adoption process of smart technologies will be useful. The common ground in the existing literature is that the adoption of an innovation (that is new to the organization) can be described as a process from idea generation to implementation an innovation. This adoption process leads to the introduction and use of an innovation (Cooper, 1990; Damanpour, 1991; Damanpour & Wischnevsky, 2006; Hameed et al., 2012; Kimberly & Evanisko, 1981; Rogers, 1983). The 'Adoption of Smart Technologies' is therefore defined as:

"*The introduction and use of smart technologies.*"

There are two different views on adoption process theories: individual level theories and firm/organizational level theories (Hameed et al., 2012). Because the focus is on smart technologies adopted by firms on a strategic level, the adoption process is analyzed on an firm level. The management of the adoption process of new technologies on a strategic level is of critical importance to organizations because managers/directors/executives have the final authority to decide whether to adopt a innovation or not (Huff & Munro, 1985). Most of the adoption theories concern the individual level of adoption and only two theories are distinguished as adoption theories on a firm level, which will therefore be the only theories considered in this study. These firm level theories are the Diffusion of Innovation theory (DOI) and the Technological, Organizational and Environmental framework (TOE) (Al-Mamary, Al-nashmi, Hassan, & Shamsuddin, 2016; Gangwar, Date, & Raoot, 2014; Hameed et al., 2012; Kim & Crowston, 2011; Li, 2010; Oliveira & Martins, 2011; Sharma & Rajhans, 2014; Taherdoost, 2017). An overview of the literature that is taken into consideration is presented in appendix 5. Hameed et al. (2012) combines both DOI and TOE and forms the foundation of this study in combination with the model of Cooper (1990). The theory of Hameed et al. (2012) will be explained first in the next section. The stage-gate model of Cooper (1990) will be assessed in the subsequent section.

3.2 Hameed et al. (2012)

Before the model of Hameed et al. (2012) is explained, DOI and TOE are assessed shortly. The TOE framework provides with the means to examine the adoption of IT products and services on firm level (Gangwar et al., 2014). TOE identifies three aspects of a firms' context that influence the way a firm adopts a technological innovation: technological, organizational and environmental context (Al-Mamary et al., 2016; Gangwar et al., 2014; Oliveira & Martins, 2011). In DOI, Rogers (1995) describe an innovation-decision process with five stages in which five attributes/factors of innovations play an important role. The five stages in the innovation-decision process are: knowledge, persuasion, decision, implementation and confirmation. The five perceived attributes of innovations are: 'Relative advantage, Compatibility, Complexity, Trialability and Observability' (Rogers, 1995). Rogers (1995) uses these attributes to explain the adoption rate of innovations. Nevertheless, these attributes turn out to be useful in the explanation of the adoption of innovations in general as well (Oliveira, Thomas, & Espadanal, 2014).

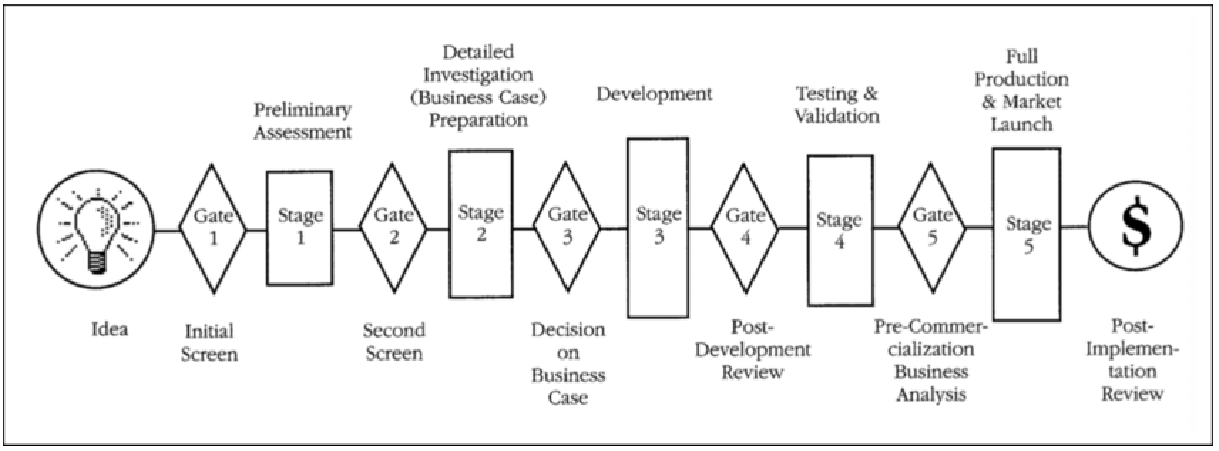
Hameed et al. (2012) analyze the adoption process of IT innovations in organizations on both firm level and individual level. The focus is on the firm level analysis part which is based on a

combination of DOI and TOE, the most used combination of adoption theories (Baker, 2011). The combination of these theories is one reason why the theory of Hameed et al. (2012) forms a good foundation for this study. The TOE framework is consistent with and closely related to Rogers' DOI theory (Baker, 2011) and therefore, the explanatory power of Rogers' DOI theory is increased by the TOE framework (Oliveira et al., 2014). Another reason why the theory of Hameed et al. (2012) is believed to provide a good foundation for this study is that "*IT practitioners may utilize this model to investigate the factors influencing the adoption of IT in various demographic settings; the model could be tested with organizations from different sectors and different countries*" (Hameed et al, 2012, p. 374).
Hameed et al. (2012) distinguish three stages: the initiation (pre-adoption), adoption decision and implementation (post-adoption). Each stage contains three activitities. The stages initiation, adoption decision and the first activity of the implementation (acquisition) are described as firm-level stages. In these stages the technological, organizational, and environmental attributes are taken into consideration (Hameed et al., 2012). Hameed et al. (2012) state that impact of the technological attributes is different in each stage of the adoption process. The technological attributes mainly play their role in the early stages of the adoption process (Hameed et al., 2012). The last two activities of the implementation stage (user acceptance and actual use of the implemented innovation) are described as individual level stages (Hameed et al., 2012). However, it is believed that the actual implementation of a smart technology can also be assessed on a firm level. An innovation is often implemented stepwise: first in one or a few sub-units and later in additional units (Huff & Munro, 1985). On top of that, after the acquisition stage, the innovation is likely to be tested before it is actually used. It is assumed that a manager would need to approve the test results before the project proceed to the next stage. This implies a firm level decision rather than an activity on the analysis level of one individual employee.

3.3 Cooper (1990)

Cooper (1990) developed the 'Stage-Gate model' in order to explain how firms can best develop new products and prevent muddling through when adopting innovations. This model function as a skeleton from which a custom-tailored model can be developed (Cooper, 1990). Therefore it is believed that a stage-gate system is also useful for firms that are about to develop process innovations by themselves. Results show that the few divisions that had implemented a stage-gate system achieved a much higher level of performance than the divisions that did not (Cooper, 1990). The stage-gate model has become a project management technique in which a project (for example the development of new products, software or process improvement) is subdivided into five ‘Stages’ and five ‘Gates’ (Cooper, 1990). The stage-gate model begins with idea generation and ends with a post implementation review. Each stage and gate entail several ‘Activities’ (Cooper, 1990). The stages function as workstations and they are connected by gates that function as quality control checkpoint created in order to ensure that the quality of the project is sufficient. In the gates the project will be checked based on a set of quality criteria that must be met before moving to the next stage (Cooper, 1990). The Stage-Gate model is presented in the figure below.

Figure 3. A Stage-Gate System.



Source: Cooper, R. G, 1990.

Cooper (1990) emphasize the importance of both an extensive research at the start and regular evaluations throughout the whole adoption process. Besides, a stage-gate model is characterized by parallel activities rather than sequential activities. The core elements leads to an improved success rate of adoptions (Cooper, 1990). This relation will be explained later.
In a stage-gate process, projects must be carried through all stages by a team and a teamleader (Cooper, 1990). The inputs are the deliverables that the project leader brings to the gate and the criteria are the items upon which the project will be judged. The outputs are the decisions made at the gate (Cooper, 1990). These decisions are made by senior managers who act as gatekeepers. They decide whether to go/kill/hold/recycle a project (Cooper, 1990). In the case of a go, the approval of an action plan for the next stage is given. A decision to kill means the rejection of a project and a hold implies a pause of a project for whatever reason. Finally, the decision to recycle means that certain activities of a preceding stage needs to be repeated (Cooper, 1990). The decision to recycle leads to a so called ‘Feedback Loop’ in the adoption

process. The existence of a recycle option is believed to increase the chance that an innovation is adopted in the end because of the fact that the project gets a second chance (Cooper, 1990).

Overall, the stage-gate systems provide a road map for the project leader, the team and the managers/executives of the firm. The stage-gate model gives executives insight into the status and progress of all the ongoing projects. In doing so, it enables them to better evaluate innovation projects, rank projects and focus resources on the best or most important projects (Cooper, 1990). In the next section it will be explained how this model is combined with the model of Hameed et al. (2012) in the research model of this study.

3.4 Research model

As mentioned before, the research model of this study on the adoption process of smart technologies is based on the model of Hameed et al. (2012) and the stage-gate model of Cooper (1990). These models are believed to complement each other, but they both have some theoretical gaps as well. Before the research model of this study is presented, two similarities and three differences between the models of Hameed et al. (2012) and Cooper (1990) are assessed. After that, the theoretical gaps of the (combination of the) two theories and the way in which these model complement each other is explained.

One similarity is that both Cooper (1990) and Hameed et al. (2012) describe an innovation adoption process that consists of several consecutive steps. Another similarity is that both models take into consideration multiple (technological) attributes that influence the way in which the adoption process is created and executed.

However, there are some differences between the theories as well. The first of the three differences is the nature of the theoretical contributions of these theories. The stage-gate model of Cooper (1990) does not have a solid theoretical foundation like the model of Hameed et al. (2012). On the other hand, the stage-gate model of Cooper (1990) provides with more tools that enable to review the adoption process within firms. Cooper (1990) provides one with a detailed description of stages, gates, feedback loops and activities, where Hameed et al. (2012) only describe some broad stages and activities. In the latter theory it remains unclear what happens exactly in and between the different stages and within the activities.

Secondly, these models differ regarding the role attributes play in the adoption process. Hameed et al. (2012) provide an overview of relevant (technological) attributes in the adoption process, but it remains unclear how and at which point these attributes influence the adoption process. On the other hand, Cooper (1990) only shortly mentions some desired and essential technology features, attributes and specifications. Nevertheless, these are somewhat similar to the technological attributes described by Hameed et al. (2012). In addition, Cooper (1990) is more specific about at which point these attributes play a role: in the early stages and in the last gate.

Thirdly, Cooper (1990) and Hameed et al. (2012) have another focus on adoption of innovations. The stage-gate model of Cooper (1990) describes stages and gates for firms that develop innovations by themselves while Hameed et al. (2012) focus on the acquisition of innovations.

Nevertheless, the combination of the models of Cooper (1990) and Hameed et al. (2012) still has some theoretical gaps. First of all, both the models of Cooper (1990) and Hameed et al. (2012) lack clear definitions of the core concepts. Only the description of attributes of smart technologies has a solid theoretical foundation. Therefore, the key components of the adoption process of smart technologies and the technological attributes of smart technologies are defined later. Second, the combination of the models of Hameed et al. (2012) and Cooper (1990) does not provide firm-level activities for each stage and gate. In order to fill this gap, other activities in the different stages are derived from the study of Eveleens (2010) in which studies on innovation process models are described and compared. Lastly, an important remark at the model of Cooper (1990) is that this model focuses on product innovation while the focus in this study is on production process innovation. Therefore, it is supplemented with stages and gates form the stage-gate model of Cooper (2006) for the development of production process technology. In the next section, the adoption process of smart technologies will be explained in more detail.

<u>Adoption process of smart technologies</u>

The ‘Adoption Process of Smart Technologies’ is defined as:

“*A process with stages, gates, associated activities and feedback loops progressing from initiation to implementation that leads to the introduction and use of a smart technology.*”

The key components of the adoption process of smart technologies are: 1) ‘Stage’, 2) ‘Gate’, 3) ‘Feedback loop’ and 4) ‘Adoption Activity’. These four key components are respectively defined in line with Cooper (1990) as:

1. “*A workstation that entails several activities and that is connected by (a) gate(s).*”
2. “*An entrance to another stage and a quality control checkpoint, which entails several activities and in which decisions are made by gatekeepers whether to go/kill/hold/recycle a project based on whether the project meets a certain set of quality criteria.*”
3. “*Redoing activities associated with a particular stage following a decision to recycle made at the gate after this particular stage.*”
4. “*The performance of an action or operation within a certain stage or gate of the adoption process.*”

The definition of ‘Adoption Activities’ is based on the definition of ‘Activity’ from the Oxford English Dictionary (2020). An activity is defined as: “*The performance of an action or operation*” (“Activity”, 2020).

The adoption process of smart technologies is formulated in line with Hameed et al. (2012), Cooper (1990, 2006) and contains seven stages and gates.
It starts with the generation of a new idea which is submitted to gate 1 where the initial or first screening takes place, mostly by senior R&D people (Cooper, 2006).
In the first gate, the screening gate, a decision is made whether to commit resources to the project or not. The project is subjected to a few should-meet and must-meet criteria on strategic alignment, project feasibility, differential advantage, magnitude of the opportunity, synergy with the firm’s core business and resources and likelihood of technical success (Cooper, 1990, 2006). A checklist for the ‘must-meet’ and a scoring model for the ‘should-meet’ criteria help focus the discussion and rank the projects. If the decision is a go, the project moves into the first stage: the project scope stage (Cooper, 2006).
In stage 1 the technical place merits are determined and the foundation for the research project is build. This stage entails a number of “*relatively inexpensive activities: a library search, contacts with key users, focus groups, and even a quick concept test with a handful of potential users.*” (Cooper, 1990, p. 52). Cooper (2006) adds activities like patent and IP search, search for competitive alternatives, the identification of resource gaps and preliminary technical assessment. The goal in this stage is to assess development and manufacturing possibility and both costs and time needed for execution (Cooper, 1990).
At gate 2, the second screening, the project is evaluated for a second time in light of new

information. The project is subjected to the same criteria as in stage 1, but new ‘should-meet’ criteria are added in the evaluation. The financial return is assessed by means of a quick and simple financial calculation. A decision is made to begin limited experimental or technical work (Cooper, 2006). After a go, the project reaches the second stage.

In stage 2, the technical assessment stage, the attractiveness of the project is verified. The project must be clearly defined which includes the formulation of goals. Furthermore, the technical feasibility of the project is examined by a detailed technical appraisal under ideal conditions (Cooper, 1990, 2006). An operational appraisal can be added in this stage whereby required investments are investigated. The input for gate 3 is a detailed financial analysis involving a discounted cash flow approach and a sensitivity analysis (Cooper, 1990).

Gate 3 is the gate where the decision to deploy resources on the project is made (Cooper, 1990, 2006). This is the last point where the project can be killed before the heavy spending on the project starts. This gate entails three main activities: evaluation, definition of the project and a decision. Firstly, regarding the evaluation, the same criteria as in gate 2 are used. Attention is paid both to the way in which the activities in stage 2 are executed and the analysis results from stage 2. In particular, the financial analysis is an important part of this screen. The second part of this gate is about the definition of the project. Agreement must be reached on items like the desired and essential technology features, attributes and specifications. Finally, the development plan and the plan for preliminary operations and are reviewed and approved (Cooper, 1990).

In stage 3, a detailed investigation takes place and a proposal is formulated. The purpose of this stage is to implement a full experimental plan in order to prove the technological feasibility and to define the technologies’ scope and value to the company (Cooper, 1990). Accompanying activities are manufacturing and impact assessments on the process possibilities and preparing an implementation proposal (Cooper, 2006).

At gate 4, the decision is made whether to allocate resources to the development or acquisition of the smart technology in question and at stage 4 the resources are allocated (Hameed et al., 2012). Money will be made available in order to buy a smart technology or to assemble and pay the salary of a development team.

The allocation of resources will be reviewed at gate 5 and a go- or no-go decision will be made regarding the start of the development or acquisition of the new smart technology.

Stage 5, the development or acquirement stage entails the development or the acquisition of the smart technology and the formulation of the test- and operation plan. The project team prepare an updated financial analysis and issues regarding patent or copyright issues are resolved. Gate 6 is called the post-development or acquirement review. When the smart technology in question is developed, the development work is checked on quality and the financial analysis is revised based on new, more accurate data. In case of an acquisition, the delivered smart technology will be checked on completeness and quality. Finally, the test and validation plans for the next stage are evaluated and operation plans are checked on whether they are fit for future execution.

In case of go, the project moves on to stage 6 where the entire viability of the project is tested through activities like "*trial or pilot production: to test and debug the production process, and to determine more precise production costs and rates*" (Cooper, 1990, p. 53). A new revised financial analysis is the last step.

Gate 7 is the final point where the project can be killed. In this gate, the focus is upon the quality of the validation activities and the evaluation of the test results. Financial projections play a key role in this gate and operation plans are approved for implementation in stage 7.

Stage 7 is the implementation stage and thereby the last stage. Most of the time, firms introduce the new smart technology step-wise to the firm (Huff & Munro, 1985).

In the post-implementation review, the last step in the stage-gate system, the project team is disbanded and the performance of the new smart technology is measured. To do so, the latest information about revenues, costs, expenses, profits and timing are compared to the predictions made at the start of the project.

Finally, the strengths and weaknesses of the project are assessed in order to determine improvements for future projects (Cooper, 1990). The adoption process of smart technologies is presented in a figure in appendix 6 and the firm-level activities in these stages and gates are summarized in a table in appendix 7. How the existence of a stage-gate system leads to an increase in the success rate of smart technology adoption is explained in the next section.

Influence of the existence of an adoption process on the adoption of smart technologies

The existence of an adoption process based on the stage-gate model can make the difference between the adoption and the rejection of smart technology (Cooper, 1990). Cooper (1990) emphasize the importance of both quality and completeness of the stage-gate model. Adoption projects can be improved by focusing on quality, homework, parallel activities and evaluation (Cooper, 1990). The lack of quality in projects is one of the main reasons of project failure. Furthermore, crucial steps are often missing and "*the more steps or activities one left out, the higher the likelihood of failure of the project*" (Cooper, 1990, p. 47). The three most important

elements of the adoption process are ‘Home-work Activities’, ‘Parallel Activities’ and ‘Project Evaluations’ according to Cooper (1990). However, Cooper (1990) identify some problems in practice regarding these elements of the adoption process.
First of all, projects lack so-called home-work activities. This means that projects lack a good initial screening and projects are often poorly defined and initiated based on little information and no formal criteria (Cooper, 1990). Home-work activities pay themselves because they lead to a reduced development time and an improved success rate of innovation adoptions (Cooper, 1990). Secondly, the stage-gate model, activities are rather parallel than sequential. This means that at each stage, “*many activities take place concurrently and involve different functions of the firm*” (Cooper, 1990, p. 49). Parallel processing leads to a reduced development time without a decrease in the quality of the project (Cooper, 1990). Finally, Cooper (1990) emphasize that project evaluations are crucial, but these evaluations are often weak, deficient or even absent. When a project made it to the development phase, a project was rarely killed (Cooper, 1990). Only one out of seven projects becomes a success so effective project evaluation is crucial in order to prevent misallocation of valuable resources. “*Good evaluation prevent* ‘*losers*’ *from proceeding too far and good evaluation focus the resources on potential winner*’’ (Cooper, 1990, p. 50). As mentioned before, the creation and execution of stages, gates and activities in the adoption process is influenced by ‘Technological Attributes of Smart Technologies’. These attributes and their influence on the adoption process will be assessed in the next section.

<u>Technological attributes of smart technologies</u>

The description and definition of technological attributes of smart technologies is based on Rogers (1995). Rogers (1995) describe multiple different attributes of innovations, among which the technological attributes of innovations. This description is used by Hameed et al. (2012) in their explanation of their influence on innovation adoption processes. Since smart technologies are examples of innovations, the five technological attributes of smart technologies in this study are defined in line with the technological attributes of innovations Rogers (1995, pp. 250-251). These descriptions and definitions are made specific for the adoption process of smart technologies. So, ‘Technological Attributes of Smart Technologies’ are defined as:

“*Factors/ features that are specific for a certain smart technology and that are considered important by people that are involved in the adoption process and influence the adoption* *process (and thereby the decision to either adopt or reject the adoption of an smart technology) due to the fact that their individual impact is different in the different stages and gates of the adoption process of a smart technology.*"

The five technological attributes of smart technologies are: 1) 'Relative Advantage', 2) 'Compatibility', 3) 'Complexity', 4) 'Trialability' and 5) 'Observability' and are relatively defined in line with Rogers (1995, pp. 250-251) as follows:

1. "*The degree to which a smart technology is perceived as better than the idea it supersedes.*"
2. "*The degree to which a smart technology is perceived as consistent with the existing values, past experiences, and needs of potential adopters.*"
3. "*The degree to which a smart technology is perceived as relatively difficult to understand and to use.*"
4. "*The degree to which a technology may be experimented with on a limited basis.*"
5. "*Is the degree to which the results of a smart technology are visible to others*."

Relative advantage is the most important technological attribute in adoption processes both absolutely and relatively. This means that relative advantage appears most often and is most often proven being significant. Complexity and compatibility appear in many studies, while observability and trialability are assessed in far less studies. However, the latter two turn out to be more often significant in a relative way (Hameed et al. 2012). The technological attributes, compatibility and trialability have little influence on the adoption process according to Mustonen-Ollila and Lyytinen (2003). Mustonen-Ollila and Lyytinen (2003) suggest that this "*can be explained by the fact that a majority of the innovations resulted from internal learning and experimentation*" (Mustonen-Ollila & Lyytinen, 2003, p. 286). However, the conclusions of Mustonen-Ollila and Lyytinen (2003) are based on an examination of adoption processes of innovation in firms between 1967 and 1997, so this conclusion is somewhat outdated. Therefore, all five technological attributes are included in this study. In the next section, the influence of these attributes on the adoption process is explained.

<u>Influence of technological attributes on adoption process of smart technologies</u>

Technological attributes of smart technologies influence the way in which the adoption process is created and executed. However, Cooper (1990) and Hameed et al. (2012) differ in the extent to which (technological) attributes/features are considered being relevant factors and how they are described. The description of technological attributes of Hameed et al. (2012) are leading in this study, however, Cooper (1990) mention some technological features of innovations as well. They are formulated in another way by, but they compare to an extent to the technological attributes described by Hameed et al. (2012). However, only Cooper (1990) associate these attributes with certain stages and gates. The technological attributes described by Hameed et al. (2012) and Cooper (1990) are considered the same in this study. The five technological attributes play a role from gate 1 to stage 3: first screening to the decision to deploy resources (Cooper, 1990). Nevertheless, these technological attributes are believed to at least play a role in gate 4 (adoption decision) and stage 6 (testing) too since the actual adoption decision is logically based upon a consideration of the technological attributes, among others. Besides, the testing stage is meant to test the new smart technology whether it meet the technical requirements. These requirements are believed to show at least overlap with the technological attributes of the smart technologies.

Striking is that, besides these five technological attributes, both Hameed et al. (2012) and Cooper (1990, 2006) distinguish some other types of innovation attributes as well. Overall, the following major categories of innovation attributes can be distinguished: technological, organizational and environmental attributes. All these attribute categories seem to be relevant (Hameed et al., 2012), however, only the technological attributes are taken into account in this study. The other attributes are not clearly defined and substantiated and/or not linkable to a certain stage, gate or activity (Huff & Munro, 1985; Tornatzky & Fleischer, 1990). Quality of the production process, financial attributes and the feasibility of the project are considered quite often. However, these attributes are associated with stages and gates across the whole adoption process instead of in the first stages and gates only, which is the case for technological attributes. Therefore, these attributes are not the main focus in this study. Nevertheless, they are believed to be of some importance, so they are considered shortly in the interviews. The respondents have been asked what other attributes; besides the technological attributes, they consider when adopting a smart technology.

An overview of attributes considered relevant in each stage and gate according to different authors is presented in appendix 8. The assumption that the five technological attributes also play a role in gate 4 and stage 6 is not taken into account in this table since there is no clear theoretical foundation that supports this believe. Based on the description of how different constructs in this study influence each other, two propositions are formulated which are presented in the next section.

<u>Propositions</u>

Overall, the combination of Cooper (1990, 2006) and Hameed et al. (2012) leads to a researchmodel that both has a solid theoretical foundation and provide with the means to properly assess the adoption process within firms. This model makes it possible to take into account both adoption options for firms, either develop or acquire a new technology. The researchmodel shows how the creation of an adoption process leads to the actual adoption of smart technologies due to the formulation of stages, gates, feedback loops and activities in which relevant technological attributes of smart technologies are taken into account. As mentioned before, it is believed that the existence of stages, gates, adoption activities and feedback loops have a positive influence on the adoption of smart technologies. Besides, all technological attributes are believed to play their role mainly in a few/the first stages and gates. On top of that, some technological attributes would play a larger role than others. The fact that attributes play a role in a certain stage or gate implies that they influence the way in which a gate or stage is created and executed. For example, these attributes determine how meetings and consultations look like in terms of which employees are involved, when and how often meetings take place, what criteria are used, etc. So, the following two propositions are formulated:

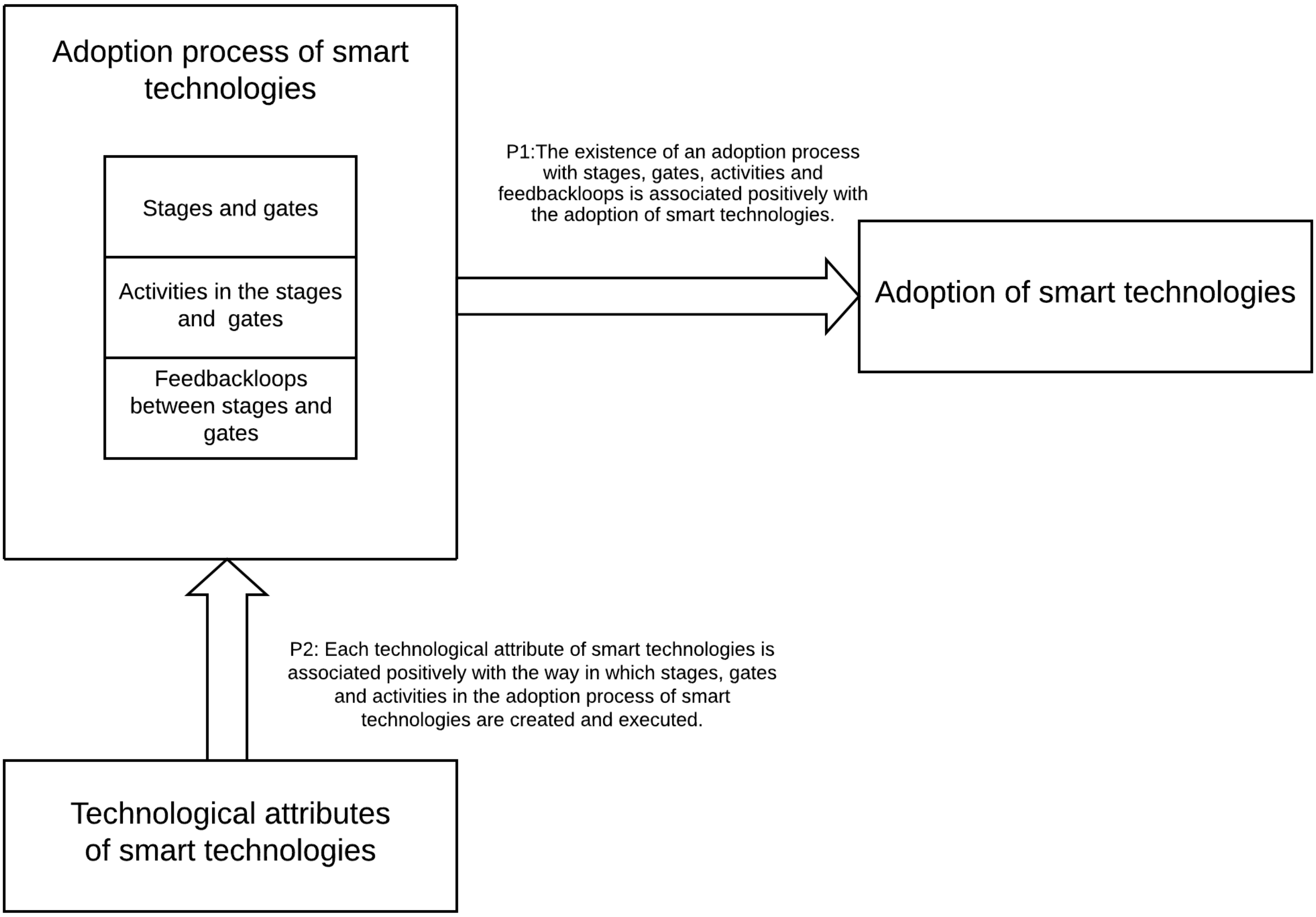
1) The existence of an adoption process with stages, gates, activities and feedback loops is associated positively with the adoption of smart technologies.
2) Each technological attribute of smart technologies is associated positively with the way in which stages, gates and activities in the adoption process of smart technologies are created and executed.

The first proposition is based upon both the models of Hameed et al. (2012) and Cooper (1990) since both models contain stages and activities. However, this study relies more on Cooper (1990) regarding this proposition. Cooper (1990) considers stages, gates, detailed activities and feedback loops whereas Hameed et al. (2012) only mention a few phases and activities. The second proposition is based mainly upon Hameed et al. (2012) since technological attributes are not mentioned explicitly by Cooper (1990).
However, the model of Cooper (1990) proved more useful in assigning technological attributes to certain stages and gates of the adoption process. It is believed that the technological attributes of Hameed et al. (2012) and the technical requirements of innovations

described by Cooper (1990) match sufficiently to assign the technological attributes to certain stages and gates.

The constructs and the propositions concerning expected relations between these constructs are displayed in the research model in figure 2. The definitions of the three constructs and concepts/components they entail, as displayed in the research model, are presented in appendix 9.

Figure 4. Research model with propositions



4. Research method

In this chapter, the research methodology of this study is explained. The research design is explained first and after that the data collection method, sampling method and the method for the data analysis are addressed. Finally, a reflection on the methods used in this study is provided.

4.1 Research strategy

This explorative study provides a more detailed insight into the role technological attributes play in the different stages and gates of the adoption process in the adoption of smart technologies by means of a qualitative research method. Research on this topic is nascent (Edmondson & McManus, 2007) and consensus in views and definitions on this topic are lacking, as mentioned before. This study is in this light best to be seen as an open-ended inquiry about a phenomenon of interest and therefore, a qualitative approach is considered to be the best methodological fit (Edmondson & McManus, 2007). In qualitative research, a researcher studies things in their natural settings, attempting to make sense of, or interpret phenomena in terms of meaning people bring to them (Denzin & Lincoln, 2005).

4.2 Research design

The goal of this study is to explore the adoption of smart technologies in the Dutch manufacturing industry in order to deepen and enrich existing theories on innovation adoption. To do so, the research method of this study is founded on the grounded theory. The grounded theory aims to develop a theory that explains a process, action, or interaction. The theory is 'grounded' in data obtained (Corbin & Strauss, 2012). The grounded theory enables to gain a deeper insight into phenomena, which makes it suitable for the modification or deepening of existing theories as well. Therefore, the grounded theory can be used in a study when the goal is to explain an organizational phenomenon while literature on this topic is scarce (Corbin & Strauss, 2008). On the other hand, multiple cases are compared in this study, which is the key character of a multiple case study. However, a case study implies that data is analyzed on multiple levels and multiple methods of data collection are used (Boeije, 2012). In this study, analysis takes only place on one level (firm level) and the conducting of interviews is the only data gathering method. In addition, this study aims to explain how the design of the adoption process leads to the adoption of smart technologies while this topic hardly has been examined yet. Therefore, the grounded theory is believed to be the best methodological fit.

The focus in this study is on pattern identification which is typical for qualitative, inductive research (Creswell & Plano Clark, 2007). Pattern identification enables the deepening of existing literature. On the other hand, this study has a deductive feature as well because some propositions are formulated (Creswell & Plano Clark, 2007). The grounded theory combines features of both deductive and inductive research (Corbin & Strauss, 2008, 2012). In line with the grounded theory, this study is explorative in nature and characterized by a flexible and iterative approach. The propositions are not tested in a quantitative, but in a qualitative way. They express the expectation of the researcher based on a literature research and they contribute in the way data is gathered. The propositions are leading in the formulation of the interview script and the creation of codes. This study relies on qualitative data obtained from explorative interviews (Boeije, 2012). The insight provided by coding and analyzing the data obtained from interviews are used to contribute to existing literature. The contribution of this study is to specify the theories of Hameed et al. (2012) and Cooper (1990) to be able to analyze the adoption of smart technologies. So, this study deepens and enrich these two theories.

4.3 Qualitative research interviews

Semi-structured interviews are conducted with people that work in manufacturing firms in the Netherlands. Semi-structured interviews are characterized by thorough preparations which lead to a list of topics and/or questions that have to be addressed during the interviews (Boeije, 2012). Respondents from different firms in different sectors have been interviewed to get a complete and representative view of the whole manufacturing sector.

4.4 Operationalization

The semi-structured interview format consisted of an introduction and four topics. In the introduction the study and the interview format were explained. The respondents were asked what smart technologies are implemented in the recent past and which one is the most relevant or typical for the firm. After that, the respondents were asked what the stages and gates look like and what activities took place in these stages and gates. In addition, an attempt was made to find out who is responsible for which stages, gates and accompanying activities in the adoption process. Furthermore, respondents have been asked about what technological attributes they believe are important for which technologies in what specific stage of the adoption process. The interview script in Dutch can be found in appendix 10.

4.5 Sample

In order to improve the credibility of this study, multiple sampling methods were combined (Patton, 2002). Both the convenience sampling and snowball sampling method were used in this study. Both methods are examples of purposive sampling (Patton, 2002). Purposive sampling means selecting targeted research units from a population with certain characteristics (Boeije, 2012). When convenience sampling was used, potential respondents were identified, contacted and included in the sample on a first-come-first-served basis until the sample size was saturated (Patton, 2002). The point of saturation is achieved when no new relevant information will be obtained from interviews (Boeije, 2012). It was believed that, after conducting eight interviews, a ninth interview will not provide completely new insights that are relevant to provide an answer on the research question. The reason is that the eighth interview did not provide with completely new and striking insights. In total, nine respondents have been interviewed. At firm 7, two respondents have been interviewed (Respondent 7a & 7b), because the second respondent had some additional and valuable information on the adoption processes of this firm.

Several conditions were set on firms that were about to be interviewed, a characteristic of purposive sampling. The most important one was that the firm in question is involved with the adoption of smart technologies. Other conditions were that firms had to be in the Netherlands and the firm had to fall in the so called ‘MKB+’ category, a Dutch abbreviation for ‘Middle/Small Firms+’ with 50-100 employees. The reason for this is that the amount of smart technologies applied increases with the number of employees within a company (van Helmond et al., 2018b). So, smaller firms lag behind in the amount of adopted smart technologies.

After the determination of the scope of relevant firms, possibilities to interview respondents within firms in different ways were assessed. First of all, the network of the researcher was used to get in contact with relevant firms. Direct and indirect contacts were approached via social media like LinkedIn with the question whether people know firms that are busy implementing smart technologies. Besides, organizations that provide firms with advice regarding the adoption of smart technologies were contacted by email and telephone. They have been asked whether they had useful connections. The same question was asked to respondents who were interviewed: a snowball sampling method (Patton, 2002). Furthermore, the researcher obtained a list with random firms of his supervisor. Many of these firms have been called for an interview in a random order. The combination of these sampling methods resulted in eight interviews. During the interviews, smart technologies were referred to by technologies that are associated with digitalization, automation and robotization. The reason for this broad description is that respondents turned out to be hardly familiar with the term SI and confused terms like digitalization, digitization, automation and robotization.

4.6 Enrolment respondents

The respondents were interviewed face to face and in their mother tongue. In two interviews, two respondents took part in the interview. In the first interview, a second respondent gave some more specific information about the implementation of an ERP system at the end of the interview. However, this obtained information hasn't been used in this study because this information is beyond the scope of this study. In the second interview, the interview was continued on the telephone with another respondent of firm 7 who knew more about the adoption process of the specific technologies that were assessed in the first part of the interview.

4.7 Data analysis

When the interviews were transcribed, quotes in the transcripts were coded using the coding application Atlas.ti. The coding method in this study was based on two coding methods: Eisenhards' template (Eisenhardt, 1989) and Gioias' methodology (Monin, Noorderhaven, Vaara, & Kroon, 2013). Eisenhardt (1989) propose a closed coding method based on propositions from theory and the Gioias' method provide means for open coding (Gioia, Corley, & Mamilton, 2012; Monin et al., 2013). This combination of coding methods enabled to code all the information that is considered relevant.

In line with Eisenhardts' template (1989), the first step was the creation of a code list with five constructed codes which was leading for the coding of the transcripts. These closed codes are based on the theories of Cooper (1990) and Hameed et al. (2012) and form the topics in the analysis chapter. These codes are:

1. Adoption of smart technologies.
2. Adoption process of smart technologies.
3. Technological attributes of smart technologies.
4. Relation between technological attributes and adoption process.
5. Relation between adoption process and adoption of smart technologies.

The second step was the coding itself. Closed and open coding were conducted simultaneously. In-vivo/open codes were created for quotes that turned out to be relevant because the codes were mentioned often by respondents while there was no code available in the code list for these quotes (Gioia et al., 2012; Boeije, 2012). These so-called first order codes were created with an open mind rather than applying pre-existing categories to the data (Gioia et al., 2012). Thereafter, second-order themes were used in order to make and understand connections between categories and their subcategories, just like Gioia et al. (2012) prescribes. These second order themes were in turn summarized in aggregated dimensions. These dimensions are the same as the existing topics that were created already. The topic ‘others’ was created for quotes that did not fit in existing topics, but that might add value to the conclusions drawn in this study and for sensitizing concepts that are more abstract than individual fragments (Boeije, 2012). The latter could be useful in later phases of the coding process (Boeije, 2012).

Finally, after the process of coding the transcripts, overlap between the first three categories were assessed in Excel. The quotes that show overlap between two variable categories were placed in the corresponding relation category. After that, the quotes were rated in terms of relevance. The relevance of the quotes was determined by the extent to which the quote in question represents a similarity or difference between theory and practice. The relevance of the quotes is rated by means of the values 1-3. 1 = very relevant, 2 = relevant, 3 = a bit relevant. The differences and similarities between the propositions from the theory and the obtained empirical data are described and analyzed in the analysis chapter.

4.8 Reflections

In order to maximize the quality of this study, multiple measures have been taken. These are mainly related to the formulation of the research model and propositions, data collection and peer reviews. Four different quality criteria for qualitative research were taken into consideration to ensure reliability (dependability) and validity (credibility, transferability and confirmability). Reliability/dependability concerns the consistency of the findings (Lincoln & Guba, 1994). There are two types of validity: internal and external validity. Internal validity concerns credibility which means the explication and justification of research inferences. In other words, credibility is achieved by subjecting the research material to validity checks (Lincoln & Guba, 1994). On the other hand, external validity concerns generalizability which entails transferability and confirmability (Lincoln & Guba, 1994). Transferability means providing a rich and detailed descriptions of context. Objectivity is achieved through confirmability, which means that the researcher is free from bias (Lincoln & Guba, 1994).

The reliability of the study was maximized by the formulation of a semi structured interview guide that has been used at all the eight interviews. Using the same method during each interview improves the chance that the findings are consistent and therefore increase the reliability of the study. Internal validity/credibility was maximized by peer reviews, reflexivity and theory triangulation. By means of peer reviews the production of data is made transparent leading to feedback and reflection. Peer reviews took place in the form of consultation session with the supervisor of the researcher and multiple other scholars. In these sessions the research data, goals, methods and decisions made by the researcher were reviewed. During these sessions, the researcher was provided with feedback. Gaining feedback contributed to the researchs' ability to reflect on himself and his own actions and decisions. Theory triangulation has been applied by combining multiple theories and models in the theoretical framework of this study (Guba, Lincoln, & Denzing, 1994). Regarding external validity/generalizability, transferability is ensured by describing the basis upon which the used theories in this study have been build. On top of that, transferability is increased by including the importance of other attributes then technological ones in the analysis and firms' future plans regarding adopting smart technologies. All these measures combined lead to a minimization of bias. However, confirmability, and a complete prevention of bias, is never ensured because the researcher himself is involved in the study (Lincoln & Guba, 1994). This bias can be mitigated at most. In this study, this bias is mitigated by peer reviews and interpretative validity is applied by rephrasing answers of respondents in the researchers' own words to check if the respondent has been understood correctly.

5. Analysis

In this chapter, insight is provided into the extent the technological attributes contribute to the existence of stages, gates and progress across stages in the explanation of the adoption process of smart technologies of Dutch manufacturing firms. In order to provide an answer to the research question a comparison is made between definitions, expectations and propositions based on theory and the results of the analysis of qualitative data. First of all, a brief description is made of the firms and the respondents that have been interviewed. Then, it is explained how the results are analyzed, followed by the actual analysis. Finally, in the epilogue, the analysis is summarized and an altered version of the research model is provided. In this altered version, the propositions are replaced by conclusions of the analysis.

5.1 Descriptive respondents

The focus of this study is on middle/small firms. Eight firms have been examined; six out of these eight examined firms are considered being middle/small. Two respondents of business units of larger firms have been interviewed as well. The size of the examined BUs of these two firms were of the same size as the other six firms. Three of the eight interviewed firms are in the province Zuid-Holland. Two other firms are in Gelderland and the remaining firms are in the provinces Flevoland, Noord Brabant and Friesland. All the firms are active in different sectors and the size of the firms/BUs varies from 42 to 250 fte. An elaborate version of the descriptive can be found in Appendix 11.

5.2 Results

The analysis entails three sections in which six topics are assessed: the three constructs in one section, the two propositions in another section and other relevant findings in the section ‘others’. The topics within the three sections are structured as follows. First, the definition and expectations or proposition of the topic in question is given. After that, the results are described and analyzed. The results are analyzed by means of a comparison between definitions/propositions based on the literature study and the elucidation of the qualitative results from interview quotes. Definitions and propositions are absent in the topic ‘others’, but some expectations exist so a comparison between expectations and results can still be made. The most relevant interview quotes that are described, paraphrased and quoted in the analysis are presented in tables per topic in appendix 12. The rest of the quotes are presented in another Word document because including all the quotes in the appendix would make the appendix too extensive.

5.3 Constructs

The three constructs of this study are analyzed in the following order: the adoption of smart technologies, the process of adoption and the technological attributes of smart technologies.

5.3.1 Adoption of smart technologies

One construct is: ‘smart technologies adopted by firms in the Dutch manufacturing industry’. The adoption of smart technologies is thereby described as the introduction and use of smart technologies. Smart technologies are characterized by autonomy and connectivity, based on the exchange of data via the connection to internet. Together, smart technologies form a smart factory and the connection between smart factories leads to a smart industry. In this section, the status of Dutch manufacturing firms regarding the adoption of smart technologies is assessed.

Qualitative results

Results reveal differences regarding how often different smart technologies are adopted. The adoption of robots and cobots is mentioned most often (Respondent 2, 3, 4, 5, 6, & 8). The use of mobile devices is mentioned by multiple firms (Respondent 1, 3, 6, & 7). IoT is only mentioned explicitly by respondent 1. Respondent 7b implies the connectivity between machines by means of IoT: “[...] *the filling machine and the conveyor belt. They talk to each other, that is in line with each other*.” (Respondent 7b). IoS is mentioned by any respondent explicitly. The use of cloud technology is mentioned by one respondent. At this firm, a cloud of another firm is used, but they aim to adopt their own cloud (Respondent 1).
Respondent 4 mentioned the plan to adopt AGVs; automated guided vehicles.
Striking is that firms struggle with both the definitions of smart industry and smart technologies and the adoption of smart technologies (Respondent 5). Results show that every respondent has another idea of how successive developments regarding automation, digitization, digitalization and smart technologies are called and look like. Digitization for example is sometimes mistaken for the adoption of smart technologies and vice versa. Respondent 7a describe the step towards smart technologies well in the following quote: “*We can put the PLCs together in one PLC, we have an ERP system. So, we are looking how we are going to make all this workable and only then you will come to make things Smart.*” (Respondent 7a). Centralization of PLCs enables the adoption for AI for example

(Respondent 7a). However, this centralization is a huge investment and the only result is a fully automatic control system, which is not smart in itself (Respondent 7a). So, there are problems to be tackled when adopting smart technologies.

The integration of smart technologies leads to a smart network and ultimately to a smart factory. The combination and integration of different smart technologies is something that is considered important by almost all the firms (Respondent 2, 4, 5, 6, 7, & 8). A network of smart technologies is absent yet, but respondents recognize the potential opportunities the creation of a smart networks provide. The creation of an integrated smart network and the smart automation of logistics turns out to be difficult, even more difficult than the implementation of the smart technologies itself (Respondent 4 & 6). A quote that reveals this struggle well is the following: "*Well, what I actually already started with was the fact that the use of a robot is not so much the difficulty, but the entire logistical process around it*" (Respondent 6). To create a smart network, a firm need to invest proper software solutions between single technologies.

The connection between smart factories lead to a smart industry. This idea to form sector wide networks is mentioned by one respondent explicitly. "*We need someone who sees the whole picture and brings it all together. Why has this not been done already?*" (Respondent 2). Compatibility problems regarding software, data and ERP systems need to be tackled first to integrate logistic systems (Respondent 3) and to form a smart industry in the end.

Discussion results

In this section, the adoption of smart technologies as defined and quoted is discussed. In addition, expectations regarding the adoption of smart technologies are compared with associated quotes. It is expected that not all smart technologies are adopted equally often. Thereby, firms are expected to lack an integration of smart technologies. In other words, smart networks are expected to be absent. It is expected that some smart technologies are adopted more often than others. Realtime production control, additive manufacturing and systems for the automation of logistics are expected to be adopted most often and mobile control devices, IoT and CPS least often. Digital technologies are expected to be even more common, but these are not smart. Results show both similarities and differences with the theory on the status of smart technology adoption.

One similarity is about the extent in which smart technologies are adopted. Firms use digital and automation technologies to obtain data to facilitate the connectivity between machines, as expected. Results show that almost every firm has an ERP system and PLC systems for example. These technologies are considered not being smart in themselves by respondents, but they are believed form the foundation of smart technologies. Another similarity is that smart networks are scarce because of connectivity issues. Firms often lack a good foundation for the adoption of smart technologies and the creation of a smart network. In other words, the third revolution often has not been completed for many firms while they join the fourth revolution (Respondent 6 & 7).

The amount of adopted smart technologies in practice reveal differences with expectations based on the theory. Firms are further regarding the adoption of smart technologies than they think. IoT and CPS are adopted more often than expected based on the literature study, but they are not mentioned explicitly. Robots and cobots are adopted the most, 3D printing and mobile devices for programming, operation and installations and machines follow as expected. IoS is adopted less often than IoT and CPS. An example is cloud technology. In some case this technology is used in collaboration with a business partner. IoS is closely related with the creation of a value chain since it has to do with collaboration with suppliers, customers or other partners in the production chain. Firms do have plans to adopt this kind of smart technology, but they struggle with compatibility problems between firms' software systems as expected. Applications of smart technologies advanced analytics of big data, cyber security and virtual- and augmented reality were not mentioned by any respondent.

To conclude, firms have made more progress regarding the adoption of smart technologies than they think. However, some firms do not have a solid basis for the adoption of smart technologies. These firms are still involved in the technologies that are typical for the third revolution: automation, digitization and digitalization. Results also reveal that some smart technologies are more often adopted and others less often than expected. In addition, the adoption of smart technologies itself is not the biggest problem, but the connectivity of smart technologies between themselves turn out to be the largest challenge. The connection of smart factories into a value chain is a challenge as well since firms use different systems. The next section will elaborate on the process underlying the adoption of smart technologies.

5.3.2 The process of adoption of smart technologies

The adoption process of smart technologies is another construct of this study. This process is described as a process with stages, gates, associated activities and feedback loops progressing from initiation to implementation, leading to the introduction and use of a smart technology. Consecutively, this section addresses the way in which Dutch manufacturing firms shape their adoption processes of smart technologies.

Qualitative results

The eight examined firms are all at a different point in the adoption process at the time of interviewing. All firms, except firm 7, have adopted at least one smart technology. Firm 7 is still in the orientation phase of the adoption process of smart technologies (Respondent 7a). Respondents describe the adoption process as a continuous, ongoing process characterized by a lot of trial and error. Respondent 1 states: "*It has really been a long process. A lot of trial and error, but in the end, you have a signal that you need to act on, only the way in which little has been documented. Trying, trying, trying a lo*t" (Respondent 1). Smart technology adoption entails three options: acquire, develop or a combination. The choice to buy or develop influences the design of the adoption process because a technology supplier can become a design or consult partner and can even participate in the project team when a firm decides to develop. A good example of a collaboration with a partner is provided by respondent 3. "*Yes, that is why we are now working with that party, [company], who guides us in this. They have a project leader, they document* […]. *They also take care of the breakdowns after five hours*" (Respondent 3). Six firms buy a smart technology and four firms choose to develop the smart technology in question themselves. Three firms choose to combine the acquisition and development of a smart technology. In these cases, firms acquire a smart technology and customize it. Reasons are that the needed technology is not for sale or that software need to be developed to connect the technology with existing technologies at the firm (Respondent 1, 5, & 6).

Overall, results reveal 78 stages, gates activities that are associated with the adoption of smart technologies, most of them stages/stage related activities. The existence of stages and gates as defined in this study are mentioned rather implicitly than explicitly. The stage related activity 'evaluation' is mentioned most often: seven times. Actual implementation of a smart technology follows being mentioned six times. Respondent 8 provides with a good description of how implementation could look like in three phases: "[…] *the first phase is installing a machine and seeing what has been delivered well, whether it meets the* *requirements.* […]. *The second is going into learning the machine and eventually releasing the process for production.* […] *Then you have a third phase that runs much longer.* [This phase concerns the question if] *did it indeed yield what we set out at the beginning?.* [If that is not the case], *then you have to adjust something*." (Respondent 8). Other important activities being mentioned often are the decision to 'go/kill', fine-tuning/optimization the smart technology in question and the training of employees. These are followed by research, visiting a fair, brainstorm sessions, testing, the development of the smart technology itself and the actual adoption decision. After the implementation, firms tend to start with the production as soon as possible, but finetuning is perceived as important too and it can take quite some time. In addition, work processes need to be updated too (Respondent 8). For example, employees need to be trained to enable them to work with the new technologies (Respondent 1, 2, 5, 6, & 8). Firms distinguish only a few clear gates which are mainly characterized by decisions and evaluations. When a decision is made, is it almost always a decision to go on with or kill a project or regarding the acquisition/development of a technology. However, the decisions hardly can be called gates. During the meetings in which these decisions are made, new activities are formulated which is a stage activity. This is shown well by the following quote: "[...] *then we just put the heads together and take a look at the drawing. This is going on, identify incidents, calamities, claims or capacity issues. Make a decision in that very hour, ready, incest, go, involve others, follow through, that is it*" (Respondent 4). By 'putting the heads together' the respondent means an informal consultation meeting. Besides, decisions are often made fast and ad hoc. Respondent 5 provides with a good example: "*It will probably be discussed in the workplace, say, cut a knot and made immediately, if it is an improvement*" (Respondent 5). 'To cut a knot' is a Dutch proverb which means 'making a decision'. Respondent 5 explains that sometimes decisions are even made by telephone. The speed of decision making is perceived being important and seems to have as a result that firms forget about documentation. Overall, every firm shows a sequence of adoption phases (stages and gates) and activities. The following specific sequence of stages is mentioned most often: brainstorm sessions, making a project planning, collaboration with a partner/supplier of a smart technology, testing, revising, the actual implementation of a smart technology and training of employees.

Furthermore, results show multiple forms of revisions in the adoption process. Sometimes they take place within a stage and sometimes between stages and gates, which leads to feedback loops. Revisions takes place within the test/validation stage, engineering/development stage and the 'fine tuning' stage. Results show that a feedback loop is present at four firms (Respondent 2, 4, 5, & 6). A feedback loop is implied by respondents 7a and 7b and is perceived as a possibility by respondent 8. Feedback loops mainly take place after the evaluation of a design/adoption proposal (Respondent 4, 5, & 8), development work (Respondent 2), test results (Respondent 5 & 6) and after an audit with customers (Respondent 8). A feedback loop after the presentation and evaluation of a design leads to a redesign (Respondent 4, 5, & 8). In addition, the evaluation of a proposed planning can lead to a feedback loop and the formulation of a new planning (Respondent 8). A feedback loop after the evaluation of test results could bring the project back to the development stage (Respondent 5 & 6). An audit with customers can lead to a feedback loop back to the development stage when customers do not agree with the product quality due to the innovation (Respondent 8). An example of a feedback loop after the evaluation of development work leading to a return to the design stage is provided by respondent 2. "[...] *we really had to take a step back when it comes to quality welding, in which we certainly could not address the roughness and really had to adjust the extrude. At that moment you actually go back an engineering phase to redesign again in the development at the drawing board*." (Respondent 2).

Finally, four out of the eight examined firms composed a project team for the adoption of smart technologies (Respondent 2, 3, 6, & 8). Project teams are often multidisciplinary and characterized by an informal culture. Some firms include employees of a partnered firm that helps them adopt a certain technology in the project team, firm 2 for example. At firms where a project team is absent, the projects were led by one or two persons. So, the creation of project teams is the only important factor that is reflected in the results. The moment at which a project team is composed differs per firm. Two firms composed a project team at the start of the adoption process (Respondent 2b and 6). At one firm a project team was composed after the proposal was approved (Respondent 8). At another firm, a project team was composed after the robot has been bought (Respondent 6).

Discussion results

To discuss the adoption process as defined and as quoted, a comparison is made between definitions of the core components of the adoption process and associated expectations on the one hand and quotes on this topic on the other hand. Some expectations regarding the adoption processes of smart technologies at Dutch manufacturing firms are formulated in this study. One expectation is that projects lack so-called home-work activities like a good initial screening and definition of the project. Another expectation is that project is initiated based on little information and no formal criteria (Cooper, 1990). It is expected that (crucial) evaluations are often weak, deficient or even absent (Cooper, 1990). Combined with the expectation that projects are rarely killed, it as expected that there is a lack of feedback loops as well. Finally, adoption processes are expected to lack documentation activities. Result show both similarities and differences with the theory on adoption processes.

Five similarities between expectations and results have been revealed. These similarities concern mainly home-work activities, evaluation and documentations. The first similarity is that the three prescribed home-work stages and gates hardly appear in the results. Home-work activities like research, screening and defining the project were scarce. Only one firm rate and rank projects but perceived these projects as phases of one adoption process. Associated activities with project scoping like search for alternatives, contact with key users, patent search and identification of resource gaps (mainly lack of floor space) and financial calculations are mentioned once. The only ‘home-work’ activities that are mentioned regularly were the visiting of fairs, research and brainstorm sessions about appropriate solutions for identified problems. Activities like screening and making inventories of the firms’ needs, customers’ demands, market research, project definitions and setting goals are rarely mentioned by respondents. Doing research is mentioned more often. The design of a concept plan and the formulation of a proposal takes place is mentioned multiple times, so this seems to be the main starting point for firms. This the first stage where results shows some similarities with the adoption process formulated in this study. The decision to commit resources is also mentioned by firms, mainly in terms of approving a concept proposal/design. So, results show that firms have a short home-work phase which entails only a few activities. The second expectation concerns the lack of documentation. Results confirm this expectation. Documentation is mentioned only two times. The third expectation about evaluations is confirmed only partially. Evaluation activities are mentioned often, but at all firms, only a few evaluations activities are distinguished. Evaluations are mainly about proposals, designs, offers form technology suppliers/partner and test results. There are hardly any evaluations on the project itself. To conclude, the expectations regarding feedback loops and how often projects are killed are confirmed as well. As expected, projects were rarely killed as expected. Two respondents mention a killed project. In addition, results reveal only a few feedback loops. Four feedback loops are distinguished at four firms.

However, results reveal some differences with the expectations as well. Two differences between results and theory are found regarding the test and implementation phases. The first difference is revealed in the testing phase. The testing stage is well represented in the results.

However, in practice this stage contains more activities than in theory. The testing stage entails testing, trial production, audits and fine-tuning. Results also reveal a difference with the theory about employees get training to enable them to work with the new technology. This activity is considered important by many respondents. Training often takes place somewhere between the adoption decision and the implementation. However, in theory this is not mentioned at all. In practice, the borders between testing, evaluating test results and implementation are vague. It is not clear when the actual production by means of the new technology starts for example. In some cases, the new technology also needs to be connected to machines already present at the firm.
Results also provide striking findings that are not expected. These findings are about the adoption decision, the phases that immediately follow this decision, project teams, parallel activities, amount and sequence of phases and borders between phases. Firstly, not all firms distinguish an explicit adoption decision. The decision to adopt/reject is mentioned five times explicitly. Regarding the stages and gates between the adoption decision and development/implementation, the only associated activities that are mentioned by respondents is the actual development or the acquisition of the smart technology in question and the smart technology on completeness and quality. Another striking finding that is not expected is that only four out of eight firms have a project team. In addition, only one firm explicitly mention parallel activities. Overall, results reveal that firm distinguish multiple consecutive phases in the adoption process of smart technologies, but firms have less stages and gates than expected. Stages often contain only one activity and borders between stages and gates are not always clear.

To conclude, adoption processes in practice are characterized by trial and error. Clear stages are distinguished, but adoption processes lack clear gates. Borders between stages and gates are unclear and the adoption process is seldom structured. Even the adoption decision gate is not mentioned explicitly by respondents. Evaluations, implementation, go/kill decisions, fine tuning, training of employees are the stages/gates/activities that are mentioned most often by respondents. Adoption processes lack home-work and documentation activities as expected. Evaluations are more common than expected, but they appear only a few times at each firm. The testing stage turns out to be an elaborate stage with more activities than expected. The implementation stage is broad and the importance of training turn out to be overlooked in the literature. Finally, projects are rarely killed and feedback loops are scarce. When these loops exist, they occur around the design and testing stage.

5.3.3 Technological attributes of smart technologies

The third and last construct in this study is: ‘the technological attributes of smart technologies’. These attributes are factors and/or features specific to smart technologies taken into consideration when adopting smart technologies. The five technological attributes of smart technologies that are distinguished by Hameed et al. (2012) are: complexity, compatibility, observability, trialability and relative advantage.

Qualitative results

Results reveal that the technological attributes ‘complexity’, ‘compatibility’ and ‘differential/relative advantage’ are perceived as important attributes by all respondents. Observability is mentioned by six out of eight respondents and trialability is mentioned by only five respondents. Observability turns out to be an important technological attribute for respondent 1, 2, 5, 6, 7 and 8 and trialability is considered important by respondent 1, 2, 3, 6, and 8. Respondent 4 mention complexity, relative advantage and compatibility. Respondent 3 adds trialability to this list while respondent 5 and 7 mention observability on top of these three technological attributes. The technological attributes that are mentioned most often are assessed first.

The differential/relative advantage of a smart technology is about a comparison between options and it means that the idea to adopt a particular smart technology is better than the one it supersedes. Relative advantage turns out to have multiple forms. First, the relative advantage can be revealed in terms of costs and payback models. “*What are you going to win with this technology, also in terms of costs. How high is the investment and how or what do you expect to win back? Well, I think mainly that, what will this ultimately yield? Is it fun or does it really help us?* (Respondent 7). Another form of relative advantage lies in the ability to connect a new smart technology to technologies already present within the firm (Respondent 2). An example is a trade-off between buying a new machine with a data analysis tool or giving old machines an upgrade and miss out on the data analysis tool (Respondent 1).

Complexity entails the difficulty to implement, use, maintain and replace (parts of) smart technologies and how quickly malfunctions can be remedied (Respondent 2, 3, & 6). Insight into the importance of complexity is provided by respondent 6. It is evident that a smart technology must not be too complex from the following quote: “[…] *easy to implement, that was the underlying idea* [...]” (Respondent 6). On the other hand, a smart technology can also be too simple. Respondent 6 indicated that at his firm a system was acquired that was meant for multiple purposes. However, this system turned out to be too simple to fulfill all those

purposes. However, a complex smart technology is often expensive. A trade-off between complexity and costs is important (Respondent 6).
Compatibility of a smart technology with the existing values, past experiences, and needs of a firm is important. An adopted smart technology needs to be compatible with the firm philosophy (Respondent 6). In addition, the adopted technology needs to be able to deliver the required performance. "*Anyway, it must fit within our product range and everything the old line can do, the new line must also be able to do.*" (Respondent 8). Compatibility is taken into consideration by respondent 2 as well. A technology needs to be compatible with the firms need which originate from the product specifications (Respondent 2). Relative advantage, complexity and compatibility turn out to be related in the following quote: "[...] *having a machine is not only about placing a machine but also about maintaining it. Placing a machine means training people who understand it and who can work with it, so you must rig a lot to make a line profitable*" (Respondent 8). In this case, multiple options are compared. In this example, relative advantage is revealed in terms of profitability. Complexity lies in the fact that people must be able to work with the machine, so it must not be too complex. In addition, the firm needs to have the resources to handle a machine properly, which implies the importance of compatibility of the smart technology with the characteristics of the firm.
Observability concerns the degree to which the results of a smart technology are visible to others. The observability is expressed in terms of whether a smart technology is proven to be useful, measurable improvements in the production, pay back and the traceability of products (Respondents 1, 6, & 7). The importance of observability is described well by respondent 2. "[...] *the long-term impact, what difference it makes in terms of product flows and quality. A human is only human, a robot can deliver consistent quality.*" (Respondent 2). Trialability of a smart technology is the degree to which a smart technology may be experimented with on a limited basis.
Trialability is described as the extent in which a smart technology can be experimented with. It is about possibilities for trial and error when implementing and getting used to the smart technology in question (Respondent 1 & 6). Respondent 8 puts it in another way: "[…] *the devices are delivered so they have been able to play with it for several weeks now.*" (Respondent 8).

Results show that many other technological attributes specific to smart technologies are considered by respondents on top of the main five described by Hameed et al. (2012). The most important ones are efficiency, quality, safety and flexibility/application possibilities.

Other technological attributes like robustness, technological compatibility, speed, sustainability, technological features in general and perceived utility of technology are mentioned only a few times. Only the most relevant technological attributes are assessed. Efficiency of a smart technology is mentioned explicitly most often; seven times. Efficiency forms the basis for one of the considered ideas regarding the adoption of a smart technology by respondent 2a. She states the following: "[…]*it makes sense that they are, of course, efficiency-based.*" (Respondent 2a). The importance of quality is twofold. Respondents make a distinction between the quality of the technology itself and the quality of the products it helps producing (Respondents 2 & 4). Flexibility can be about the ability to make the required moves (Respondent 2) but is more often more about application options (Respondent 3, 4, 5, 7a, & 8). Sometimes, trade-offs and combinations of between attributes are made. Speed appears to be an important technological attribute of smart technologies as well. Because sometimes a robot needs to be able to make fast movements, but speed can be a safety risk to people working with this robot. This leads to a trade-off between speed and safety. Respondent 4 illustrate this trade-off well: "[…] *it is a collaborative robot, so the approach is that it collaborates with humans and then speed quickly becomes a risk.*" (Respondent 4). However, safety is hard to estimate (Respondent 6). Respondent 4 combines the attributes quality and speed in the following quote: "*Qualitatively better but also faster.*" (Respondent 4). The importance of technological compatibility is described well by the following quote: "*Important factors are of the logistics around it, so you should only want to do each movement once.* […] *It is quite difficult to do that right the first time.*" (Respondent 4).

Discussion results

The technological of smart technologies as defined and quoted are discussed in this section. In addition, the expectations regarding the importance of these attributes are validated. It is expected that all main five technological attributes (complexity, compatibility, observability, trialability and relative advantage) are important when adopting smart technologies. Based on Hameed et al. (2012), it is expected that relative advantage is the most important, followed by complexity and compatibility. Observability and trialability are expected to be the least important.

Similarities and differences exist between expectations and results regarding the importance of technological attributes. A similarity is that results show that relative advantage, complexity and compatibility are considered being relevant by all respondent while observability and trialability are mentioned less often. So, the expectations regarding the

importance of the main five technological attributes are confirmed by the results. The expectation that some other technological attributes being mentioned more often than the main five technological attributes is partially confirmed. Based on theory, it is expected that safety appears more often in the results then some of the main five attributes, but this turns out to be efficiency and quality. Efficiency appear more often in the results than observability and trialability. In addition, quality is more common than trialability. On top of that, flexibility/application possibilities and safety appear as often as trialability. Safety is not mentioned more often than trialability and observability.
Results show striking findings that are not necessarily expected as well. A striking finding concerns technological compatibility attribute. The technological compatibility of different technologies is about the ability to connect the technology to other machines and integrate it into the production line. This attribute is perceived as being important by only four respondents, half of the respondents. This is a striking result because many respondents seem to struggle with the alignment of multiple different machines. So, one could expect that this attribute is taken into consideration when adopting a smart technology more often then appears from the results. Finally, technological attributes turn out to be associated with other attributes. This association is assessed in the topic ‘others’ since results about other attributes are not the focus and the results on these attributes needs to be elucidated first. One difference is that all five technological attributes are expected to be considered important in the adoption process of smart technologies. However, results review that only three out of three technological attributes are considered important by all respondents. These are complexity, relative advantage and compatibility of smart technologies. Observability is mentioned six times and trialability only five times. Another difference is that Hameed et al. (2012) provides a broad definition of these attributes while managers mention these attributes implicitly, but in a more detailed way.

To conclude, five technological attributes are distinguished in this study: relative advantage, complexity, compatibility, observability and trialability. Based on Hameed et al. (2012) it is expected that all five technological attributes are important, but do not appear equally often. Relative advantage is expected to be most important. Complexity and compatibility are expected to be more common then observability and trialability. Results are in line with the expectations. It appears that the first three are considered being important by all respondents and that observability and trialability are less common. Trialability is mentioned least often. Some technological attributes turn out to be even more common than observability and trialability. These are efficiency and quality, not safety as expected. So, the expectation that other technological attributes than the main five are more important than observability and trialability is partially confirmed. Finally, respondents make trade-offs between and combinations of different technological attributes. Some technological attributes turn out to be related.

5.4 Relations

Insight is provided into the extent in which smart technologies are adopted, what adoption processes of smart technologies at Dutch manufacturing firms look like and what technological attributes are considered important. Two propositions about relations between the three constructs are formulated and presented in the research model. In this section, these propositions are validated.

5.4.1 Proposition influence adoption process on actual adoption of smart technologies

One proposition concerns the influence of the adoption process on the actual adoption of smart technologies. Based on the literature study, the existence of an adoption process with stages, gates, activities and feedback loops is expected to be associated positively with the adoption of smart technologies. This proposition is verified after the elucidation of the qualitative results.

Qualitative results

Results reveal multiple relations between the existence of an adoption process with stages, gates, associated activities and feedback loops and the actual adoption of smart technologies. These four components of the adoption process lead to (non) adoption of smart technologies and influence the project duration. Non-adoption is always considered to be an unsuccessful outcome, but an adoption is not necessarily perceived as completely successful.

Results show differences between firms regarding the structure of the adoption process. There are differences between firms regarding the extent in which the adoption process is structured, the amount of (successive) adoption phases and activities and the existence/absence of important phases and other elements. In addition, firms differ in the way adoption processes are perceived. Some firms show a delay in the adoption process, which can lead to an adoption being perceived as less successful.

One difference between firms is the extent in which a structured adoption process is designed. Results show that the structure/design of the adoption process influence whether a smart technology is adopted or not. Respondent 7b for example explains that at his firm, the adoption process of a large innovation was split in a lot of small pieces to prevent failures. This approach was believed to lead to adoption. Results show that the absence of a clear structure in a single adoption process and the absence of a clear sequence of stages not necessarily leads to a non-adoption. Respondent 7b provides an example: "[...] *for example, the cobot, that is an interesting innovation, I want to work on it, I consult with the director, I intent to do this and that, should I continue with it or not. And often it is: 'yes, it sounds interesting, sort it out and keep going'.*" (Respondent 7b). In addition, respondent 7b prefer quick, ad hoc decisions which are believed to prevent failures. "*It is not the case that we sit on the moor with eight men, no, very down to earth, bam. In the end I always believe that smaller steps with a great success is more valuable than a large implementation with a lot of failure because it stresses everyone. So preferably divide the project into what is manageable and can be monitored than large projects where the end is lost and becomes a major failure.*" (Respondent 7b). Firm 2 does not have a project team nor an IT manager. In this case, no one is responsible for the adoption process of certain smart technologies and the firm remains stuck in the idea generation phase (Respondent 2). Furthermore, the design of the adoption process has an influence on the project duration and the extent in which deadlines are met. The lack of a clearly defined adoption process turns out to be an explanation for a delay in the project planning and an exceedance of deadlines (Respondent 6). At firm 7, deadlines are very strict, which prevents project delays (Respondent 7b). Respondent 1 mentions the duration of a project on data management and programming. This long-term process is characterized by a lot of trial and documentation is scarce. In practice, it turns out to be difficult to go through adoption stages and gates that are formulated at the start which lead to a lot of trial and error (Respondent 1). Respondent 1 state that his firm does not show explicit delays, but the adoption process takes longer than expected. In short, the design of the adoption process determines whether a smart technology is adoption or rejected. Besides, the process design provides an explanation for delays and the perceived chance of success of an adoption. Another difference between firms concerns the amount of (successive) adoption phases/activities as well. Respondent 1 for example state that the adoption process does not have defined stages. However, the following quote of respondent 1 revealed a relation between the sequence of adoption activities and the adoption of a smart technology: "*First see how you are going to set it up, then collect data, put everything in the system and then train and then finally prepare the system and implement the new system.*" (Respondent 1). Respondent 5 mentioned multiple stages in a specific sequence as well. However, he states that this sequence arises unconsciously and therefore automatically. Respondent 5 distinguish the following sequence to be sure that the adoption will be successful: making an inventory, involving employees and then the acquirement of the smart technology (Respondent 5). Respondent 5 describe another order of stages: submitting a proposal to the board of directors, explain when needed and after that, a decision is often made to buy the technology in question. Overall, respondent 5 believe that it is important to involve employees from the beginning to create a support base. Respondent 5 thereby implies that this approach contributes the to likelihood that a smart technology is adopted successfully. Respondent 7b describe a planned period of revisions on the smart technology with a deadline on which the smart technology was officially implemented. They prioritized activities and focused on the most important one to improve the chance of a successful adoption (Respondent 7b). In short, a specific sequence of phases/activities leads to adoption of smart technologies. In one case, the absence of a specific sequence of phases and activities is believed to lead to an increased chance of a successful adoption.

Results reveal difference between firms regarding the existence/absence of certain adoption phases and activities as well. Both the existence and the absence of certain stages and gates in the adoption process appear to influence the adoption of smart technologies. Respondent 2 implies its own approach to increase the chance of a successful adoption. They collaborate with partners when it comes to the development of a 3D robot, which has led to a successful adoption (Respondent 2). They ensure quality of the newly adopted smart technology by making clear financial agreements with the partner: "*Both parties agreed on 3D robot printing that they would build, test and deliver the robot on the spot, no cure no pay, agreed a fixed amount, which you get when you can move the robot and deliver it while it is working.*" (Respondent 2). In some cases, the absence of certain activities leads to non-adoption. For example, at firm 6, a lack of good home-work activities leads to a decision to kill the project because a project turns out to be not as feasible as expected (Respondent 6). Respondent 1 mentioned a lack of definitions of the phases in the adoption process of IoT, sensor and networktechnology. Respondent 1 state that "*phases were not defined up front*" and that they "*rolled into it*" (Respondent 1). The project turned out to be more difficult and complex then expected and therefore the project was killed (Respondent 1). In this case, the absence of proper home-work activities leads to non-adoption. Another striking finding is provided by respondent 7b. Respondent 7b state that evaluations occur, but he believes that it is most important to have a no-nonsense attitude and to focus on problem solving. Respondent 7b prefer quick ad hoc decisions and believes that it makes no sense to go back one or more stages. In this case, evaluations are not likely to lead to a decision to recycle or kill the project. In addition, brainstorm sessions are absent here, but this does not lead to non-adoption (Respondent 7b). In short, the most imporant findings about the effect of existence/absence of phases on adoption is that the collaboration with a development partner leads to a succesfull adoption and the absence of home-work activities leads to non-adoption in general.

The last difference between firms is about the way respondents perceive the utility of a structured adoption processes with a sequence of steps. Results show the existence of a structured adoption process has both a positive and a negative effect on the perceived chance of a successful adoption (Respondent 5 & 7b). Nevertheless, in both cases the adoption processes show a structured process with multiple sequential steps.

Discussion results

In this section the relation between the adoption process and the actual adoption of smart technologies as proposed and as quoted are discussed. It is expected that the existence of an adoption process with stages, gates, activities and feedback loops is associated positively with the adoption of smart technologies. The chance that an adoption is completed succesful increase when the adoption process is designed in line with Coopers' stage gate model (1990). In addition, feedback loops are expected to increase the chance of a smart technology being adopted since the project gets a second chance instead of being killed. The so-called homework, documentation and evaluation activities in particular are expected to be important for the succeeding of the project. In addition, it is expected that a project was rarely killed when a project made it to the development phase. Therefore, the eventual decision to kill the project is expected to be made mainly in the first stages of the project or at the adoption decision gate.

Results confirm the expectation that when an adoption process that is designed in line with Cooper (1990), the chance the adoption being completed successfully is increased. The relation between the process of adoption and the actual adoption of the smart technology has multiple different forms. The perception on adoption process, the way it is designed, the sequence of phases and activities and the existence/absence of these elements determine whether an smart technology is adopted or rejected. The design of the process is associated with delays and the perveived chance of an adoption to succeed. Even the respondents' perception of adoption processes is associated with the perceived chance of a succesful adoption.

The expectation that the existence of an adoption process with stages, gates, activities and feedback loops is associated positively with the adoption of smart technologies is proved to be correct. A structured adoption process with and a specific sequence of stages, gates and associated activities leads to adoption of smart technologies at five out of eight firms. A lack of structure at the adoption process leads to delays. Despite the fact that not many feedback loops have been found in the results, it is proved that feedback loops prevent the project of being killed. Firms that show feedback loops have not killed any adoption project. Besides, a feedback loop is never followed by a decision to kill. The expectations that a lack of home-work activities in which research is done, the project is defined, a schedule is made, goals are formulated, proved to be an explanation for non-adoption. However, results show that a lack documentation and evaluation activities do not necessarily lead to non-adoption. Furthermore, the expectations about killed projects are partially confirmed. Results confirm the expectation that a project was rarely killed. However, when a project is killed, projects get killed in different stages. Results show rejections at the research stage, technical assessment/experimentation stage, development stage and even after the implementation. Thus, the expectation that project gets killed mainly in the early phases of the adoption process is not confirmed. Finally, results reveal findings that are not expected. An adoption process characterized by small steps and strict deadlines increase the chance of success of an adoption. In addition, poject team members working part time on the project leads to delays.

In summary, results reveal 15 relations between the adoption process and the actual adoption of smart technologies at five firms. In order of importance, the following phenomena are associated with adoption: process design, the existence/absence of stages, gates and activities, the amount and sequence of adoption activities and respondents' perception of adoption processes. An adoption process that lacks a structured design leads at least to delays. Collaboration with a partner when developing a smart technology increase the chance of an adoption being successfully completed. The existence of home-work activities leads to adoption and its' absence leads to non-adoption. Lack of evaluations does not necessarily lead to non-adoption. Feedback loops prevent projects from being killed. Nevertheless, results show that projects can get killed at all times and documentation and evaluation activities turn out to be less important than expected for the adoption project to succeed. The amount of (successive) adoption phases leads to adoption in some cases and to delay in other cases. Results do not show relations between the existence of project teams and parallel activities and the adoption of smart technologies. Overall, most of the expectations about the relation between the adoption process and the adoption of smart technologies are confirmed.

5.4.2 Proposition influence technological attributes on the adoption process

Another proposition concerns the influence of the technological attributes on the adoption process of smart technologies. Each technological attribute of smart technologies (relative advantage, complexity, compatibility, trialability and observability) is expected to be associated positively with the way in which stages, gates and activities in the adoption process of smart technologies are created and executed. It is expected that the technological attributes of smart technologies mainly influence the early stages and gates of the adoption process. After the elucidation of associated quotes, this proposition is verified.

Qualitative results

Results reveal relations between the main five technological attributes and certain specific stages and gates. These relations can be divided in three main categories. They take place at the adoption decision, the early and late stages and gates. Early stages and gates are the ones prior to the adoption decision while late stages and gates take place after the adoption decision. There are some differences between these categories. Technological attributes turn out to be related with 14 early stages and gates. In these 14 stages and gates, 21 relations are distinguished. Results show that all the five technological attributes are related with the adoption decision of smart technologies. 18 relations between technological attributes and the adoption decision have been found. Technological attributes show 5 relations with 4 stages and gates after the adoption decision. So, the five technological attributes of smart technologies mainly influence the early stages and gates and the adoption decision.

All firms consider at least one technological attribute in the early stages and gates. However, there are differences between the firms. An explicit relation between technological attributes and the adoption decision is absent at two firms (Respondent 2 & 8). Relations have been found between technological attributes and late stages and gates at only four firms (Respondent 1, 4, 7b, & 8). Respondent 7b reveal 9, and therefore the most, relations between technological attributes and phases in the adoption process while Respondent 2 reveal the least with 3 relations. Respondent 8 only describes relations in the stages and gates before and after the adoption decision.

Besides the differences between firms, there are some differences between the five technological attributes regarding how often they are taken into consideration by firms.

Complexity is most often associated with adoption stages and gates: 16 times. Relative advantage follows with 14 relations. Results show relations between observability, compatibility and trialability and adoption phases respectively 6, 5 and 3 times. All firms show relations between relative advantage and adoption phases. Complexity is at all firms related to adoption phases except one firm (Respondent 2). In the stages and gates before the adoption decision all attributes play a role except trialability. At the stages and gates after the adoption decision all attributes are considered being important except for relative advantage. Early stages and/or activities at which technological attributes play the largest role are making an inventory of what the firm needs (Respondent 1 & 5), orientation on smart technology options (Respondent 5 & 8), research (respondent 2, 5, & 7) and search for and comparing alternatives (Respondent 2, 3, 6, & 7). When making an inventory and orientation compatibility and observability are important (Respondent 1 & 5) and when doing research, relative advantage is considered being important (Respondent 2, 5, & 7). Research has multiple different forms; market research is an example (Respondent 5). "[…] *market research: what is for sale, which brands, what are the ranges, what can they do, what are the differences, what are the costs?*" (Respondent 5). When comparing alternatives, relative advantage is considered by respondent 2 and 7 and complexity and observability by respondent 6. The adoption decision has different forms. This is because certain questions need to be answered. A smart technology can be bought or developed. Another option is buying a smart technology and adapting it to the firms' needs. So, buying and developing are combined in this case. Besides, a firm can buy a technology and choose to develop the associated software or otherwise. Respondent 6 consider all technological attributes except compatibility when deciding to buy a robot after comparing multiple alternatives. The following quote provides a good example of how complexity influence the adoption decision. When the respondent was asked why he chose a particular type of robot he answers: "*Easy to implement*" (Respondent 6). Respondent 7 considers all technological attributes but trialability when deciding to develop after, just like respondent 6, comparing alternatives. Respondent 3 considers complexity and trialability when deciding to reject or invest in a project. Results reveal that the complexity of a smart technology was the reason to kill a project at firm 3. This 'non-adoption' decision took place after the evaluation of multiple offers (Respondent 3). At the decision to outsource development, respondent 4 takes relative advantage and complexity into account. When deciding to develop themselves and/or outsource development relative advantage and complexity of a smart technology are considered important by respondent 1. The development and update of the old machine with new sensors is perceived as complex, more complex than a new machine (Respondent 1). Adapting the old machine takes too much time and many external firms are needed for help. When adopting a new machine, only some cables need to be connected to the machine. On top of that, data technology is already built in (Respondent 1). So, the new technology is perceived as less complex and has the larger relative advantage. Finally, an example of a relation between a technological attribute and the process of adoption is provided by respondent 8. Here, trialability plays a role after the implementation of the smart technology. At one firm, employees can 'play and learn' with the implemented technology. This implies that trialability is perceived as important (Respondent 8).

Discussion results

To discuss the expected relation between technological attributes and the adoption process of smart technologies as proposed and quoted, the associated proposition is validated by means of a comparison with the qualitative data. It is expected, based on Cooper (1990, 2006) and Hameed et al. (2012), that technological attributes influence the way in which the first stages and gates are created and executed. This proposition is confirmed by the results. Technological attributes are considered important at the early stages and gates up to and including the adoption decision. They also play a role in the late stages and gates but far less relations have been found here and only at four out eight firms. Striking is that technological attributes mainly influence early stages in the process of adoption. In the early phase of the adoption process, there are only two gates in which technological attributes play a role: evaluation of proposals and offers (Respondent 3 & 4). In both cases, only the complexity of a smart technology is considered important. The adoption decision is the only gate which is characterized by a decision and in which (all) technological attributes are considered.

An important remark is that results show that the creation and execution of stages and gates is not necessarily a conscious process. In other words, stages and gates are seldom explicitly created and executed. The adoption process of smart technologies turns out to be a continuous process characterized by a lot of error. Results show at most some activities associated with stages and gates: brainstorming, evaluations and decisions for example. Nevertheless, the influence of technological attributes in the early phases up to and including the adoption decision is clear. Technological attributes are namely taken into consideration in the activities associated with the early stages and gates in the adoption process, up to and including the adoption decision.

Overall, the most relations between technological attributes and the adoption process of smart technologies are found respectively at the adoption decision and in the early phases of the adoption process. All the five technological attributes are considered being important in these phases, as expected. However, the five technological attributes turn out to mainly influence stages in the early phase of the adoption process, rarely the gates. Technological attributes only play a role at evaluation activities associated with two early gates. In addition, stages and gates are not clearly defined and executed in practice and boundaries between them are blurry. So, the proposition that all five technological attributes influence the adoption process is proven to be only partial correct.

5.5 Others

In this section findings about other attributes than the technological attributes and their influence on the adoption process are addressed. These results are not directly related to the constructs and propositions in the research model but are considered relevant by both scholars and respondents anyway. These other attributes will be described first before their relation with the adoption process is assessed.

Qualitative results

Results reveal two main attributes categories apart from technological attributes: organizational and environmental attributes.

Organizational attributes entail financial, firm specific and employee attributes. Results reveal that financial attributes are the most important kind of organizational attributes. Five financial attributes are distinguished, two of which are mentioned often. These are investment costs and return on investment, respectively mentioned six and five times. Firm specific are about firm characteristics taken into consideration and firm related reasons for the adoption of a smart technology. The most important firm specific attributes turn out to be about strategy related, firm size and the goal to maximize production capacity. Regarding firm strategy, two firms considered the strategical relative advantage a smart technology would provide (Respondents 1 & 8). Respondent 1 and 4 even describe a perceived strategic necessity as a reason to adopt a smart technology. Two main employee attributes can be distinguished: employee characteristics like education/knowledge/expertise level and employee attitude towards innovation. This attitude is mainly characterized by the fear to be replaced by new technologies and associated resistance (Respondent 2, 5, & 6). Employee attributes are associated with cost attributes as well. Respondent 6 state: "[…] *and we could show that there was a profit, so it is always related to the human factor, what does a person cost?*" (Respondent 6).

Environmental attributes entail technology supplier/partner, customer and competitor attributes. The technology supplier/partner attributes turn out to be the most important. These attributes are mainly about geographical proximity, spoken language within this partner firm, opening hours and the extent to which a partner firm has time to help (Respondent 1, 3, 4, & 7). Customer attributes are another type of environmental attributes. The relation with a customer is considered important when adopting a smart technology by respondents 4, 5 and 6 and customer demands by respondents 5, 7 and 8. Customers demand a certain product quality and a smart technology needs to be able to provide the demanded product quality (Respondent 8). Customers are sometimes invited for an audit. When a customer is unsatisfied after an audit, a feedback loop can take place after the audit (Respondent 8). Finally, the importance of competitors is mentioned only once (Respondent 3).

Results reveal that organizational attributes are strongly related to the adoption process of smart technologies. On the other hand, hardly any relations between environmental attributes and the adoption process have been revealed. Relations between both organization and environmental attributes and the adoption process are revealed mainly in the early phases of the adoption process. So, the expectation that these attributes can not be associated with certain stages, gates and associated activities is not confirmed. In more detail, 26 attributes turn out to be related with 13 adoption stages, gates and activities prior to the adoption decision gate. 16 attributes are related to the adoption decision itself and 5 attributes with 3 stages/gates/activities after the adoption decision. Overall, most of the relations are between financial attributes and the early adoption phases up to and including the adoption decision. Financial attributes are mentioned by all respondents except for respondent 7a and 7b. The adoption of smart technologies is associated with high costs and therefore, firms often choose to acquire relatively cheap technologies and/or develop it themselves. This choice leads often to a lot of unexpected struggles, mainly in the testing phase.

The influence of employee attributes is mentioned four times (Respondents 2, 5, 6, & 8). Employee attributes often are the reasons for struggles in the adoption process. There is resistance among employees against change, elaborate planning and the overload of adoption steps in an unpredictable environment. Employees are often afraid to lose their job because of digitalization, automation and robotization. This makes it difficult to find support for the adoption of smart technologies. Employees also need to be retrained to enable them to work with the new technologies. Training is associated with high costs on top of the investment costs coming with the acquisition and development of smart technologies that are already high. So, financial- and employee attributes turn out to be interrelated.

Discussion

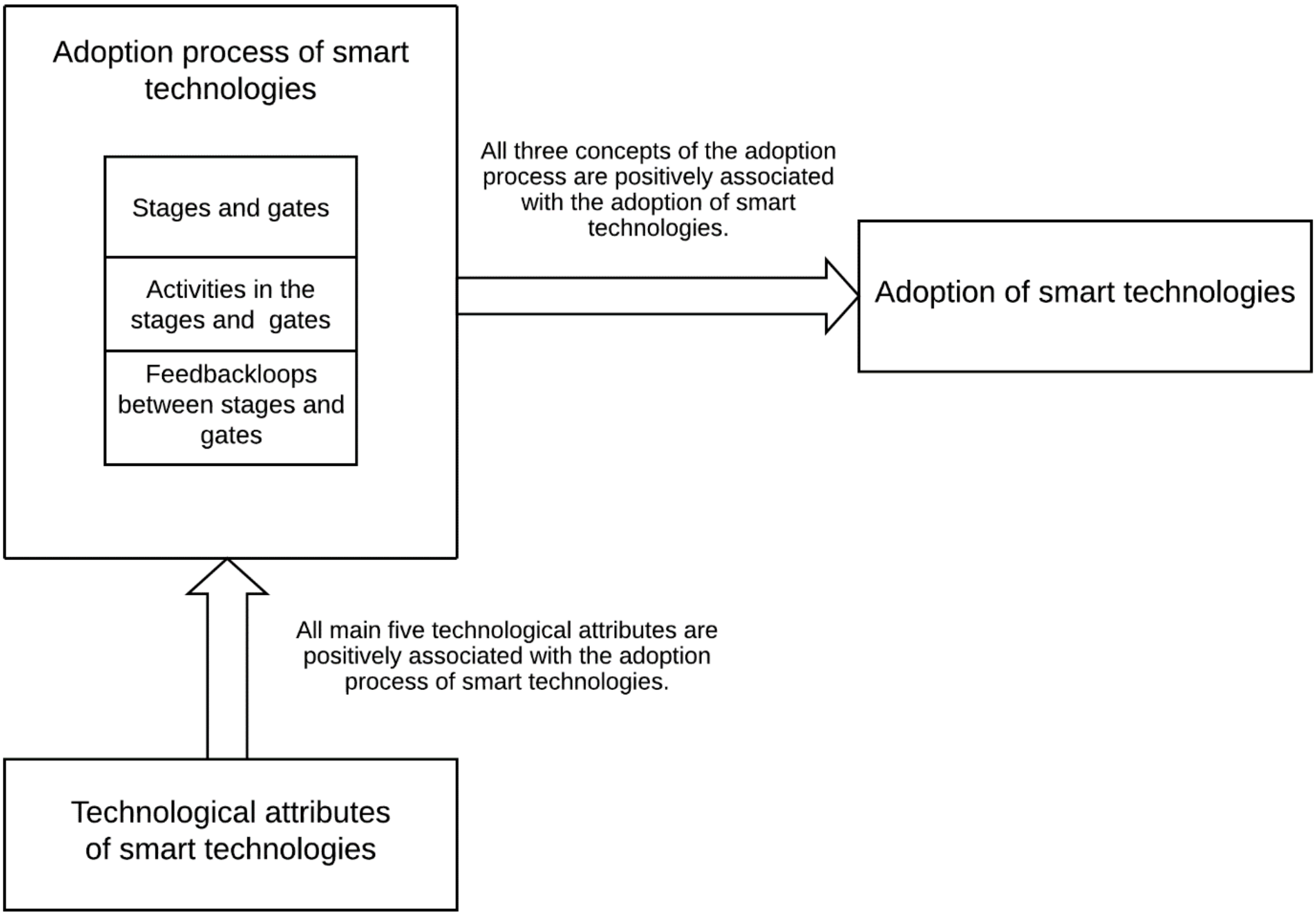
Organizational and environmental attributes are expected to influence adoption stages, gates and associated activities throughout the whole adoption process. Organizational attributes, and financial attributes, were mentioned often both by respondent and by scholars. Environmental attributes are rarely mentioned by respondents. Results reveal that only organizational attributes are related to the adoption process. Financial and employee attributes are the organizational attributes that are related to the adoption process. These are mainly associated with the early stages up to and including the adoption decision. Striking is that financial attributes like investment costs and return on investment appears even more in the results than the five main technological attributes. All the firms claim the employee factors to be very important and a relation with the adoption process is revealed at half of the firms. So, these attributes turn out to be more important than expected and are therefore underestimated in the literature. Furthermore, the classification of attributes differs between theory and practice. Results show the following three main categories: technological-, organizational- and environmental attributes. In addition, results reveal that user level attributes; ‘user acceptance’ and ‘CEO’ attributes fall short to explain employees’ attitudes to the adoption process of smart technologies. The results provide with findings about the importance of employees on a firm level as well, ‘overall attitude of employees towards change’ for example. This attribute concerns firm culture and therefore can be analyzed on a firm level.

To conclude, organizational attributes turn out to be very important: the financial and employee attributes in particular. Important financial attributes are expected costs and return on investment. Employees’ attitude towards change and educational, knowledge and expertise level are important employee attributes. Employee attributes turn out to be overlooked in the literature on the adoption process of smart technologies. Results reveal that employee behavior can be analyzed on a firm level as well. Furthermore, financial and employee attributes show clear relations with the adoption process, mainly in the early adoption phases up to and including the adoption decision. In addition, financial- and employee attributes turn out to be interrelated. Finally, environmental attributes like customer and technology supplier/partner attributes are considered relevant, but their influence on the adoption process is negligible.

5.6 Epilogue

To conclude, six topics are addressed in three sections: respectively the three constructs, the two propositions and ‘others’. These six topics entail the elucidation of qualitative results and a discussion in which the actual analysis takes place. The results are analyzed by means of comparing definitions, expectations and propositions on the one hand with the results on the other hand. Smart technologies in adoption at/adopted by Dutch manufacturing firms, the process of adoption and technological attributes considered being important in this process are assessed first. After that, both propositions about the relations between technological attributes and the adoption process and between this process and the actual adoption of smart technologies are assessed. The chapter is concluded by the assessment of other attributes and their influence on the adoption process of smart technologies. In summary, firms are further regarding the adoption of single smart technologies than they realize. However, the connectivity of smart technologies turns out to be the biggest struggle. Evaluations, the actual implementation, go/kill decisions, fine-tuning and training of employees turn out to be the most common stages/gates/activities in the adoption process. A clear structured adoption process turns out to be the main predictor for adoption, followed by the existence/absence of certain stages, gates and activities. Results show a clear relation between the absence of proper home-work stages/activities and non-adoption. Feedback loops are scarce but appear to prevent a project from being killed. All five main technological attributes are considered relevant at the adoption process and relative advantage, complexity and compatibility in particular. Technological attributes mainly influence respectively the actual adoption decision and the early stages of the adoption process. Relative advantage and complexity appear to have the biggest impact. The first appear out to be more important in the early stages and the latter at the actual adoption decision. In the figure below, a new version of the research model is provided. In this version, the propositions are replaced by the conclusions of the analysis.

Figure 5. Research model with conclusions.



6. Summary and discussion

The final chapter of this study consist of three section. First of all, a summary is provided of this study. Secondly, both theoretical and practical implications are assessed. Thirdly, recommendations are made for scholars and managers. Scholars are provided with recommendations for further research into the adoption process of smart technologies and the development of Smart Factories and ultimately smart Industries. The recommendations for managers focus on how to successfully adopt smart technologies by means of creating an appropriate adoption process. This chapter concludes with a reflection on the study and the research method.

6.1 Summary

This study concerns the existence of an adoption process with stages, gates and feedback loops leading to the adoption (introduction and use) of smart technologies and how this process is influenced by technological attributes. Smart technologies are characterized by their connectivity which enables the creation a of smart network, a smart factory and a smart industry in the end. Five technological attributes have been distinguished: relative advantage, compatibility, complexity, trialability and observability. The following two propositions are formulated. 1) The existence of an adoption process with stages, gates, activities and feedback loops is associated positively with the adoption of smart technologies. 2) Each technological attribute of smart technologies are associated positively with the way in which stages, gates and activities in the adoption process of smart technologies are created and executed.
It was expected that not many smart technologies were adopted yet and smart networks are absent in the Dutch manufacturing industry. This expectation is partially confirmed. Dutch manufacturing firms are adopting and/or have adopted more smart technologies than expected, but smart networks turn out to be absent indeed. Firms struggle with the adoption of smart technologies and the creation of smart networks for two reasons. Results reveal a lack of understanding of smart technologies and struggles with the connectivity and logistics.
Regarding the adoption process, and its influence on smart technologies, the expectations and proposition are partially confirmed by the result. The existence of a structured adoption process with (subsequent) stages, gates, associated activities and feedback loops leads to smart technology adoption. However, results reveal that many of the stages and gates described in the literature are absent in practice. In addition, by far most of the activities that appear in the results are stage related. Stages and gates are often combined and borders

between stages and gates are seldom mentioned explicitly. The most common stages, gates and activities in practice are evaluation, implementation, go/kill decisions, fine tuning and training. The latter two are absent in the literature. Homework activities like defining the project, planning, setting goals and research are the most important predictors of adoption, but firms distinguish only a few homework activities. The absence of homework leads to non-adoption. Collaboration with a partner when developing a smart technology improves the chance for a smart technology to be adopted. Documentation and evaluation are important according to scholars, but these activities are not mentioned very often by respondents. Nevertheless, an absence of these activities does not necessarily lead to non-adoption. Feedback loops prevent a project form being killed, as expected. However, these loops turn out to be scarce. Feedback loops emerge from gates, so the existence of gates is proved to affect adoption. The lack of clearly defined gates explains the fact that projects are rarely killed.

All technological attributes are proven to be important, as expected. The proposition that technological attributes mainly influence the early phases up to and including the adoption decision, is confirmed. Relative advantage and complexity turn out to be the most important technological attributes. Relative advantage is mainly associated with the early stages and gates and complexity with the actual adoption decision. Compatibility, observability and trialability are considered important by far less respondent and are less often associated with specific phases.

To conclude, the answer on the research question is that all main five technological attributes contribute to the existence of stages and gates and progress of the adoption project across stages. The five technological attributes are mainly taken into consideration at the early stages and gates up to and including the adoption decision in particular. These early stages and gates or ‘home-work phase’ turns out to be one of the biggest predictors for smart technology adoption. Technological attributes affect the formulation and evaluation of proposals, the making of a design and the choice to adopt one particular kind of smart technology out of multiple possibilities. In addition, they are considered at the decision to buy or develop, which has a big influence on how the adoption process looks like and what role a technology supplier/partners play in the adoption process. These results have both theoretical and practical implications. These implications are addressed in the next section.

6.2 Discussion

In this section, three implications of this study are addressed. In addition, these implications lead to both theoretical and practical recommendations that are discussed afterwards.

<u>Implications</u>

The results of this study have certain implications which enable to review the theories that form the foundations of this study in light of new information.

One implication concerns smart technologies. Results show that firms struggle with the adoption of smart technologies for different reasons. Respondents mention a gap between theory and practice regarding smart technologies and smart industries. Theory lack clear definitions and a clear distinction between digital and smart technologies is absent. Besides, respondents remark that literature on smart technologies is very visionary and lack practical tools that help them formulate short term goals. On top of that, theory lacks a proper inventory of adopted smart technologies by Dutch manufacturing firms. Therefore, it is hard to determine the progress firms have made regarding the adoption of smart technologies. This study contributes to existing literature with clear definitions of smart technologies, distinction between digital and smart technologies and advice regarding the design of the adoption process. The latter will help firms to break down the ultimate goal, of creating a smart industry, into small pieces in the form of clear and achievable goals.

Another implication is about the adoption process. The stage-gate model of Cooper (1990), customized by means of the adapted version of Cooper (2006), turns out to be incomplete. Important stages after the adoption decision are missing. This study provides these missing stages: the ‘training of employees’, ‘testing’ and ‘audit’ stage. In addition, results show that firms have three options when making an adoption decision, leading to three possible paths. Not just the acquisition path and the development path, but also the path in which these two options are combined. At each path, the technology supplier/development partner has a different role: mainly giving advice when a firm choose to buy and closer collaboration, by means of a project team containing employees from both firms for example, when a smart technology is developed.

A third implication concerns attributes which are based on the theory of Hameed et al. (2012). Hameed et al. (2012) distinguish three firm level and two individual level attributes, technological attributes being a part of innovation attributes. This study provides with an alternative categorization that does more justice to the importance of these factors and that fills some gaps in the literature. The categories distinguished in this study are technological, organizational and environmental attributes. These categories are all on firm level. First of all, results show that the category 'technological attributes' is a more accurate and relevant category than 'innovation attributes'. At the model of Hameed et al. (2012) the technological attributes are part of innovation attributes. This category is broad and mainly the distinguished five technological attributes turn out to be important. In addition, the importance of the collective of employees on a firm level is overlooked in literature, which is compensated for by the results of this study. Results show that employee attributes enable to analyze employees' behavior on a firm level instead of on an individual level. So, Hameed et al. (2012) fall short when only considering the individual level attributes 'CEO and user acceptance attributes' at the implementation stage.

Theoretical recommendations

One phenomenon that could be studied in more detail is the connectivity between individual smart technologies since this appears to be more challenging than the adoption of single technologies. Underlying problems are that: 1) it is not clear for managers what technologies are actually smart, and 2) firms struggle connecting them due to software problems and logistical issues. Respondents mention a gap between theory and practice regarding the application possibilities of smart technologies. This study focuses on the adoption of single smart technologies, so further research could focus on how to connect smart technologies, how to overcome software mismatches between firms and how to collaborate with partners in the supply chain. This kind of research will enable managers to make clear and feasible plans for exploiting the possibilities that comes with smart technologies. A possible research question is: 'How to connect smart technologies in order to create smart factories and industries?'.

This research provides insight into the importance of certain stages and gates. However, to gain more precise insight into relations between the existence and absence of certain stages, gates and activities and smart technology adoption, researchers could conduct a quantitative research. By means of quantitative research, the importance of phases can be tested. Results will provide insight into the extent in which phases are important and whether their importance is significant. In a survey, respondents can be asked to rate stages, gates and activities regarding perceived importance. A research question could be: 'Which stages, gates and activities in the adoption process are significantly important for the adoption of smart technologies?'.

Finally, researchers could study other attributes that influence the adoption process and even the adoption of smart technologies itself directly. The focus in this study was on technological attributes of smart technologies, but organizational attributes turned out to be important as well. Besides, not all technological attributes turned out to be equally important. On top off that, results show that technological attributes are associated with other attributes that are described separately by scholar. In practice, attributes are not a list of factors taken into consideration in the adoption process, but more a web of relations between the attributes themselves and with the multiple phases in the adoption process. These relations could be studied in further research to gain even more insight into the different attributes and the role they play in the adoption process of smart technologies. An example of a possible research question would be: ‘How do different attributes of smart technologies affect each other during the adoption process of smart technologies?’. A quantitative research would be a good approach since it provides with clear data on the strength of the relations between attributes and the adoption process and the attributes among each other.

Practical recommendations

As mentioned before, firms do not exploit the possibilities that smart industry provides. A few smart technologies have been adopted, but these technologies do not form an integrated network yet. In order to help managers to create a smart network, some recommendations are made.

Literature on smart technologies is broad and rather visionary, while firms often do not have the required knowledge and/or expertise to create an overview of the smart possibilities, let alone adopting the most suitable option. On top of that, connecting smart technologies and adapting the logistics turn out to be even a bigger struggle than the adoption of a single smart technology. So, extensive preparations are in order before making plans for adopting smart technologies. One recommendation for firms is to invest time and resources in proper research, formulating clear goals and a feasible project planning. Involving persons/firms with expertise regarding both the adoption and the connectivity of smart technologies is helpful. When acquiring and/or developing smart technologies, collaborating with other firms is proved to be a successful approach. In these cases, firms often create project teams containing employees from both firms, with two project leaders. However, in these cases it is important to formulate clear agreements and set deadlines.

Another recommendation is to involve employees in the right way and appoint them to the right positions. The most important remark is to at least appoint someone responsible for IT development at the firm to build a solid basis for the adoption for smart technologies. In addition, managers need to explain to employees that the adoption of smart technologies does not necessarily mean that they will be replaced by robots. On top of that, it is important to explain that and how their job might change due to the adoption of smart technologies. This will help to create support instead of resistance among employees. The creation of a project team is a good idea but does not guarantee that an adoption will be successful. The success of a project team depends on several factors. When creating a project team, it is important to make it a multidisciplinary project team in which all members are committed to the project for a defined number of hours per week. Otherwise, it is likely that the project will not get the required priority. Homework activities like setting clear goals, defining the project, scoping of options and proper research should be the first activities executed by a project team. At these activities, technological attributes should be taken into consideration. Furthermore, to prevent muddling through, it is recommended to set deadlines and plan meetings in which the results are evaluated properly by means of the technological attributes. It would be wise for managers to enable feedback loops by making room for revisions since these loops prevent projects from failing.

Finally, more attention needs to be paid to documentation and evaluation activities. In order to learn form experience and capture knowledge, it is important to include evaluation and documentation activities at least at the end of the adoption process. This makes the firm less dependent on one or a few employees and/or on another firm. Respondents often state that knowledge disappears due to turnover of personnel for example. Evaluation and documentation prevent a loss of knowledge when certain employees leave the firm. In addition, documenting what stages and gates appear in practice logically helps to create a suitable adoption process for future adoptions of smart technologies. In conclusion, it is most important to set deadlines, evaluate, document, invest in research, involve employees from different disciplines from the beginning and enable feedback loops by making room for revisions.

6.3 Strengths, limitations and ethical reflection

This study has both strengths and limitations, regarding the research design and methods used. A strength of this study is the solid theoretical foundation since the study is based upon two studies that complement each other well. Hameed et al. (2012) provides a solid theoretical basis by using a combination of multiple different adoption theories and Cooper (1990, 2006) provides with useful practical tools to assess the adoption process in practice. Another strength is the sample of this study. The sample is representative because al examined firms operate in different markets. This makes the results generalizable, which contributes to the validity of this study.

However, this study also has its limitations which are mainly about the generalizability. One limitation is that the description of how often different smart technologies are adopted are based upon only two articles. Further research is needed in order to be able to determine the differences between smart technologies regarding the extent in which they are adopted.

Another limitation concerns the interview sample. This limitation is twofold. Firstly, the focus in this study is on middle/small firms (50-100 fte), but it turned out to be a challenge to find eight firms of this kind. So, two interviews have been conducted at larger firms. Nevertheless, the interviews have been conducted at business units of these firms and these BUs still match the criterium of firm size. Larger firms might have more resources, but they still face the same struggles when adopting a certain technology. Besides, these BUs operate independent and show the same adoption results as the middle/small firms. There are some minor differences between large and smaller firms, but the relevant differences, related to the constructs and propositions, are negligible. Second, it is believed that the examination of eight firms from eight different sectors provide enough data in order to draw reliable and generalizable conclusions. However, the study would be even more reliable and generalizable when more firms than just one firm per sector were examined. Besides, some sectors remain unexposed in this study. In order to create a view that is even more representative, firms in more sectors than just the eight examined in this study should be interviewed.

Finally, multiple measures were taken to safeguard the interests of respondents involved, privacy in particular. During the interviews, respondents were guaranteed that the provided information will be handled confidentially, and the obtained data will be anonymized due to privacy and discretional reasons. The interviews were recorded and removed from the recording device after the records were transcribed.

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Picture on frontpage: Innovative contemporary smart industry: product design, automated production line, delivery and distribution with people, robots and machinery: industry 4.0 infographic. Source: aiza.com, retrieved from: *https://aiza.com.br/lean-construction-a-filosofia-oriental-aplicada-ao-processo-produtivo/industry-4-0-automation-and-innovation-infographic-2/*

Appendices

Appendix 1: Definitions/descriptions of SI

Definitions/descriptions SI	**Source**
"*Products and services are flexibly connected via the internet or other network applications like the blockchain (consistent connectivity and computerization), the digital connectivity enables an automated and self-optimized production of goods and services including the delivering without human interventions (self-adapting production systems based on transparency and predictive power) and the value networks are controlled decentralized while system elements (like manufacturing facilities or transport vehicles) are making autonomous decisions*"	(Hofmann & Rüsch, 2017, p. 25)
"*The increasing intelligence of products and systems, their intra-company cross-linking and cross-company integration into value creation network*"	(Schneider, 2018, p. 1)
A new level of value chain organization and management across the lifecycle of products	(Kagermann et al., 2013)
A collective term for technologies and concepts of value chain organization	(Hermann et al., 2015)
The next phase in the digitization of the manufacturing sector	(Breunig, Kelly, Mathis, & Wee, 2016)

Digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber physical systems, and analysis of all relevant data	(Wee, Kelly, Cattel, & Breunig, 2015)
Descriptions assessed by Saucedo-Martínez et al. (2017)	*Authors paraphrased Saucedo-Martínez et al. (2017)*
Integration of complex machinery and devices, with sensor and software networks, used to predict, control and improve plan business and results in society	(Toro et al., 2015; Moreno et al., 2016; Simonis et al., 2016; Radziwon et al., 2014).
New level of organization and management of the value chain throughout the product life cycle	(Trends, 2015; Prause & Weigand, 2016).
Collective term for technologies and concepts of the organization of the value chain	(Shafiq et al., 2015; Juan-Verdejo & Surajbali, 2016; Stojki'c et al., 2016).
A holistic system of information technologies, people, machines and tools, which allows the flow of goods, services and data in a controlled way, through the value chain, with operations with a high degree of autonomy and high capacity to transmit useful information to decision-making	(Dombrowski & Wagner 2014; Hermann et al. 2016; Mazak and Huemer 2015; Qin et al. 2016; Wolter et al. 2015; Botthof 2015).

Appendix 2: The creation of the definition for Smart Industry

In this appendix, it is explained how the definition of smart industry is created. By comparing and combining the different definitions presented in appendix 1, a distinction is made regarding how often certain words are used in definitions of SI. Thereby, the differences and similarities/overlap between the definitions are considered.

The definitions differ in multiple ways. First, the definitions differ in their level of analysis: industry, firm, technology and application level. Most of the definitions are characterized by a holistic view, which means that they take into account multiple levels of analysis (Botthof 2015; Dombrowski & Wagner, 2014; Hermann et al., 2016; Mazak & Huemer, 2015; Qin et al., 2016; Schneider, 2018, p. 1; Wolter et al., 2015). The second level of analysis that occurs the most is the technology and their application level (Hofmann & Rüsch; 2017, p. 25; Moreno et al., 2016; Radziwon et al., 2014; Simonis et al., 2016; Toro et al., 2015). The industry level of analysis has been used twice (Kagermann et al., 2013; Wee et al., 2015). A firm level of analysis have not been found in the considered definitions.
Secondly, some of the definitions are on a narrow meta level other on a broad and detailed level. In the meta level definitions, SI is often described as a value chain organization (Botthof, 2015; Dombrowski & Wagner, 2014; Hermann et al., 2015; Juan-Verdejo & Surajbali, 2016; Kagermann et al., 2013; Mazak & Huemer, 2015; Prause & Weigand, 2016; Qin et al., 2016; Shafiq et al., 2015; Stojki’c et al., 2016; Trends, 2015; Wolter et al., 2015). Other definitions are more detailed and consider more levels of analysis (Botthof, 2015; Dombrowski & Wagner, 2014; Hermann et al., 2016; Mazak & Huemer, 2015; Qin et al., 2016; Wolter et al., 2015). The definition of Hofmann and Rüsch (2017) is the broadest. Their focus is on technologies, but they also mention the meta level of SI, the value chain organization (Hofmann & Rüsch, 2017, p. 25).
Thirdly, some definitions link SI to digitization, the third industrial revolution, while the rest focus on the distinctive, and most important, characteristic of SI: the connectivity of smart technologies. Breunig et al. (2016) describe SI as the next phase of digitization and Wee et al. (2015) describe SI as the digitization of the manufacturing industry. In addition, the latter authors consider the importance of the use of sensors and CPS. However, the use of the term ‘digitization’ is confusing.

Fourth, the perspective of the different authors in SI differs. Some definitions have an organizational focus (Kagermann et al., 2013; Prause & Weigand, 2016; Trends, 2015). The rest of the considered authors describe SI from a technological perspective.

The multiple definitions of smart industry have the following main concepts in common: the connection of smart technologies in a decentralized value network. Not all the considered definitions contain all these concepts, but most definitions contain several of these concepts.
First of all, connectivity of smart technology is mentioned often in the different definitions (Hofmann & Rüsch, 2017, p. 25; Moreno et al., 2016; Radziwon et al., 2014; Schneider, 2018, p. 1; Simonis et al., 2016; Toro et al., 2015).
Secondly, the aspects that make technologies smart (sensors among others) are also considered important (Moreno et al., 2016; Radziwon et al., 2014; Simonis et al., 2016; Toro et al., 2015; Wee et al., 2015).
Thirdly, the creation of a value network, the goal and/or consequence of connectivity, has a prominent role within smart industry. The creation of a value network implies the integration of smart technologies in a network in which added value is considered especially important. A value network starts within a smart factory and can ultimately be expanded supply chain and industry wide (Saucedo-Martínez et al., 2017). The value network is mentioned most often (Botthof, 2015; Dombrowski &Wagner, 2014; Hermann et al., 2015; Hofmann & Rüsch, 2017, p. 25; Juan-Verdejo & Surajbali, 2016; Kagermann et al., 2013; Mazak & Huemer, 2015; Prause & Weigand, 2016; Qin et al., 2016; Schneider, 2018, p. 1; Shafiq et al., 2015; Stojki’c et al., 2016; Trends, 2015; Wolter et al., 2015).
Fourth and finally, the ability of smart system elements to make autonomous decisions is mentioned less often than the importance of the value network, but still plays an important role (Botthof, 2015; Dombrowski & Wagner, 2014; Hermann et al., 2016; Hofmann & Rüsch; 2017, p. 25; Mazak & Huemer, 2015; Qin et al., 2016; Wolter et al., 2015).

To conclude, the following four core concepts of smart industry are considered defining smart industry:

1. The connection/integration/cross-linking of system elements like products and services/technologies/machinery/devices.
2. Elements associated with smart technologies like sensors, software networks, CPS and analysis of data.

3. The value chain organization/value creation network/value networks/value chain/organization of the value chain.
4. System elements making autonomous decisions/high degree of autonomy.

The definition of smart industry formulated in this study also forms a bridge between the differences in the multiple definitions considered. First, this definition has a holistic perspective. The technology and firm level of smart industry are taken into consideration as well as the place of the firm in the value network on an industry level.
Secondly, the (link with the) terms digitization and digitalization are excluded from the definition of smart industry. These terms are associated with the third/digital revolution while the fourth revolution is associated with smart industry: the connectivity of smart technologies. Finally, the definition has a technological focus since the adoption of smart technologies is the central theme in this research.

Appendix 3: Smart technologies

Zhou et al. (2015)	*Saucedo Martinez et al. (2018)*
Key smart technologies	**Group techs and tools SI**
From CPS to CPPS	Industrial IoT
Mobile internet and IoT	Big data and Analytics
Cloud computing	Simulation
Big Data and Advanced Analysis Techniques	Additive Manufacturing
	Horizontal and vertical integration
	Cyber Security
	Augmented Reality
	The cloud
	Autonomous robots

RuBmann et al. (2015)	*Agostini and Filippini (2018)*
Nine smart techs	**Smart techs in category CPS**
Industrial IoT	IoT
Big data and Analytics	Big data and analytics
Simulation	Cybersecurity
Additive Manufacturing	Advanced manufacturing systems
Horizontal and vertical integration	Additive manufacturing
Cyber Security	3D printing
Augmented Reality	
The cloud	
Autonomous robots	

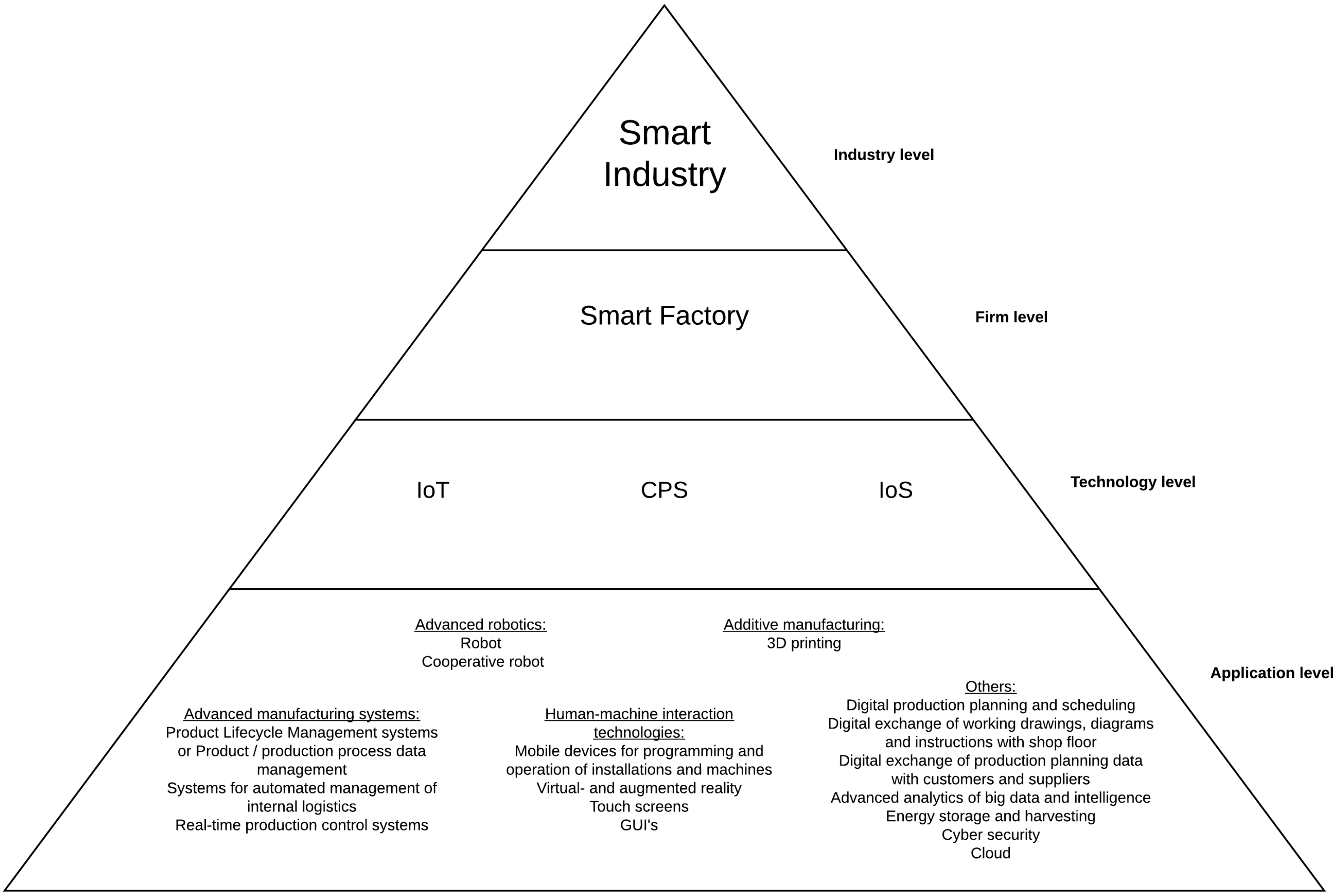
Lu (2017)
SI key technologies
Mobile computing

Cloud computing
Big data
IoT

van Helmond et al. (2018a)
24 process innovations, 3 examples of smart technologies (EMS)
Digital production planning and scheduling (used often)
Control systems that shut down machines by understaffing
Advanced processing technologies for new materials (like production techs for micro mechanic components, nanotechnological production processes, and bio- and gene technology in manufacturing processes)

Van Helmond et al. (2018b)
12 SI technologies (ESB): from most to least adopted by firms.
Digital production planning and scheduling
Digital exchange of working drawings, diagrams and instructions with shop floor
Real-time production control systems
Digital exchange of production planning data with customers and suppliers
Additive manufacturing for mass production
Automated management systems of internal logistics
Additive manufacturing for prototyping
Product Lifecycle Management systems or Product/production process data management
Mobile devices for programming and operation of installations and machines
Systems for machine-to-machine communication
Cyber-physical systems and cloud-based computing
Technologies for safe human-machine interaction. Example: cooperative robots

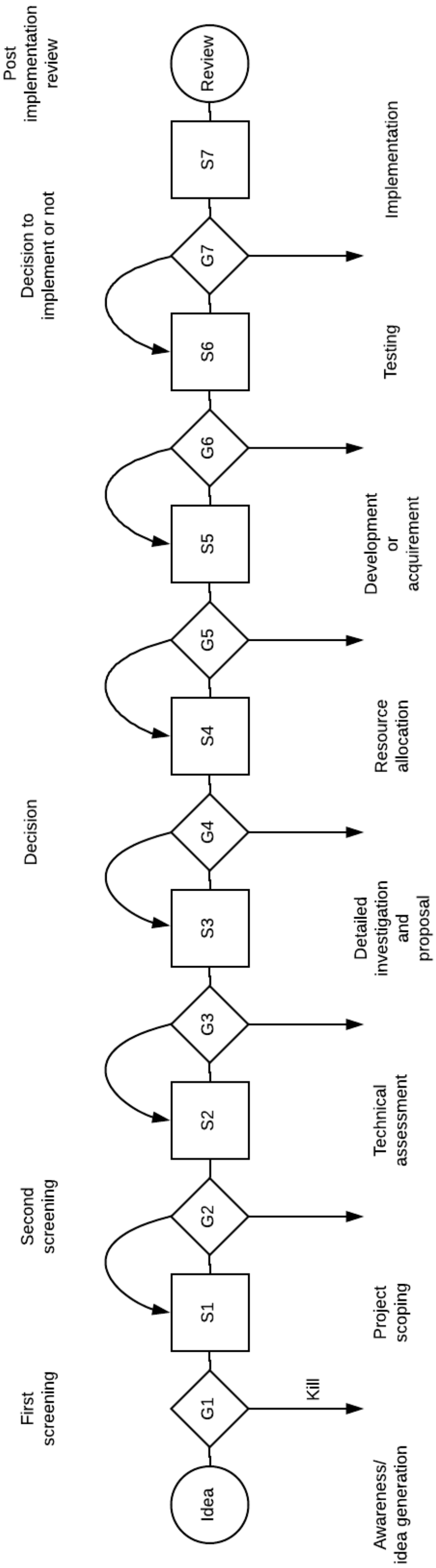
Appendix 4: Smart Industry Piramid



Appendix 5: Summary table of literature review articles on technology adoption process

Authors	**Individual level theories**	**Firm/group level theories**	**Not clear/defined**
Taherdoost (2018)	TRA, TPB, TIB, TAM, ETAM, IM, SCT, DOI, PCIT, MM, U&G, MPCU	SCT, DOI, U&G	ETAM, UTAUT
Al-Mamary et al. (2016)	TRA, SCT, TAM, TPB, MPCU, MM, C-TAM-TPB, UTAUT and IDT	DOI, TOE	
Long Li (n.d.)	TRA, TAM, TAM2, MM, TPB, MPCU, IDT, SCT		UTAUT
Gangwar et al. (2014)	TRA, TPB, UTAUT	TAM and TOE	
Kim and Crowston (n.d.)	UTAUT, TRA TPB, TAM, TAM2, IDT, SCT		
Oliveira and Martins (2014)	TAM, TPB, UTAUT	DOI, TOE	
Sharma and Mishra (2014)	TRA, TPB, SCT, TAM, MPCU, MM,	DOI	TAM2, UTAUT, MAPS

Appendix 6: Adoption process of smart technologies



Appendix 7: Activities in different stages and gates

Stages/gates	**Activities**
Idea generation: start of the adoption process.	
Gate 1. First screening: Decision to commit resources to the project.	The project is subjected to a few criteria by means of a checklist Rating and ranking projects
Stage 1. Project scoping: Building the foundation of the project.	A library searches Contacts with key users Focus group Patent and IP search Search for competitive alternatives The identification of resource gaps Preliminary technical assessment
Gate 2. Second screening: Evaluation of the project in light of new information and decision to start with experiments.	The project is subjected to a few criteria by means of a checklist Financial calculation/budget preparation A decision to begin limited experimental or technical work
Stage 2. Technical assessment: Defining the project and assessing its' attractiveness and feasibility and formulation of goals.	Defining the project Formulation of goals Detailed technical appraisal (under ideal conditions) Design of a concept Detailed financial analysis
Gate 3. Decision to deploy resources.	Decision to deploy resources on the business case Examination of the quality of the execution of activities in stage 2 Examination of the financial analysis

	Reaching agreement on items like the desired and essential technology features, attributes and specifications Reviewing and approving development plan and the plan for preliminary operations
Stage 3. Investigation and proposal: Making a plan for experiments and formulating an implementation proposal.	Detailed investigation Formulating an implementation proposal Manufacturing and impact assessments on the process possibilities
Gate 4. Adoption decision: Deciding whether to buy or develop.	Deciding to allocate resources to the development or acquisition of the technology
Stage 4. Resource allocation.	The allocation of resources
Gate 5. Reviewing the resource allocation.	Reviewing the allocation of resources Deciding to the start of the development or acquisition of the new technology
Stage 5. Development/acquisition of the smart technology and formulation of a test- and operation plan.	Development or the acquisition of the technology Formulation of the test- and operation plan Preparing an updated financial analysis Resolving patent or copyright issues
Gate 6. The post-development or acquirement review: Quality check of the smart technology.	Checking the eventual development work on quality Revising financial analysis based on new and more accurate data In case of an acquisition, the delivered product will be checked on completeness and quality.

	Checking, evaluating and approving the test and validation plans and operation plans
Stage 6. Testing: Assessing the entire viability of the project by means of tests and trial production.	Trial or pilot production: -Test and debug the production process -Determine more precise production costs and rates Revising the financial analysis
Gate 7. Evaluation of the test results.	Evaluating the quality of the validation activities and the test results. Making financial projections Approving operation plans for implementation
Stage 7. Implementation of the smart technology.	Introducing the new technology (stepwise) to the firm
Post implementation review. The end of the adoption process: disbanding the project team, evaluation of the adoption process, project team and the adopted smart technology.	Disbanding the project team Reviewing and measuring the performance of the project(team) Evaluating on the quality of the new process technology Assessing the strengths and weaknesses of the project

Appendix 8: Attributes associated with /different stages and gates op the adoption process

Stages/gates in the adoption process of smart technologies (Cooper, 1990, 2006)	**Technological attributes of smart technologies** (Hameed et al., 2012)	**Distinctive elements: other attributes** (Cooper, 1990, 2006; Hameed et al., 2012)
Idea generation: start of the adoption process.		
Gate 1. First screening: Decision to commit resources to the project.	Compatibility Differential/relative advantage	Likelihood of technical succes Project feasability, magnitude of the opportunity Synergy with the firms' core business and resources Strategic alignment
Stage 1. Project scoping: Building the foundation of the project.	Trialability	Development and manufacturing possibility Both costs and time needed for execution
Gate 2. Second screening: Evaluation of the project in light of new information and decision to start with experiments.	Compatibility Differential/relative advantage	Same as in G1 Financial return
Stage 2. Technical assessment: Defining the project and assessing its' attractiveness and feasibility and formulation of goals.	Complexity	Attractiveness of the project Financial analysis Technical feasibility of the project

Gate 3. Decision to deploy resources.	Compatibility Differential/relative advantage Complexity Trialability Observability	Quality of the execution of the activities Financial analysis
Stage 3. Investigation and proposal: Making a plan for experiments and formulating an implementation proposal.	Relative advantage Observability Compatibility These three in short: Technological feasibility and technologies' scope and value to the company.	Technological feasibility and technologies' scope and value to the company.
Gate 4. Adoption decision: Deciding whether to buy or develop.		
Stage 4. Resource allocation.		
Gate 5. Reviewing the resource allocation.		
Stage 5. Development/acquisition of the smart technology and formulation of a test- and operation plan.		Financial analysis Patent or copyright issues
Gate 6. The post-development or acquirement review:		Financial analysis Quality and completeness of development work/delivered product

Quality check of the smart technology.		
Stage 6. Testing: Assessing the entire viability of the project by means of tests and trial production.		Financial analysis Viability of the project
Gate 7. Evaluation of the test results.		Quality of the validation activities Financial projections
Stage 7. Implementation of the smart technology.		
Post implementation Review. The end of the adoption process: disbanding the project team, evaluation of the adoption process, project team and the adopted smart technology.		Revenues, costs, expenses, profits and timing Strengths and weaknesses of the project

Appendix 9: Definitions of (components of) constructs

Term	**Definition**
Adoption of smart technologies	"*The introduction and use of smart technologies.*"
Adoption process of smart technologies	"*A process with stages, gates, associated activities and feedback loops progressing from initiation to implementation that leads to the introduction and use of a smart technology.*"
Gate	"*An entrance to another stage and a quality control checkpoint, which entails several activities and in which decisions are made by gatekeepers whether to go/kill/hold/recycle a project based on whether the project meets a certain set of quality criteria.*"
Stage	"*A workstation that entail several activities and that is connected by (a) gate(s).*"
Feedback loop	"*Redoing activities associated with a particular stage following a decision to recycle made at the gate after this particular stage.*"
Adoption activities	"*The performance of an action or operation within a certain stage or gate of the adoption process.*"
Technological attributes of smart technologies	"F*actors/ features that are specific for a certain smart technology and that are considered important by people that are involved in the adoption process and influence the adoption process (and thereby the decision to either adopt or reject the adoption of an smart technology) due to the fact that their individual impact is different in the different stages and gates of the adoption process of a smart technology.*"

Appendix 10: Interview script in Dutch - Excel version

Onderdeel	**Interviewvragen**	**Tijd**
Introductie	Kort voorstellen en het onderzoek uitleggen Toestemming vragen voor opname interview: benoem dat de opname alleen gebruikt wordt voor de transcriptie, het geheel anoniem is en dat het bedrijf niet identificeerbaar gerapporteerd wordt Interview duurt ongeveer een uur	10 minuten
Oriënterende vragen	Introductie onderdeel: Een algemeen beeld krijgen van de geinterviewde en het bedrijf.	5 minuten
	1. Wie bent u en wat is uw functie binnen het bedrijf? Functie, takenpakket?	
	2. Wat voor bedrijf is het? Kern activiteiten, hoofdproducten, strategie, grootte?	
Slimme productietechnologieën	Introductie onderdeel: Een beeld krijgen van welke technologieën zijn geimplementeerd en welke het meest relevant/typerend is voor het bedrijf.	10 minuten
	3. Heeft u al slimme productietechnologieën geïmplementeerd of zijn er slimme productietechnologieën die op dit moment worden aangenomen/geadopteerd? Hoeveel? Welke? Machines/installaties/systemen? Wat is de meest relevante/typerende voor dit bedrijf in het recente verleden? Waarom?	
Het adoptie proces: stages, gates en loops	Introductie onderdeel: Dit onderdeel gaat over de fasen, besluiten, activiteiten en loops in het adoptieproces en hun invloed op de adoptie van slimme productietechnologieën.	15 minuten

	4. Welke fasen worden doorlopen in het adoptieproces van nieuwe slimme productietechnologieën? Welke activiteiten onderscheidt u in deze fasen? Wie zijn hierbij betrokken? Hoe zijn de fasen met elkaar verbonden? Projectteams? Teamleiders? Verschillende departementen? Managers?	
	5. Welke besluiten worden genomen in het adoptieproces? Wie zijn hierbij betrokken? Na welke stappen? Hoe worden besluiten genomen? Aan de hand van welke activiteiten? Hoe vaak? Waarover? Wordt er ook aandacht besteed aan evaluaties?	
	6. Worden er wel eens stappen terug gezet in het adoptieproces? Waarom/wat zijn de redenen? Wat zijn de barrières? Heeft u voorbeelden? Bijvoorbeeld: een nieuw proposal geschreven, een test opnieuw uitgevoerd, een analyse uitgebreid, etc?	
Innovatie aspecten	Introductie onderdeel: In dit onderdeel worden de aspecten van slimme technologieën en de invloed van deze aspecten op het adoptieprocess van slimme technologieën besproken.	10minuten
	7. Welke aspecten neemt u in overweging bij de adoptie van nieuwe slimme productietechnologie (van het ontstaan van het idee tot de implementatie)? Technologische factoren? Welke? In welke stappen/fasen spelen deze factoren een rol? Andere factoren zoals organisatorische factoren, omgevingsfactoren of financiële factoren?	
Contextuele/extra vragen	Introductie onderdeel: Het doel van dit onderdeel is om een volledig beeld te krijgen van de redenen waarom sommige slimme	5 minuten

	productietechnologieën wel worden toegepast en andere niet.	
	8. Op welke manier gaat u verder? Gaat u nieuwe slimme productietechnologieën implementeren? Zo ja, welke? Waarom deze? Gaat u op basis van opgedane ervaringen met de adoptie van slimme technologieën het proces nu anders vormgeven? Zo ja, wat zou u de volgende keer anders doen? Welke factoren zou u volgende keer in overweging nemen?	
Afsluiting	Bedanken Afspraken herhalen en bevestigen Vragen of de respondent een eindverslag wil ontvangen Vragen of de respondent bereid is later eenmalig een vragenlijst in te vullen (noteer email adres)	5 minuten

Appendix 11: Descriptive respondents

Firm ID	Sector of firm	Products	Size of firm (in fte)	Region firm
1.	(Petro)chemical industry and Food&Pharma	Diaphragm seals, pressure gauges, temperature gauges, thermowells, valves and manifolds	120	Zuid Holland
2.	Plastics industry	Assembling plastic semi-finished parts into a semi-finished product	Total: 200 BU of 50	Gelderland
3.	Door solutions	Residential and industrial doors and components of doors	Total: 250 BU: 100	Flevoland
4.	Metal industry	Products and product parts out of metal sheets	100	Zuid Holland
5.	Transport machinery	Machines and transport systems	125	Noord Brabant
6.	Aerospace, transport, food	Hydraulics, Pneumatics & Filtration manufacturer	Total: 58000 BU: 50	Zuid Holland
7.	Preserves	Preserving food in tins and jars	42	Gelderland
8.	Electronics	Assembly of PCB electronics/circuit boards	Total: 3000 BU: 120	Friesland

Firm ID	**Function(s) respondent**	**Date of interview**
1.	Engineering director Project leader	4-2-19
2.	Site manager	14-2-19
3.	Project leader	28-2-19
4.	Managing director	3-4-19
5.	Engineer Student project mentor Innovation scout	18-4-19
6.	Lean coordinator Project leader	23-4-19
7.	R1: External Project developer R2: Internal planmanager	12-6-19
8.	Managing engineer, member of project team	14-6-19

Appendix 12: Most important quotes per topic.

In this appendix, the most relevant quotes per topic are presented. These topic entail quotes on the three constructs, the propositions and on other relevant quotes which are not directly associated with the constructs nor propositions. The entire collection of quotes is gathered in another document since including all quotes would make this appendix too extensive. The tables in this appendix consist of three columns with respectively from left to right the following information: ID firm (1-8), quotes and open codes. The relevance of the quotes is determined by means of the values 1-3. 1 = very relevant, 2 = relevant, 3 = a bit relevant. The quotes presented here are all considered to be on relevance level 1 (very relevant), so the column 'relevance' is left out.

Quotes on the adoption of smart technologies.

ID	Quotation Content	Codes
4	robot bij ons reizen op een track, dus ze kunnen naar allerlei stations toerijden over 22 meter en zo kan je combinaties maken,	Integration/combination of smart technologies (in a smart network) Robot Smart technologies
5	R: Ja, een cobot is een zeg maar een.. cobot staat voor collaboratieve robot, oftewel een robot met gevoel. Een normale robot gaat gewoon keihard door zeg maar, staan hekken omheen, met sensoren, mag je niet bijkomen maar met deze cobot mag je samenwerken. Zijn verwerkingssnelheid is langzamer en mocht hij weerstand ondervinden bijvoorbeeld dan stopt hij of deint zelf terug.	Robot Sensors Smart technologies
6	I: Ja. En wat zijn dan de grootste dingen die je hebt geleerd in het verleden of huidige processen die nog lopen? R: Nou, waar ik eigenlijk al gewoon mee begon, het feit dat het toepassen van robot niet eens zozeer de moeilijkheid is maar het hele logistieke proces eromheen.	Complexity Logistics Robot Smart technologies Technological attributes of smart technologies
4	R: Dat is wat ik net zei, alle machines koppelen aan eem magazijn, dat gaan we nu doen, dat is bijna smart, AGVs, eigenlijk wil je alle logistieke bewegingen gaan automatiseren. Geen kranen, geen heftruck, dat soort zinloos gedoe. Dus dat, en het ambachtelijke zal steeds meer op de achtergrond verdwijnen. Het is veel te tijdrovend geworden. We zijn wel minder flexibel geworden.	AGV (Automated Guided Vehicles) Automation Integration/combination of smart technologies (in a smart network) Plans for the future Smart technologies Systems for automated management of internal logistics

1	Dus het hele datastuk of het IoT stuk is van facilitair belang en doen we een beetje wat er mogelijk is met die oude machines. En als daar heel veel uit te halen is kan het vanzelf interessant worden van: "joh, we gaan versneld nieuwe machines kopen".	Adoption process of smart technologies Relation between adoption process and adoption of smart technologies Relation between technological attributes and adoption process Smart technologies Trial and error
7	Wij hebben ook vanuit het ketendenken gedacht: "kunnen we bijvoorbeeld iets doen samen met toeleveranciers en klanten?". Dat je toch wel in je planning data gaan delen of voor je planning data gaan delen. Maar dan hebben we het over nog wel een stukje nog verdere toekomst.	Adoption process of smart technologies Collaboration with partner Data sharing Integration/combination of smart technologies (in a smart network) Network Smart technologies
3	en die productiebonnen willen we vervangen door tablets of door andere devices. Dat kan een telefoon worden of een tablet of een handscanner. We hebben nu een proef draaien met handscanners van [bedrijf] waar een telefoon in zit.	Mobile devices (for programming and operation of installations and machines) Smart technologies
7	vulmachine en de afvoerband. Die praten met elkaar, dat is in lijn met elkaar en dat is alleen maar beter dat alleen maar de sensoren worden bedekt want dat is heel fragiel.	Differential/relative advantage IoT Relation between technological attributes and adoption process Smart technologies Technological attributes of smart technologies
1	En vandaar uit halen we dat binnen, gaat via de cloud van [bedrijf] zelf dan. Nu nog. Het plan is nu om dat op een eigen cloud te krijgen.	Cloud Smart technologies
6	We proberen nu over de grenzen heen te kijken. I: Alles breder te trekken en alles samen te voegen eigenlijk. R: Klopt! Ja, als je één techniek hebt die je door je hele bedrijf kan uitrollen dan moet dat de voorkeur hebben.	Integration/combination of smart technologies (in a smart network) Smart technologies Synergy
2	R: Volledig kan men een stepfile uploaden en de eerste man die überhaupt aan het proces te pas komt is bij het ontladen van de lasermachine, maar dat is alleen maar laseren, wij hebben 7 technieken. Wij zijn nu aan het proberen, nu zijn we weer een nieuw project gestart, en ik denk dat het nu gaat lukken om volledig via internet de klant zelf via het uploaden van een stepfile zijn prijs te laten bepalen en te laten bestellen. Op sommige vlakken zijn sommige technologieën er al, 3D printen is een mooi voorbeeld.	Plans for the future Smart technologies

Quotes on the adoption process of smart technologies.

ID	Quotation Content	Codes
1	Wel het programmeerstuk waar mijn collega mee bezig is van: “joh, hoe krijg je dan die data uit je apparaat in een format dat je wat mee kan”. Dat is wel echt een lang proces geweest. Heel veel trial en error, maar ja uiteindelijk heb je een signaal waar je wat mee moet, alleen de manier waarop daar is weinig over gedocumenteerd. Heel veel proberen, proberen, proberen.	Adoption process of smart technologies Development of smart technology Programming Relation between adoption process and adoption of smart technologies Smart technologies Trial and error
4	I: Dus als ik het zo hoor hebben jullie een soort van projectteam samengesteld van verschillende personen? Kan ik het zo noemen? R: Nou, het is bijna een één tweetje, en dat groeit en gaat vanzelf en natuurlijk ga je met elkaar brainstormen en als je dat projectteam noemt dan mag je dat noemen maar je gaat met elkaar aan tafel, we zijn dit van plan, we hebben dit als issue, we moeten dat oplossen, we hebben een probleem en dat gaan we tackelen. Nou en dan komen er allerlei oplossingen of voorstellen/opties en dan ga je dat op elkaar gooien. En dan ga je, je schut elkaar wakker en zet elkaar aan het denken en door het met elkaar te doen krijg je de mooiste uitkomsten.	Adoption process of smart technologies Project team
3	R: Wat wij proberen is dat, licht eraan in welke fase van het project je zit, in het begin zit je elke week wel even samen, wordt alles op papier gezet dus wat er gebouwd moet worden, daar gebruiken we online tools voor, en dan moeten de offertes gemaakt worden, dat moet goedgekeurd worden, dan moet er een proef opstellinkje gemaakt worden, ja dat is een continue proces, maar wel kort.	Adoption process of smart technologies Project team meeting Relation between adoption process and adoption of smart technologies
4	Dan steken we gewoon nu de koppen bij elkaar en rollen en we een tekening uit. Dit is er aan de hand, dit is een voorval of we hebben een calamiteit of een claim of een we hebben capaciteitsissue. Koppen bij elkaar: en nu? Zelfde uur, hoppa, klaar, investeren, gaan, man erbij, doorgaan vannacht! Dat.	Ad hoc decisions Ad hoc meetings Adoption process of smart technologies
8	R: Ja wat wij bij vorige machineplaatsingen of processen meestal ook wel gemerkt hebben is dat wij gaan redelijk snel, kijk, we zetten d'r een machine neer zo snel mogelijk willen we daar productie op kunnen draaien en dat is eigenlijk wat je dan het doen bent, je gaat al produceren maar daarnaast moet je ook je werkprocessen nog upgraden en dat moet je ook vooral goed afmaken en dat hebben we in het verleden niet altijd even goed gedaan.	Ability to finish phases in the adoption process Adoption process of smart technologies Finishing phase Implementation Post implementation review Relation between adoption process and adoption of smart technologies

5	R: Dan steek ik daar geen tijd meer in. Ik vraag wel eerst even, als ik denk dat ik iets gevonden heb, waarvan ik denk, bijvoorbeeld die cobot, dat is interessant, wil ik werk van gaan maken, overleg ik even met de directeur, dat ben ik van plan, moet ik daarmee doorgaan of niet. En vaak is het: "ja klinkt interessant, uitzoeken, doorgaan".	Adoption process of smart technologies Cobot Design of a concept/plan Director Evaluation of the proposal Formulation of an implementation proposal Go Relation between adoption process and adoption of smart technologies Smart technologies
5	Maar uiteindelijk plan ik dan wel even een overlegje in en ik zeg dat ik drie offertes heb lopen bij verschillende mensen, wat mijn keuze is geworden, je wilt altijd meerdere offertes hebben, iets te vergelijken hebben en dan wordt er vaak gezegd: "wie moet ik bellen?", dan wordt er gebeld en dan wordt desbetreffende vertegenwoordiger uitgenodigd of als het een kleinigheidje is worden en telefonisch knopen doorgehakt.	Adoption process of smart technologies Compare alternative technologies Decision Evaluation of the offers Offer/quote Scheduling meetings
3	I: Ja precies, ja het is wel gewoon jammer als er iemand uit het project stapt en dan, dat er kennis weggaat, dan denk je: "had ik maar..". R: Ja daarom hebben we nu die partij, [bedrijf], die begeleidt ons daarin. Die hebben echt een projectleider en die documenteren en die zorgen dat ehm, die willen dat ook zelf omdat zij ook met verloop zitten en mensen op andere projecten, ze moeten het over kunnen nemen. Ze verzorgen ook de storingen na vijf uur, dus..	Adoption process of smart technologies Dependability on technology supplier/partner Disappearance of knowledge Documentation Other attributes of smart technology Project (team) leader Support
5	I: Ik vraag me af, ik ben toch nog iets vergeten in de vorige secties, hebben jullie ook wel eens in die processen bepaalde evaluatiepunten, bijvoorbeeld aan het eind dat je het hele proces nog even doorneemt met elkaar van: wat ging goed en wat ging fout? Of hebben jullie dat niet. Dat je dat documenteert. R: Nou, het is niet echt dat we daar vergaderingen aan besteden en documenteren. Waarschijnlijk wordt het op de werkvloer zeg maar besproken, een knoop doorgehakt en meteen gemaakt, als het een verbetering is.	Adoption process of smart technologies Evaluation
2	"Dat is jullie budget, daarmee moet je het doen", wat randvoorwaarden, een soort van hoofdplanning, en dan gaat gewoon het projectteam aan het werk en dan doe ik eigenlijk niks meer. Het gaat over het algemeen gewoon vanzelf.	Adoption process of smart technologies Project planning

5	de werkwijzer is altijd hetzelfde, maakt niet uit over wat voor machine dat gaat, de werkwijze is altijd marktonderzoek: wat is er te koop, welke merken, wat zijn de bereiken, wat kunnen ze, wat zijn de verschillen, wat zijn de kosten? En dat zet je op een rijtje en dan ga je een keuze in maken, dan ga je je er verder in verdiepen en daar volgt de uiteindelijke keuze dan uit die ik dan voorleg aan de directie, adviseer, toelicht indien nodig en dan wordt het vaak gekocht.	Adoption process of smart technologies
2	worden er wel eens stappen teruggezet in het proces? Bijvoorbeeld: je doet een test, test is niet goed, is dat ook hier gebeurd bijvoorbeeld? R: Ja, we hebben echt in het verlassen in kwaliteit een stap terug moeten zetten waarbij we zeker de ruwheid niet konden opvangen en ook echt de extrude hebben moeten aanpassen. En dan ga je eigenlijk een engineersfase terug om weer opnieuw in de ontwikkeling aan de tekentafel weer opnieuw te gaan ontwerpen.	Adoption process of smart technologies Design Design of the technology Recycle/revise Relation between adoption process and adoption of smart technologies

Quotes on technological attributes of smart technologies.

ID	Quotation Content	Codes
8	I: Alsnog goedkoper dan daar ook een machine neerzetten. R: Op dit moment wel ja want machine hebben is niet alleen een machine neerzetten maar ook onderhouden, machine betekent mensen opleiden die er verstand van hebben en die daarmee ook overweg kunnen dus je moet best wel veel optuigen om een om een lijn rendabel te maken.	(Re)training of employees Adoption process of smart technologies Differential/relative advantage Compatibility Complexity Maintaining smart technologies Other attributes of smart technology Relation between technological attributes and adoption process Technological attributes of smart technologies
8	Maar goed, dat moet wel binnen ons productpakket passen en alles wat de oude lijn kan moet de nieuwe lijn ook kunnen.	Adoption process of smart technologies Compatibility Decision Relation between technological attributes and adoption process Technological attributes of smart technologies
6	I: Ja maar viel dat uiteindelijk tegen dan toen je hem binnen kreeg zeg maar? Dat je denkt: “oh, we hadden er eigenlijk meer mee willen doen dan alleen dit”? R: In eerste instantie wel, wat we hadden aangeschaft was ook een simpel visionsysteem, te simpel en datgene wat ik had gehoopt te kunnen doen, dat ging dus niet, ik had hem ook gelijk voor controle willen gebruiken. Ging niet. Systemen die dat wel kunnen kosten meteen hetzelfde als een robot.	Adoption process of smart technologies Complexity Differential/relative advantage Investment costs Poor orientation/project scoping Relation between other attributes and adoption process Relation between technological attributes and adoption process Robot Smart technologies Technological attributes of smart technologies
6	R: Makkelijk implementeren, dat was de achterliggende gedachte zodat de mensen op de werkvloer, in dit geval de supervisors dat die inderdaad met hun kennis makkelijker instromen om die handeling die we willen laten doen met die robot, om die zelf te kunnen doen.	Adoption process of smart technologies Complexity Implementation Relation between adoption process and adoption of smart technologies Relation between technological attributes and adoption process Robot Smart technologies

		Technological attributes of smart technologies Trialability
8	Ik heb performers trouwens nog niet echt overal genoemd maar dat is natuurlijk ook wel een, je hebt best wel veel factoren waar een lijn wel aan moet voldoen, hij moet ook gewoon de performance leveren en de output kunnen leveren die wij nodig hebben dus naast de leverancierskeuze en dergelijke.	Compatibility Observability Other attributes of smart technology Relation between technological attributes and adoption process Technological attributes of smart technologies
6	I: Snap ik. Dus de belangrijkste zijn: het moet makkelijk te implementeren zijn, kosten, je weet wat je krijgt want het is vaak toegepast en de veiligheid vooral. R: Ja.	Complexity Relation between technological attributes and adoption process Safety Technological attributes of smart technologies
7	R1: Ik denk vooral, wat levert het op in de zin van maak het dingen echt gemakkelijker. Wat ga je hier nou echt mee winnen, ook in termen van kosten. Hoe hoog is de investering en hoe of wat verwacht je terug te winnen? Nou ik denk eigenlijk vooral dat, van wat gaat dit uiteindelijk opleveren? Is het een lolletje of hebben we hier echt wat aan.	Differential/relative advantage Other attributes of smart technology Return on investment Technological attributes of smart technologies
6	R: Ja je weet wat je krijgt. Er zijn mensen die zeggen: het is geen industriële robot en als je gaat kijken naar andere industriële toepassingen met robots waar je heel snel bewegingen moet maken en dan zeg je van: “je hebt gelijk”, maar het is een collaboratieve robot, dus de insteek is dat hij samenwerkt met de mens en dan wordt snelheid al snel een risico.	Cobot Other technological attributes of smart technologies Smart technologies Speed
5	marktonderzoek: wat is er te koop, welke merken, wat zijn de bereiken, wat kunnen ze, wat zijn de verschillen, wat zijn de kosten?	Other technological attributes of smart technologies Relation between technological attributes and adoption process Technological criteria

2	R: Ja. Dan moet je in dit geval toch wel denken aan toch wel 30% van de totaalkosten die het project kosten die we relatief goedkoop kunnen doen, een freesmachine kopen is duurder dan het ontwikkelen van deze lasrobot, dat was echt niet duur.	Adoption decision Adoption process of smart technologies Differential/relative advantage Investment costs Relation between technological attributes and adoption process Technological attributes of smart technologies

Quotes on the relation between the adoption process and adoption of smart technologies.

ID	Quotation Content	Codes
7	dat heet officieel een bepaalde afname maar ik ben even de naam kwijt en op het moment dat het naar tevredenheid was, of daar kwamen misschien nog kleine wijzigingen uit voort, zijn die doorgevoerd zo nodig, maar daarna was eigenlijk het moment van: “oke, tweede helft van mei,dat is onze revisieperiode, dan wordt dat gewoon geïmplementeerd”,	Adoption process of smart technologies Deadlines Evaluation of the operational appraisal Evaluation of the test results Go Implementation decision Other attributes of smart technology Recycle/revise Relation between adoption process and adoption of smart technologies
7	Toen is ook gezegd, laten we nog niet A tot en met G maar C tot en met G, dus A en B laten we nog even buiten schot, om het te vereenvoudigen en de succesfactor te vergroten.	Adoption process of smart technologies Other attributes of smart technology Recycle/revise Relation between adoption process and adoption of smart technologies Simplification
7	Niet dat we met acht man op de hei gaan zitten, nee, heel nuchter, bam. Uiteindelijk ben ik altijd van mening, kleinere stapjes met een groot succes is waardevoller dan een grote implementatie met heel veel falen want daar wordt iedereen gestrest van. Dus het liefst dan het project opsplitsen in wat behapbaar is en gemonitord kan worden dan grote projecten waar het eind van zoek is en een grote failure wordt.	Adoption process of smart technologies Formulation of goals Other attributes of smart technology Relation between adoption process and adoption of smart technologies Relation between other attributes and adoption process
1	I: En hoe zag het implementatieproces eruit? R2: Eerst kijken hoe je het gaat inrichten, dan data verzamelen, alles in het systeem zetten en dan vervolgens trainen en dan uiteindelijk het systeem klaarzetten en over.	Adoption process of smart technologies Relation between adoption process and adoption of smart technologies Successful adoption
5	R: Nee ik ben me er niet echt bewust van dat ik iets.. ja, ik doe het misschien wel een beetje zonder nadenken, automatisch een beetje in de goede volgorde. Ja eerst inventariseren en dan pas, dan de mensen erbij betrekken en dan pas kopen. Zodat ik weet dat het kans van slagen heeft.	Adoption process of smart technologies Relation between adoption process and adoption of smart technologies Sequential development steps Trial and error

1	R1: Nou, we hebben het eigenlijk nog niet heel erg gedefinieerd, die fases, zoals je wel zult snappen. Ehm, in dit stukje zijn we een beetje ingerold nadat we eerst heel veel IoT hadden geprobeerd, een heel netwerk en bepaalde sensoren en dat soort dingen en uiteindelijk kwamen we erachter dat dat lastig is.	Adoption process of smart technologies Complexity Integration/combination of smart technologies (in a smart network) Relation between adoption process and adoption of smart technologies Relation between technological attributes and adoption process Technological attributes of smart technologies
7	er wordt geëvalueerd ja maar laten we heel nuchter zijn, je moet je verstand bewaren en je moet oplossingen bedenken en we hebben er niks aan om te zeggen: "we gaan terug".	Adoption process of smart technologies Other attributes of smart technology Recycle/revise Relation between adoption process and adoption of smart technologies
7	Er is namelijk geen weg terug, zo simpel is het. Het is niet zo van: "oh, dan pakken we de oude auto weer", die bestaat niet meer want alles is eruit gesloopt. Dus je moet wel door en uiteindelijk is het allemaal wel gelukt hoor.	Adoption process of smart technologies Irreversible decisions Relation between adoption process and adoption of smart technologies Successful adoption
5	dan uit die ik dan voorleg aan de directie, adviseer, toelicht indien nodig en dan wordt het vaak gekocht.	Acquisition of smart technology Adoption process of smart technologies Decision to acquire/buy Director Evaluation of the proposal Go Relation between adoption process and adoption of smart technologies
5	R: Het moet gedragen worden door de mensen die ermee moeten gaan werken. Je moet ze niet proberen iets door de keel te drukken, of door de strot te duwen, ze moeten zelf het idee hebben dat ze het wel zien zitten en ze moeten er voor willen gaan. Ik moet niet hebben dat die cobot over een half jaar in een hoekje staat en dat niemand hem gebruikt omdat het veel lastig is, daarom probeer ik ze er ook vanaf de beginfase erbij te betrekken zodat ze betrokkenheid krijgen en dat ze daarmee gaan dragen.	Adoption process of smart technologies Cobot Creating support/commitment among employees Human/employee attributes Other attributes of smart technology Relation between adoption process and adoption of smart technologies Relation between other attributes and adoption process Smart technologies

2	En we hebben beide partijen 3D robot printing afgesproken dat zij ter plekke die robot zouden opbouwen, testen en pas opleveren, no cure no pay, vast bedrag afgesproken, dat krijg je als je de robot werkend kunt verplaatsen en opgeleverd hebt.	Relation between adoption process and adoption of smart technologies Robot Smart technologies

Quotes on the relation between the technological attributes and the adoption process of smart technologies.

ID	Quotation Content	Codes
5	marktonderzoek: wat is er te koop, welke merken, wat zijn de bereiken, wat kunnen ze, wat zijn de verschillen, wat zijn de kosten?	Other technological attributes of smart technologies Relation between technological attributes and adoption process Technological criteria
8	investeringsvoorstel maken dus een business case van: “Waarom willen we het? Wat gaat dat kosten? Wat levert het ons op?	Adoption decision Adoption process of smart technologies Assessment of financial return on investment Differential/relative advantage Investment costs Other attributes of smart technology Relation between technological attributes and adoption process Technological attributes of smart technologies
8	Toen hij d'r nog niet was en nu is inmiddels is het apparaat binnen dus ze hebben er nu een aantal weken mee kunnen spelen.	Adoption process of smart technologies Getting used to new technology Relation between technological attributes and adoption process Technological attributes of smart technologies Trialability
3	en dan komen de offertes, dan komen de.. wat houdt het in, hoe moet het geprogrammeerd worden, kunnen we het zelf programmeren. Ja dan komt er zo’n plaatje uit van: “Ja, jongens, dit is gewoon niet haalbaar”. I: Nee precies. R: Kosten zijn te hoog, het is te moeilijk. I: Duurt te lang misschien ook?	Adoption process of smart technologies Evaluation of the offers Evaluation technical assessment Examining the technical feasibility of the project. Other attributes of smart technology Relation between technological attributes and adoption process Technological attributes of smart technologies
1	R1: Ja, en dan kun je altijd nog beslissen van: “Joh, dit is te complex, dit gaan we wel uitbesteden of dit niet of een deel daarvan”. Kijk, de hardware is redelijk zelf te doen. En inderdaad, het programmeren van software, daar zijn bedrijven voor die daar heel handig en goed in zijn. Doen we ook hoor, hebben we ook een bedrijf voor die dat nu al voor ons doet.	Relation between technological attributes and adoption process

5	Waarschijnlijk wordt het op de werkvloer zeg maar besproken, een knoop doorgehakt en meteen gemaakt, als het een verbetering is.	Ad hoc decisions Adoption decision Adoption process of smart technologies Differential/relative advantage Relation between technological attributes and adoption process Technological attributes of smart technologies
2	“maak dan maar berekeningen, dat je mij overtuigd dat ik wél in een robot moet investeren.” Dan maak je nieuwe berekeningen wat dat dan op lange termijn doet, wat het qua productstromen en kwaliteit voor verschil maakt, want een mens is toch maar een mens, een robot kan constante kwaliteit leveren.	Adoption process of smart technologies Compatibility Differential/relative advantage Observability Proposal Relation between technological attributes and adoption process Technological attributes of smart technologies
7	R1: Ik zou denk ik eigenlijk als allereerste gewoon een soort van scan maken. Van wat is alle informatie die er is? Hoe vertaal je dat naar data en in welk format is dat het meest praktisch?	Adoption process of smart technologies Differential/relative advantage Idea generation/awareness Inventarisation Orientation Relation between technological attributes and adoption process Research Start adoption process Technological attributes of smart technologies
1	Dus het hele datastuk of het IoT stuk is van facilitair belang en doen we een beetje wat er mogelijk is met die oude machines. En als daar heel veel uit te halen is kan het vanzelf interessant worden van: “joh, we gaan versneld nieuwe machines kopen”.	Adoption process of smart technologies Relation between adoption process and adoption of smart technologies Relation between technological attributes and adoption process Smart technologies Trial and error
8	R: Dan heb je geen service meer. Dat soort zaken en voor de rest ja, zoals ik al zei, dit is dan een technologie en dan hebben we eigenlijk al een voorkeursupplier dus wij gaan redelijk snel naar de mogelijkheden en de onmogelijkheden. Wie gaan niet zozeer kijken van: "is het wel robuust genoeg enzo", want dat is eigenlijk al uitgezocht.	Adoption process of smart technologies Other attributes of smart technology Relation between technological attributes and adoption process Robust Service

Quotes on other attributes and their relation with the adoption process of smart technologies.

ID	Quotation Content	Codes
1	Een selectie van de hardware is dan echt van wie is er, wie heeft er goede documentatie, wie is er aanwezig en ook wel wereldwijd, hoe goed bereikbaar. Toen kwamen we bij, daar heb je nog een andere, hoe heette die andere nou, zijn er een aantal die dit doen. Bij [bedrijf] had ik er op een of andere manier een goed gevoel bij.	Other attributes of smart technology
2	En de mens heeft van nature een houding: robot gaat mij vervangen.	Attitude towards innovation Other attributes of smart technology
3	robotarm en daar bleek al heel snel uit dat die robotarm, de technieken daaromheen, ja een automotive, die kan dat gewoon betalen, die regelt gewoon dat het goedkomt. Maar wij, een als [bedrijf], die mkb+ is, is voor ons gewoon te duur.	Financial/cost attributes Firm size Investment costs Other attributes of smart technology
4	Dus daar hebben we naar gekeken maar verder in de organisatie, wat ik al zei, je hebt vloeroppervlakre nodig dus waar we tegenaan liepen, ja we waren hier gevestigd, waar gaan we dat ding dan zetten?	Organizational attributes Other attributes of smart technology
5	R: Zoals de klant het wil hebben. Het is altijd langer, breder, hoger, korter, dikker, dunner, het is altijd weer anders.	Environmental attributes Flexibility Other attributes of smart technology
6	en we konden wel aantonen dat er dus winst in zat dus het wordt altijd gerelateerd aan de mensfactor, wat kost een mens?	Other attributes of smart technology
7	R2: Nee ja, je moet het vertrouwen in elkaar hebben, dat sowieso, en in dit geval was het ook wel heel waardevol dat ze om de hoek zaten, die partij. Dat klinkt heel praktisch maar soms heb je leveranciers, die komen uit Italië en die bieden iets heel goedkoop aan en dan heb je een probleem en ja, volgende vliegtuig gaat volgende week vrijdag, ja hebben we allemaal niks aan dus de partner die om de hoek woont is ook wel fijn.	Attributes of technology supplier/partner Financial/cost attributes Other attributes of smart technology Proximity
8	Wij moeten gewoon aan de wensen van de klant, de vraag van de klant, kunnen voldoen en ja dan kun je bepaalde dingen niet meer produceren en dan loop je achter.	Customer attributes Other attributes of smart technology