The importance of the Smart Industry concept for innovation in Dutch companies

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The importance of the Smart Industry concept for innovation in Dutch companies

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Preface and Acknowledgment

I started to study Innovation Sciences at Eindhoven University of Technology in September 2014. This thesis is the final product of my master program. What I like about Innovation Sciences is the multidisciplinary perspective it provides for innovation studies. This enables students to bridge the gap between technology and society.

I took an internship at High Tech NL (HTNL) in the third semester of my master study. HTNL is a network organization at the High Tech Campus in Eindhoven that aims at contributing to the Netherlands high tech ecosystem by conducting various initiatives. The internship was a good opportunity for me to apply my academic knowledge to solve problems in the high tech industry. During my internship, I got familiar with the very interesting concept of the Smart Industry. The insights that my dear colleague Jos van Erp provided about the subject made me enthusiastic to start my master project on this subject.

I would like to thank the people who made writing this thesis possible. My regards go first to my supervisor, dr. Bert Sadowski, who guided me through all steps of this project with his useful feedback. I would also like to thank my second supervisor, dr. Önder Nomaler, for the time that he enthusiastically allocated to my research, especially in the design of the survey and the quantitative analysis.

Additionally, I would like to thank my third supervisor, Jos van Erp, for his support through all steps of the research, especially in introducing me to the different organizations for the interviews. Furthermore, I would like to thank Nikki Jacob from the Smart Industry Program Office, who helped me to send out my survey questionnaire to the members of HTNL. Further, I would like to provide my gratitude to Nur America for sharing her knowledge about the Smart Industry and her feedback on the design of my survey questionnaire.

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I hope you enjoy reading my master thesis.
Abstract

Integration of the manufacturing process by Internet of Things (IoT) is considered by many as the 4th Industrial Revolution. Within the Netherlands, the Smart Industry concept is a new initiative by the Dutch government to help the industry catch up with the new challenges such as sharing information between companies. Although the Netherlands has a good Information Communication Technologies (ICTs) infrastructure, only a few companies are currently using ‘smart’ solutions. In particular, non-technology sectors (such as agriculture and construction) and very small companies are less inclined to utilize opportunities emerging based on the Smart Industry concept (KvK, 2015). This research aimed at developing a framework for the Smart Industry by using a mixed method approach. In the literature study, research has shown that the Smart Industry concept is not only about new technologies, but also requires organizational changes within companies. So, human capital and smart technologies are two important elements of the Smart Industry. Moreover, investment in the Smart Industry concept leads to more innovation activities.

In the empirical part of the thesis, nine case studies and a survey study were conducted to test the framework. The results confirmed that there is no single technology within the Smart Industry concept, but there is a convergence of ICTs, IoT and advanced manufacturing technologies. However, IoT and manufacturing technologies are perceived to be more important than commonly used ICTs like internet connection and telecommunication. Moreover, there is a balance between smart technologies and human capital development in the companies using the smart industry concept. This balance is a necessity for success with the Smart Industry concept.

The case studies showed that the Smart Industry has many facets. Each company has its specific way to implement the concept. Companies using the smart industry concept are looking within their organization to find the most serious knowledge gap. The application of smart solutions accelerates innovation activities and brings real-time intelligence to the companies. The results are high quality and customized products, increased revenue and turnover and business growth. The smart companies do not focus on the end products, but on innovation in the whole process of manufacturing. The integration of the manufacturing process requires effective collaboration activities inside and outside the organizations.

Investment in technical and soft skills of the labor force is a must if the Smart Industry concept can successfully be applied. All groups of employees in an organization, especially engineers, are important in implementation of Smart Industry solutions. Moreover, social innovation plays a very important role in
this implementation. Finally, this study identified three groups of smart companies based on their investment on smart technologies and human resources. These groups are compared based on their size, collaboration activities, innovation output and challenges.
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1. Introduction

The Netherlands is ranked at the 5th place of the Global Competitiveness Index developed by the World Economic Forum (WEF) in 2016. Innovation is an important driver of competitiveness, economic growth and sustainable development. However, many technological inventions never become implemented in the market place. As the WEF report puts it, “Inventions of the last decade, such as social networks and the sharing economy, have had less effect on increased productivity and sharing knowledge between companies than the Internet revolution”. It has been proposed that the recent economic crisis is the time period before the adjustment of the economic systems, organizations, and industries to a new techno-economic paradigm (Perez, 2010).

Currently this techno-economic paradigm seems to be driven by a new industrial revolution based on the emergence of the IoT (Rifkin, 2014). The digitization of industry is very important pre-requisite of this new industrial revolution. The fourth industrial revolution is differently described in advanced countries (for example; “Industrial Internet” in United States and “Made Different” in Belgium), but the ambition of countries are the same. Germany announced the so-called Industry 4.0 program officially during the Hannover Messe Exhibition 2013.

The Dutch government announced the “Smart Industry” policy in order to help the Dutch industry to catch up with the new economic reality and become more competitive in the international arena. TNO, the Ministry of Economic Affairs, VNO-NCW, the Chambers of Commerce and FME prepared the report “Smart Industry, Dutch Industry fit for the future” to help companies, knowledge institutions, and government in the way to the 4th industrial revolution. The report was presented at the Hannover Messe 2014.

The Smart Industry concept is not limited to the manufacturing sector and high tech companies. As it has been described in the report, “the Smart Industry is driven by smart use of ICT to interconnect machines for smart operation. This is not only within factories but also between companies and between companies and customers. It involves a combination of the use of production technology, digitization, and a network approach (figure 1)”. However, the current mindset of decision makers in the industry is perceived to be different than promises of a new industrial world based on Internet of Things (IoT). The underlying definitions, elements, and consequences of the Smart Industry or Industry 4.0 are still not clear (Brettel, Friederichsen, Keller, & Rosenberg, 2014; Hartmann & Halecker, 2015). If the entrepreneurs do not respond fast enough to disruptive changes in the IoT area, their business will not be competitive in
coming years. The development of the Smart Industry concept requires providing a definition which is simple and applicable for all companies.

Although the Netherlands is scored as the 10th best country in the World in technological readiness index, the Netherlands is 29th with respect to firm-level technology absorption in the world. As Egbert-Jan Sol (2015) states economic growth is mainly achieved through the use of ICT, rather than by investing in ICT and hardware infrastructure. It is important to explore further what technical changes the Dutch companies need to undertake if they want to implement the Smart Industry concept.

More than technology, examples of obstacles mentioned in previous studies about the Smart Industry in the Netherlands are the current culture of work (e.g. the fear of losing a job because of the application of new technology or the fear of sharing knowledge), collaboration of supply chain, financial issues, lack of skilled staff, and out dated business models (FME, 2015; Huizinga et al., 2015; KvK, 2015).

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1 The technological readiness pillar measures the agility with which an economy adopts existing technologies to enhance the productivity of its industries, with specific emphasis on its capacity to fully leverage information and communication technologies (ICTs) in daily activities and production processes for increased efficiency and enabling innovation for competitiveness.
A very important element of the Smart Industry concept is the human being, who is involved in the implementation of the concept and controls the whole process. Therefore, it is important for organizations to have highly skilled employees with comprehensive knowledge about the Smart Industry. The Netherlands is ranked as the third best country in the World in respect to higher education and training system (WEF, 2016). However, the result of a Smart Industry survey showed that 86 percent of entrepreneurs in the Netherlands are still relatively uninformed about the Smart Industry concept and its implications for their business (Action Agenda Smart Industry, 2014). Therefore, it is important to investigate to what extent the knowledge of employees in organizations is sufficient to implement the Smart Industry concept.

Based on the Smart Industry report, “the 4th industrial revolution will end the economy of scale and confront the large companies with the threat of new start-ups and Small and Medium Sized Enterprises (SMEs) that use disruptive technology and business models that takes advantage of more innovative staff”. However, the empirical evidence shows that the approach of small companies in the Netherlands to upcoming changes is considerable lower than that of bigger companies (KvK, 2015). Moreover, several sectors, especially non technology sectors, seem to be later adopters of the Smart Industry concept. However, the explanation of the differences is not provided in that quantitative research. Agarwal and Brem (2015) claimed that the convergence of Information Technologies (IT) and operational technology (OT) across high tech sectors such as healthcare and aviation reduces costs, optimizes business processes, and increases productivity.

This research is aimed at providing new empirical insights into the competitiveness of the Netherlands industry in the global race for "smarter" industry solution that transforms the threat of disruption to new opportunity. This research includes a diversity of companies in the industry because implementation of the Smart Industry concept requires cross sector and cross disciplinary thinking.

1.1. Research questions

The main research question is as follows: “Why is the Smart Industry concept vital for innovation of Dutch companies?”

The main research question can be split up into three sub questions that are answered by a literature study, multiple case studies and a survey study:
• How important are new technologies, learning new skills, and collaboration activities for implementing the Smart Industry concept in theory and practice?
• To what extent does the Smart Industry concept provide for higher innovation output in theory and practice?
• To what extent are the Smart Industry solutions implemented in the Dutch industry?

1.2. Research Method

The Smart Industry is quite a new subject. Therefore, there is not much known about its elements and effects on innovation of the Dutch companies that use the concept in their organization. The research uses a mixed-method approach using both qualitative and quantitative research methods in a single study (Yin, 2009). This method is appropriate to address the research questions. Sub questions one and two will be answered by means of a literature study and multiple case studies. Therefore, the research starts with a literature study. Meanwhile, participation in events about the Smart Industry, for example the Smart Industry annual event, built up my knowledge about the concept. This helped me to combine my knowledge from publications with the approach of companies toward the Smart Industry concept. The result of this research step prepared me to develop semi-structured interview questions for a multiple case study.

The case companies are at different stages of the changes toward Smart Industry solutions. The interview questions include both structured and open questions. The structured questions allow me to compare and contrast the result of the case studies. The open questions aim to explore the opinions of experts active in the Smart Industry.

The conceptual model is developed based on the result of the literature review and were used in the case studies. The survey study was aimed at generalizing the empirical findings and provide answers to sub-question three. The advantage of a mixed method is that the qualitative approach can provide additional insights into the findings of the quantitative (survey) study. Although, the low response rate and small sample of respondents provided some limitation for the empirical research, it provided some information to answer the research question.

1.3. Research Justification

This section explains how this project fits the domain of Innovation Sciences with respect to theoretical and practical implications.
1.3.1. Scientific Relevance

The Smart Industry concept currently is a new emerging research area within Innovation Sciences. However, there is no unique and common definition of the Smart Industry concept which is shared by companies, the government, knowledge institutions, and network organizations in the Netherlands. Moreover, the available academic publications about the Fourth Industrial Revolution are mostly from other countries like Germany (on the “Industry 4.0” concept) or the United States (on the “Industrial Internet”). The innovation history has shown that after the first industrial revolution each country has its own path towards innovation (Horn, 2009). This has consequences for the Netherlands as the Dutch industry has its own characteristics and cannot follow the model of other countries toward the Fourth Industrial Revolution.

There is a lack of common definitions of the Smart Industry, which makes it difficult for the Dutch academic institutions to contribute to the international discussion. Therefore, on a theoretical level, the study aims at filling the gap by studying the literature on Smart Industry concepts and by providing new insights into the Dutch version of a Smart Industry concept.

1.3.2. Relevance to Industry

A study done by Smart Industry team showed that uncertainty of entrepreneurs about new business models is an important concern for companies to utilize Smart Industry concepts in the Netherlands. In the short term, the aim of the Dutch government should be to increase the awareness of companies about the smart industry concepts to 80%, and bring the number of companies using Smart Industry-approaches from 14% to 40% in 2018 (Action Agenda Smart Industry, 2014).

This master thesis aims at providing new insights into the competitiveness of the Dutch industry in the global race for "smarter" industry solutions. I did my research at High Tech NL (HTNL), the network organization of Dutch high tech companies as well as different research institutions and universities in the Netherlands. HTNL aims to advise member companies with consultancy information about the Smart Industry concept.

The knowledge and experience from this master thesis can be shared in the short term with a large number of companies in the Dutch innovation ecosystem, especially the members of HTNL. The result of my research will provide advice for those entrepreneurs who still hesitate to invest in Smart Industry concepts. Therefore, on a practical level, this study will be relevant for the entire Dutch industry.
1.4. Reading Guide

In the next chapter, the theoretical literature on the Smart Industry concept will be discussed. It focuses, in particular, on the technological and human capital aspects of the Smart Industry. The study about the effects of smart industry solution on innovation output of Dutch companies will be undertaken in Chapter two. Chapter three provides the report of case studies of nine companies and organizations that are active in opting for digitalization and the application of Smart Industry concepts.

Chapter four explains how the result of the literature study led to the design of the conceptual model. Guided by the conceptual model, a survey study is designed. The remaining part of Chapter four describes the variables in the survey and the sampling method.

Chapter five presents the findings of the quantitative analysis including both descriptive and inferential statistics. Finally, Chapter six summarizes all the results and draws conclusions. Finally, I present limitations of the research and remarks for future research (Chapter six).
2. Literature Study

2.1. Introduction

The report “Smart Industry, Dutch Industry Fit for the Future” (available at Smart Industry website\(^2\)) provided a good starting point for this master thesis. There are few academic publications about the Netherlands Smart Industry in scientific data base like Google Scholar. The main bulk of publications about the Smart Industry are industry level publications by Dutch research instructions. This emerging literature was a good starting point to conceptualize the concept of Smart Industry.

Next, I searched for academic publications in Google Scholar using key words such as “Smart Industry”, “Industry 4.0”, “Industrial Internet”, “The 4\(^{th}\) Industrial Revolution”, “Digital Revolution”, “Industrial Internet of Things”, “Smart Manufacturing”, “Smart Factories”, “new ICT and Innovation”. This guided me to number of literatures that reported difficulties in clearly defining “Industry 4.0” or the “4th Industrial Revolution”. For example, Lee, Kao, & Yang (2014) conducted a literature study on English and German publications about the Industry 4.0 concept and included similar terms such as “Smart Industry” or “Smart Manufacturing”. They used five publication databases (CiteSeerX, ACM, AISel, EBSCOhost, Emerald Insight) and Google Scholar in their research. Their research identified four key components of the Industry 4.0 concept: Cyber-Physical Systems (CPS), Internet of Things, Internet of Services (IoS), and Smart Factory.

According to Hermann, Pentek, & Otto (2016) “Industry 4.0 is a collective term for technologies and concepts of a value chain organization. Within the modular structured Smart Factories of Industry 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPSs communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross organizational services are offered and utilized by participants of the value chain”. This definition covers the main aspects of the Smart Industry. The results of my literature study confirmed that there is no commonly agreed definition of the Smart Industry concept, but this concept includes different elements, especially technological concepts like CPS, Big Data, and Cloud Computing are difficult to define based on the literatures. Moreover, the definition by Hermann et al (2016) does not explain how the employees can prepare for their new task in the smart factories. Furthermore, the challenges for the companies in implementation of the Smart Industry are not explained in this definition.

\(^2\) Smart Industry website: http://www.smartindustry.nl/
Therefore, I searched for academic publications using Google Scholar with keywords such as “Technologies for Industry 4.0”, “Implementation of Industry 4.0”, “Challenges for Industry 4.0”, “Barriers for Industry 4.0”, “Collaboration of Industry in Digital Revolution”, “the Role of Employees in Digital Innovation”, “Work Culture and Digital Innovation”, “Sharing Knowledge and Information to implement Digital Innovation”, “Industry 4.0 and Sharing Knowledge”, “Complementary of Human Capital and ICT in Industry 4.0”, “Innovation Output of Industry 4.0”.

Afterwards, I reviewed the citation and reference list of the relevant article in order to collect more data for the literature study. Since the concepts of “Smart Industry” or “Industry 4.0” are an emerging topic, I did not exclude recently published articles which may have (in some cases) fewer citations in Google Scholar. Reviewing the articles prepared me for in depth information to answer my sub questions one and two in theory. The next section summarizes the results of the literature study and draws conclusions for conceptual framework of the thesis.

2.2. Convergence of technology domains

Two new important trends in the manufacturing industries are CPS-based manufacturing and service innovations (Lee, Kao, & Yang, 2014). As stated in the Smart Industry agenda: “one of the important goals is to accelerate the development and co-creation of new business (models), products, services and production technology by new companies or companies in service sectors which are not traditionally engaged in production”.

Actually, CPS and IoT concepts are converging to the Internet of Services that widely uses the cloud-based approach for creating, publishing, and sharing services (Kagermann, Helbig, Hellinger, & Wahlster, 2013; Pisching, Junqueira, Santos Filho, & Miyagi, 2015). The Internet will facilitate the Smart Industry concept, because it allows communication between humans as well as machines in CPS throughout large networks (Brettel, et al., 2014). The implementation of CPS in factories of the future can lead to work which is done autonomously and in which the production interacts with the environment if factories are equipped with microcontrollers, actuators, sensors and a communication interface (Kolberg & Zühlke, 2015).

Based on the Smart Industry report, it has been stated that “…there is no single technology or technology domain that governs the Smart Industry revolution, but it is the convergence of multiple technology domains. Machine to machine (M2M) communication is revolutionized by new ICTs. Sensor technology, embedded systems, cloud technology, advances in RFID and GPS constitute the Internet of Things, an
internet-style network of interconnected, intelligent machines termed CPS. Secure and robust network, which are powered by more intuitive forms of human-machine interaction, is another contribution of ICT. Finally, ICT enables the practical application of manufacturing techniques such as 3D printing to a large extent” (Huizinga, et al., 2015).

A case study by Agarwal et al (2015) identified different technologies which are converging at General Electric (GE) based on the integration and alignment of OT and IT. They used the following definition by Gartner (2011) to characterize OT, “hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes, and events in the enterprise”. The conclusion of this case study was that “localized exploitation in IT, involving decentralizing IT and deploying standard IT across businesses is likely a prerequisite to the technology convergence, which led to the embedded IT capabilities within the organization” (Agarwal et al., 2015).

2.3. Collaboration Activities

Technology is not the only pillar of the Smart Industry concept. Organizational change is required in order to capture the potential of technologies like IT in companies (Brettel, et al., 2014; Tippins & Sohi, 2003). As Hartmann and Halecker (2015) put it, “Industrial Internet of Things (IIoT) is a system innovation and CPSs are an essential technical component of it. Therefore, the balance between all factors of a system (output, input, organization, staff/workforce, and technical equipment) is very important”

As Lee, et al (2014) argues “Implementation of the Industry 4.0 is not only about connectivity between machines and using sensors, but the presence of correct information at the right time for the right purpose is a necessity”. Information as value driver that leads to new business models in the (traditional) industry (Sol, 2015).

In addition, it has been proposed that “collaborative networks are a necessity in order to share data throughout the supply-chain for full exploitation” (Brettel, et al., 2014). Furthermore, convergence of CPS and IoT leads to a growing number of virtual enterprises (VE) around the world that need to collaborate effectively (Kagernann, et al., 2013; Pisching, et al., 2015). Huizinga et al (2015) proposed, in contrast, a different definition “Smart Industry is enabled by a network-centric approach, making use of the value of information, driven by ICT and the latest available proven manufacturing techniques”.

There are also some technical definitions of Smart Industry concepts, Schuh, Potente, Varandani, Hausberg, & Fränken (2014) attributed CPS as the technological driver of the Industry 4.0 concept and
the collaboration as an organizational driver fostering it. They propose a framework for collaborative practices with three dimensions: coordination, cooperation and communication. According to them, “sharing information among partners is costly and often fails due to a lack of willingness to bear costs unless one party sees a direct benefit”. In addition, Brettel et al (2014) write “Industry 4.0 will only work, if machines can communicate via CPS and commodity flows are tracked by RFID or similar technologies throughout large sections of the industry”. Reluctance to share knowledge is an obstacle for companies to take advantage of the opportunities that Smart Industry offers (FME, 2015).

According to Schuh et al (2014), “Communication provides the means to share information and enables sense-making. Cooperation indicates that the involved entities recognize the importance of the overall goal and consequently work together in order to reach it”. So, these soft skills are pre requirement of the implementation of the Smart Industry concept.

Abrell (2016) claims that using customer's explicit knowledge can help firms with incremental products and services innovation, while users’ tacit knowledge contributes to radical digital innovation. Focus on users’ tacit knowledge is more useful for the firms because customers cannot guide them find the right directions in long term digital innovations. However, more empirical research is needed to investigate the reliability of this argument.

The literature has also pointed at other factor in the Smart Industry concept like coordination, customization and skills requirements. For example, Schuh et al (2014) propose “coordination is managing dependencies between activities”. Furthermore, according to Brettel et al (2014) “customization needs coordination and change in labor work”. In addition, organizations implementing Smart Industry concepts need high skill employees (Action Agenda Smart Industry, 2014). The next section describes the important role of employees in the Smart Industry concept based on the literature.

2.4. The role of employees

Kagermann (2015) claims that “Industry 4.0 reduces the half-life of academic skills and education of staff. Employees will increasingly perform high skills task in systems planning, engineering and integration or coordination and orchestration rather than simple tasks in the Industry 4.0 concept”. Actually, increasing use of self-controlling systems that communicate via the Internet and/or humans may lead to unforeseen problems. The workers need to coordinate to solve new kinds of problems (Brettel et al., 2014). As a result, the complexity of new ICT systems requires higher problem solving skills. Therefore, investment in training of employees is inevitable for companies if they want to remain
competitive in their industry. Moreover, the companies should involve employees in the decision-making procedure (Kagermann., 2015). This will lead to an increase in the productivity of companies (Black & Lynch, 2001).

Another necessity to successfully implement the Smart Industry concept is to hire new knowledge employees. Employers in some countries appear to be reluctant to hire recent graduates and prefer to hire workers with previous experience (Holtgrewe, 2014). This is a major concern because young engineers (even without long working experience) are highly interested in providing their contribution to implement new ICT solutions.

Michaels, Natraj, & Van Reenen (2014) investigated eleven OECD countries (including the Netherlands) from 1980 to 2004 and found empirical evidence for skill shortages in many regions. According to Holtgrewe (2014), “the skill shortage includes both technical and nontechnical skills, such as English competencies, project management and organizational skills, team working and communication skills, and both creative and systematic ways of working”.

In other words, the implementation of Industry 4.0 or Smart Industry concepts requires interdisciplinary “training, lifelong learning and personalized learning” (Kagermann., 2015). As Holtgrewe (2014) puts it, “actions are needed to align vocational training and university curricula better with the needs of the industry and of students”.

Burmeister, Luettgens, & Piller (2015) claim that “a good way to go beyond technological capabilities and focus on the customer or user perspective is to participate in relevant conferences or working groups and connect both within and outside the industry to broaden the view. Multi-disciplinary work between R&D, operations, and IT, sales or service functions provide the motivation for business model innovation. This can be done by informal meetings, expert panels with invited speeches from external speakers, or exploratory workshops”. For example, a case study on Volvo (car manufacturing company) by Svahn, Lindgren, & Mathiassen (2015) attributes multi-disciplinary employee groups as an important factor that has helped to collaborate with external parties and minimize divergence between digital innovation and product innovation.
2.5. Innovation output of the smart companies

The production concepts have changed from mass to individualized production. Increased competition in the market forced manufacturing companies towards product differentiation based on the demand of customers.

The Industry 4.0 (or the Smart Industry) concept provide companies with some guidance to bring new products to the market faster based on the demand of individual customers (Pisching, et al., 2015). The concept provides a better prediction which allows to “optimize manufacturing management and maintenance scheduling, guarantees machine safety, reduces labor costs and provides a better working environment, leads to more transparent and organized industrial management and reduces the cost” (Lee, et al., 2014). Modular simulation and modeling leads to more flexible, decentralized and rapid product innovation in a future Industry 4.0 (Brettel, et al., 2014).

The joined use of the concepts of Industry 4.0 and lean production add value to users. In this context, “lean Production is a collection of synchronized methods and principles for controlling production sites. It strictly integrates humans in the production process” (Kolberg & Zühlke, 2015). According to Womack, Jones, & Roos (1991), eliminated waste in the manufacturing process by lean production increases product variation.

Agarwal et al (2015) claims that the Industry 4.0 concept increases productivity, reduces cost, and provides real-time intelligence. Brettel et al (2014) claims, in addition, that “use of the real-time data in the production process is a new approach toward inter-company operations and supply-chain efficiency”.

According to Huizinga et al (2015) “Smart Industries are industries that have a high degree of flexibility in production, in terms of product needs (specifications, quality, design), volume (what is needed), timing (when it is needed), resource efficiency and cost (what is required), being able to (fine) tune to customer needs and make use of the entire supply chain for value creation”. This definition goes beyond traditional firm level approaches by focusing also on the external environment.

Little quantitative research, however, is conducted to link the implementation of Smart Industry concept to innovation output of the companies. Empirical research by (Schmidt et al., 2015) among 133 experts of Industry 4.0 in German speaking countries found positive correlation between “use of technologies (like Big Data or Cloud)”, “mass customization”, “use of idle data” and “production time improvement” and the potential use of Industry 4.0 (as the target variable). However, their research did not provide any
information on the causation relationship between the explanatory variables and target variable. Moreover, their research only focused only on experts which were aware of the Industry 4.0 concept. However, characteristics like “Big Data” and “CPS” have not yet been investigated in an empirical setting.

2.6. Type of companies

The implementation of the Smart Industry concept differs across types of companies, with in particular SMEs benefiting from these new technologies. Pisching et al (2015) claim that “virtual enterprise establishment empower SMEs on the Industry 4.0 concept because shared skills, knowledge and resources as services over the cloud-manufacturing context leverage the business potential and improve their customer satisfaction”.

Furthermore, the Smart Industry is about network centric approach (the end of the value chain approach). “This will result in new customer-centric business models, both at the level of organizations and across entirely new value clusters. Consumers and small businesses will co-create in a new and complex manufacturing system previously inhabited only by large companies” (Huizinga, et al., 2015).

However, the results of a Smart Industry panel survey by KvK in 2015 show that a relatively high number of small companies (less than 50 employees) think that the Smart Industry concept does not affect (contribute to) their business. Big companies (more than 50 employees) see more opportunities in the Smart Industry concept (KvK, 2015). The result of survey, however, did not identify the reason behind of this finding.

2.7. Conclusion

This chapter provides more insights about the elements of the Smart Industry and their contribution to innovation activities of the companies. The aim was to answer sub-question one and two by undertaking a literature review.

The common definition of innovation (the introduction of a new or significantly improved product, process, organizational method, or marketing method by an enterprise (Eurostat, 2005). The Smart Industry accelerates the innovation by taking advantage of new technologies and high skill staff.

The Smart Industry concept contains a multiple of technology domains especially ICT, IoT and manufacturing technologies. However, technology is not the only driver of the Smart Industry. The
organizational change is pre-requisite of technology innovation. The workers involved in the implementation of Smart Industry concepts need to learn new skills. As an example Holtgrewe (2014) argued that “employers do not just rely on marketing and sales specialists or management to be aware of the market environment, but ‘customer focus’ or a ‘profit mindset’ are demanded from ICT professionals at large, regardless of their decision-making powers in these areas”.

The human capital aspect of the Smart Industry is not limited to inside a company or organization, but requires a new approach in collaboration with other parties. Collaboration of the parties facilitates the circulation of knowledge and information between the industry. However, it is not easy in practice. One known problem is fear of information disclosure. Proximity, effective communication and coordination between parties can address the problem. Abrell (2016) introduced the “controlled environment” as a mechanism to facilitate sharing knowledge. Participation of B2B manufacturing companies with their end-users in “digital innovation labs” is an example in this context.

The aim of this master thesis is to develop a framework that combines the human aspect and the technological requirements of the Smart Industry concept. Furthermore, as Smart Industry solutions have to contribute to innovation output, this dimension is added to the conceptual model. This framework should be able to examine different companies and organizations (from different sectors, size, core business and etc.) and explain possible differences between them. Therefore, this conceptual framework will be used to answer the research questions introduced in the introduction.
3. Case studies

3.1. Introduction

This section explains the second phase of my research. In this chapter, I describe multiple case studies of companies, which are at different stages of implementing the Smart Industry concept, in order to answer sub-questions one and two empirically. Moreover, according to Baxter & Jack (2008), case studies provide an opportunity to compare qualitative data with quantitative data from a survey study.

As Tellis (1997) stated, poor questions and response, incomplete recollection, and reflexivity may influence the interview results. Therefore, I prepared a set of questions before the interviews (see Appendix 1). The list of general questions was similar for all companies. However, because of the diversity of the cases and business activities I designed, in addition, special interview questions for each case. For example, a technology like 3D-printing is not relevant for a non-manufacturing company. Moreover, as discussed in the introduction, the Smart Industry concept still is in flux in the Netherlands. Therefore, its definition is not commonly understood across companies.

I used face-to-face interviews. The advantage of face-to-face interviews is that the researcher can explain the questions in case the interviewee is not familiar with the subject. Moreover, this allowed me to ask follow-up questions during the interview based on the arguments of my interviewees.

I used semi-structured questions in order to ask both open and structured questions. The structured questions enable the researcher to compare the findings from multiple case studies. However, it was sometimes difficult for the interviewees to scale their answers. In this case, I asked them to explain their answers and scaling was skipped. The open questions allowed me to identify the new aspects of the subject because it provided more space for interviewees to talk about the subject.

3.2. Description of Cases

Regarding the research questions it was important to select a diverse set of companies for the interviews. This allowed me to capture various aspect of the Smart Industry. I tried to choose interviewees who had knowledge about the subject. However, the knowledge of my interviewees about the Smart Industry concept was differing among respondents. First of all, few of organizations were active in implementation of the Smart Industry concept even without knowing the name of it or just having some information about it. Secondly, based on my observations there is no common definition of the Smart Industry concept.
Table 1 below summarizes the main information about the sector and size of the companies involved in the case study:

<table>
<thead>
<tr>
<th>Case</th>
<th>Core Business</th>
<th>Size</th>
<th>Sector</th>
<th>Age of Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Agriculture machinery</td>
<td>140</td>
<td>Manufacturing</td>
<td>20</td>
</tr>
<tr>
<td>Company B</td>
<td>Processing machines</td>
<td>45</td>
<td>Manufacturing</td>
<td>70</td>
</tr>
<tr>
<td>Company C</td>
<td>Automation &amp; robotics</td>
<td>6</td>
<td>Consultancy, research and other specialized business services</td>
<td>15</td>
</tr>
<tr>
<td>Company D</td>
<td>Software and services</td>
<td>10-19</td>
<td>Consultancy/ICT/Manufacturing</td>
<td>7</td>
</tr>
<tr>
<td>Company E</td>
<td>IT and document management</td>
<td>1300</td>
<td>Information and communication</td>
<td>20</td>
</tr>
<tr>
<td>Company F</td>
<td>Machines for automation</td>
<td>3500</td>
<td>Manufacturing</td>
<td>70</td>
</tr>
<tr>
<td>Organization G</td>
<td>IT and statistics</td>
<td>1800</td>
<td>Public</td>
<td>112</td>
</tr>
<tr>
<td>Organization H</td>
<td>Social service</td>
<td>350</td>
<td>Public</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Company I</td>
<td>Business app</td>
<td>13</td>
<td>Information and communication</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1. Main Information of case studies

This next section describes the most important findings of the case studies. Because of confidentiality issues, names of the companies are not provided.

3.3. Results of case studies

3.3.1. Case Study A

Introduction

Company A is a medium sized company that has been active in the manufacturing industry for twenty years. The head office is located in the Netherlands. The branch company X with about 70 employees located in abroad.

The first 10 years after starting the company the staff and manager had been working for long hours every day. However, the productivity of company was not as high as it should be. Around 2010, the organization structure changed significantly. This made it possible to implement the Smart Industry concept. However, my interviewee believes that company A is to 50 percent already “smart”.

My interviewee suggested defining the Smart Industry concept should be done by using easily understandable words not abstract concepts like Internet of Things, Cyber Physical Systems and Big Data science.
**Smart technologies**

Company A has been investing in Smart Industry concepts since 2010. The ICT systems like ERP have put company A in control of production lines (by giving updated statistics of production and financial numbers) and process innovation. Moreover, technologies like sensors are important for company A to make the production process more effective.

The investment in smart technologies is a continuous process. For example, after they started using the ERP system, it appeared that company A needed to connect or integrate data from different programs in the organization. Other technologies like robots and 3D printing are new to the company. They know that they may need those technologies in the next five years. Company A may use automated guided vehicles (AGV) in the coming years, but not yet robots for assembly lines.

According to my interviewee, the financial advantage of using technologies like “cloud computing” has not been proven for his company. Now, it is more logical to rent the cloud space (as an example) than to buy it.

**Human capital**

According to my interviewee, the Smart Industry is not only about a well-equipped factory, but the mentality of the staff should be ready for it. The employees are the most important asset of company A. Before providing vocational training to workers, the manager of company A himself decided to follow an academic education to upgrade his knowledge, especially about soft skills like communication which is very important in governing his organization.

The manager of company A has learned that he should have a close relationship with his engineers. He pays attention to their feeling and emotion. If they feel good in the workplace and are happy with their workload and salaries, then the productivity of the company will go up. The manager asks his employees to work with lower speed, but constantly. The motto of company A is now “we do not work hard, but we work smart”.

The international employees feel committed to the company, because the company respects them regardless of their nationality and religion. There are places provided for religious workers, where they can pray or meditate. There are special places provided for smokers. Therefore, the staff feels that they
are at home. Moreover, company A has recently bought a new company and aims to perform academic (vocational) training internally. So, they can recruit new employees.

The branch company X, located abroad is the most important collaboration partner for Company A. Company X works for services provided by company A. Therefore, staff in company A can watch, follow and communicate with the branch organization effectively.

Company A has an internal platform, not an external or industry wide platform, because Company A can manage almost everything internally now. However, company A is considering creating a platform that facilitates the information channel with key suppliers in order to speed up the whole process. This will eliminate the necessity of interacting with lots of parties when performing a project. However, this is a very challenging ambition. Secrecy is one serious challenge in creating that platform. The possible solution may be to organize supplier events to bring different parties together.

The performance of company A depends more on customers and end-users than on suppliers. The end-users are very important because, they provide ideas to company A.

Company A is a very small customer for big companies which have Smart Industry concepts as a top priority in their agenda. Unfortunately, those big companies work slowly using the Smart Industry concept. It is sometimes difficult for company A to reach the right person from those companies. In that case company A has to find an own solution.

**Complementary aspect of human capital and smart technologies**

Before 2010, the staff had been using ICT for simple tasks, for example, by using personal computers. The company started to use ICT systematically in new ways in 2010. That was because of very smart and dedicated staff and their autonomy in decision making. They made some changes in the process of manufacturing without discussing it with the manager beforehand. Later, they explained to the manager how with just using ERP software and drawing diagrams they had increased the production. The manager appreciated their work very well. Thereafter, in collaboration with a knowledge institution, company A created a new concept in lean manufacturing process.

Company A focuses on niche markets and therefore its name is not that much well known as a source to be attacked by hacking activities of competitors. The security of data is not only addressed by investment
In advanced ICT technologies. The loyal and committed staff is the most important asset to secure the data of the company. Therefore, any attempt of the competitors to bribe workers of company A, asking to give away critical business information or asking join the competitor organizations has failed so far. This is a very interesting complementary aspect of human capital and smart technologies.

**Innovation output**

The most important change in company A was related to organizational methods. This has led to process innovations which were new to market. As a consequence, company A introduced significantly improved products that were new in Europe. Almost all increase in turnover of the company A is because of using the Smart Industry concept.

The capacity of the production lines is nearly fully used with the help of the Smart Industry concepts. As a consequence, company A has increased productivity by 100 percent, while the number of workers needs to increase by about 70 percent.

Moreover, the Smart Industry concept has helped to increase flexibility in production. Since 2010, company A has not been making machines before selling them. Company A has 3-6 models. Every customer needs special machines. Every product is build based on the order of the customers. Therefore, the products cannot build on stock (“No Sales, No Production”). The flexible production has helped company A to compete with similar products of international competitors.

**Challenges**

The Smart Industry concept is also about finance. This is a very challenging issue for very small companies because they do not have money available to invest in new technology. However, it was not a problem for company A, because they had enough finance to invest in Smart Industry concepts. Moreover, company A has defined the ambition from the Smart Industry based on the available budget of the company. Everybody in company A is aware of the target of the company for 2020. This is the most important point.

Finally, company A has had a shortage of engineering staff in recent years. The manager wants to increase the number of engineers very soon in order to reduce the workload of current engineers. This is crucial for company A.
3.3.2. Case Study B

Introduction

Company B was founded in the mid-20th century. It currently has about 45 employees. Processing machines are the main product of company B.

Smart technologies

Company B has been using robotics in the manufacturing process for 30 years. The advanced technologies like robotics have been improving automation of production processes. Use of radio frequency identification chips (RFID chips) is very important for the operators to perform their task faster and more efficient. Moreover, company B uses ERP to collect and analyze data from many business activities, for example, production plan, manufacturing, inventory and marketing.

Complementary aspect of human capital and smart technologies

The use of smart technologies is not new to company B, because the founder of company B has visited many companies around the world in order to acquire knowledge about the exact demand of customers. He has transferred this knowledge to his organization. That is the reason behind the continuous innovation of his company.

The staff in company B knows that their job will not be replaced by robots. The knowledge workers train the robots and control them. Therefore, they have been updating their skills since the introduction of robots in the factory.

The implementation of the Smart Industry solutions takes time and requires vocational training. The manager of company B believes in fast learning ability of young knowledge workers. The role of experienced employees in the innovativeness of the company is undeniable. That is why the manager of company B sometimes invites the retired employees to the vocational training sessions. Therefore, the entrepreneurs do not need to worry about the lack of sufficient number of ICT specialists for the future of their organization if they are considering investing in Smart Industry concepts. Instead, they should try to transform the knowledge base of current and older employees by digitizing it in their organization.

Collaboration activities

The Smart Industry concept has been used to integrate products, machines, and people in company B. Standardization of processes and effective collaboration between parties were necessary in this respect.
The organization of many processes had to be changed to implement the Smart Industry concept. The collaboration activities within multiple disciplines like engineering, production, and distribution inside and outside of the companies were the pre-requisite to implement Smart Industry concepts.

**Innovation output**

Innovation in company B is defined as supplying flexible, high quality and low price products to the customers. The company holds 26 patents for its innovative products and services. As a consequence of continuous innovation, company B exports its high quality products to a high number of customers around the world. My interviewee believes that service innovation will be very important in the market in the coming years.

### 3.3.3. Case Study C

**Introduction**

Company C is a small organization that helps other companies with the best suitable solutions for welding and automation. The product lines include consultancy, research and engineering services.

**Smart technologies**

Company C is not only providing manufacturing technology, but helps the customers to implement Smart Industry solutions. According to my interviewee technologies like sensor, robotic, and data analysis are very important within the Smart Industry concept. The implementation of Smart Industry concept has not only started automation within the firm but has accelerated it.

Additive manufacturing with welding robots or with laser using robotics is part of the scope of company C.

**Human capital**

Currently the most important challenge for the customers in adoption of the Smart Industry concept is to acquire the right knowledge and employees who can deal with this new knowledge. Therefore, the collaboration inside and outside organizations in sharing knowledge and information is very important. Company C is very active in extending the collaboration between universities and industries in order to align higher education with vocational training in field of automation, robotics and the welding process.
One may argue that using the Smart Industry concept in sectors like agriculture may require space, while the Netherlands is a small country. For example, companies in the agriculture sector in larger countries like Germany are very active to implement Industry 4.0 concepts. For example, farmers need bigger and bigger tractors, but the bigger the tractor is the bigger its footprints on the surface becomes. Therefore, smaller tractors with more connectivity (and more shared machines) could be a solution. Another example is the use of drones to scan the surface to combat the growth of weeds. You can do it with one very big system, but also with multiple smaller systems that are connected together. Another example is harvesting cranes in countries like Russia and the United States, where only one person drives the harvesters and four or five cranes follow him.

Since the Netherlands do not have enough space, the Dutch farmers know how to use land in order to have optimum yield per hectare by innovative agriculture equipment. The Dutch agriculture industry is the second exporter of agricultural products in the World. The Dutch agriculture sector can deliver systems for the Smart Industry solutions. The Wageningen University for example is active in this field. If the Dutch farmers can keep up with their knowledge and share it effectively, then they will be able to face international competitors from larger countries.

The Smart Industry contributes to all industry sectors if they have a culture of group working inside the organizations and among the organizations. The employees in the organizations should be able to communicate and cooperate with each other in the implementation of Smart Industry solutions. They should always update their education and professional skills, because the implementation of the Smart Industry concept in practice is more difficult than in theory. The employees should be able to learn it fast.

Moreover, if companies from a so-called non-high tech sector integrate their products and process by ICT, the end-products will be smart.

**Innovation output**

The contribution of company C to other customer organizations differs per subject or project they carry out for their customers. Company C offers the Smart Industry solutions not only to improve the product, but to improve the whole process. Process innovation is often forgotten when product innovation has been done. Product innovation will be successful if the process is being adapted to the new situation. If this step is forgotten product innovation will not be successful. The integration of people and technology, workplace and business, and manager and employee are a necessity to successfully implement Smart Industry solutions.
Using robot technology by a company is very good step toward the Smart Industry solutions, but it is not sufficient. The entire company needs to be ready if they want to take advantage of the Smart Industry technologies like robotics. Three examples of customer companies that have leveraged the Smart Industry concept are the following:

Customer A (a producer of ice skates) had to prepare sufficient conditions in order to implement the Smart Industry concept. It was not only about the design of products, but also the process, organizational change and education of the staff. My Interviewee explained it as follows: “We look at the whole supply chain. We can invent a very good design in university, but it is still not an innovation in the market. Next to technology, the skills of the staff have to be updated. The Smart Industry is about craftsmanship, quality, and planning in companies. The staff should know where the necessary tools for Smart Industry are embedded in their organization and how they interact together just like connected machines work together. That is why we look at the entire process and not just the end product of a company. It allows us to offer our services in the best way” (Project manager company C (March 3, 2016)).

My interviewee explained a second example of a customer companies as follows: We have to imagine ourselves as the customer company. We did feasibility, technical and economic studies for customer B (a producer of climbing equipment) two years ago. We looked at what they offer to their suppliers. We used our knowledge to the best level of innovation. They asked us “what is the best solution for our current installations? What do we need in the hardware part of the investment, but also in soft skills; on the knowledge of operators and the engineering department?” Customer B had robots, but we helped them with connectivity of the robots in order to accelerate the innovation. The entire organization must work together to implement the Smart Industry solutions. The lack of their knowledge was in engineering, for example about controlling welding quality, not in programming the robots.

What we needed inside customer B was to have a good, reliable state of the art installation in order to have the production here in the Netherlands instead of abroad. Using our visualization and simulation software, we simulated the production at the shop floor in the old situation. Customer B had 13 old robots to do the production with those old installations. Then we simulated how their work process would look like in the future. The big question was whether company B needed 5, 6 or 10 robots. That of course, had to do with the required investment. We also trained their staff on the new work process. We presented our simulation and plan to their stakeholders and showed them how we can help them to innovate in the production facilities with robotizing the welding process. In the new situation, the company has 15 manipulators, but only 5 robots. They run around the beams when production is ready. Then the robots go...
there and operators pick up the finished products. The complete 75 meters of robot installation is installed (Project manager company C (March 3, 2016).

Customer B had the choice to keep their production in the Netherlands by implementing the smart industry solutions or to move there production location to low wage countries. Moreover, they are able to produce more than before, with same number of staff. Automation has made them leader in the market. They export to other countries as well.

My interviewee explained the third example of the customer companies as follows: “Customer C is a producer of winter equipment products. For example, one of their machines spreads salt on the surface of highways. It is very important to throw salt on the roads before the temperature gets below zero. They had robots, but they had lack of knowledge about programming. Therefore, we advised them about the right knowledge in their organization. The new products of company C are very connected to weather forecast apps that. The connection to a bio radar gives information to the community and lets them know how much salt they need for the next day. That is the interconnectivity of things (Internet of Things). Although this equipment is not high tech, the whole system is high tech. The new system and the skills of the people, who produce the systems and equipment, are significantly improved.” (Project manager company C (March 3, 2016).

If companies do not keep the information to themselves, but share it with other parties, they will develop more innovation. They do not have to share critical information like secrets of their organization or the end products, but the process of making the product. We invite parties to sit together, share knowledge and collaborate in innovation activities (Project manager company C (March 3, 2016).

**Challenges**

The implementation of the Smart Industry solutions depends on each customer company. The solutions are tailor made, because every company is different. One company has skilled employees and a product suitable for automation, while another one does not have them. Therefore, company C investigates the knowledge gap in the customers’ organization.

According to my interviewee education and training is very important in the Smart Industry concept. The different parties should collaborate effectively in sharing knowledge in the fields of robotic and automation. This knowledge can be spread to living labs to improve the manufacturing process.
3.3.4. Case Study D

Introduction

Company D started as a spin-off from a university in the Netherlands. They began as a medium sized company a few years ago. Company D produced within the aeronautical or aircraft industry because that industry had not innovated enough during the past 30 years. The complexity of their systems had become so high that it was impossible to innovate. The risk of adapting new technology was so high that the whole innovation process was declining.

Smart technologies

The Smart Industry concept did help customers of company D, especially those who offer engineering services. There are many consultancy systems in existence; however, in technical industries the manufacturing companies do not want to have external consultancy. Rather, they want to do everything themselves, because it involves their own intellectual property (IP). This is why IoT or IT solutions have been introduced.

Company D is specialized in optimization of engineering intensive projects for the manufacturing industry with a software platform that enables customer companies to accelerate the product development processes. The “smart” here means that the manufacturing companies can perform the task by translating the knowledge from experts to computers and systems. Moreover, they are able to maintain it; which means even in offline time (not running the project) they can take advantage of applications (smart application and smart process). Further, the knowledge rules accelerate the way of working.

The platform software is cloud based and you can access it from everywhere. This enables manufacturing companies, especially in the aeronautics industry, to implement the Smart Industry concepts. The platform software is an IoT solution for the design and engineering process; from customer request up to specifications for the manufacturer. This includes everything that is outside the factory and not related to the logistical or procurement process. Moreover, the software service reduces the workload of the customer companies.

Company D constantly examines the technology of the customers in order to understand their needs and improve that part of software by building systems around it. This is how they rebuild the software platform. For example, customer A (a manufacturer in aviation industry) is active in building radar systems. So, it is important for company D to have knowledge in that field of technology in order to
couple its IP with the customer and prepare its platform for the adoption by customers. Previously, it was a process with lots of trial and errors, because company D needed to redefine the foundation (core technology) of the platform, but now company D only has to redecorate the platform. The customer has to spend time in this process as well.

Company D invests always in new technologies. So far the staff has worked with email, phone and documents. They have had no way to accumulate data. Currently, they are considering implementing sensors in everything to generate data. As a consequence, creating and analyzing data and cloud computing will be more important for company D than in the past. Another challenge is security of data. Company D has to protect the services and IP by maintaining a fast pace of innovation to remain competitive in the market.

**Human capital**

The implementation of the Smart Industry concept for customer companies takes time. The time has to be spent in order to identify the knowledge gap of the customers. They had to find out how technology matches with the current state of the art in order to implement or connect the technology to reality. Company D identifies bottlenecks in the business of the customers by sending people to visit their company. Therefore, engineering and consultancy services increase proximity with customer companies.

Indeed, taking advantage of agility and flexibility of young engineers helped company D to offer the best services for the customers. The young engineers do not know how much is possible, but they sometimes end up with findings that actually are possible to implement. Therefore, company D has a separate department for the young engineers to facilitate radical innovation. In another part of the company other employees (mostly with MBO degree) work with discipline and routines in order to produce high quality sustainable products.

**Innovation output**

The Smart Industry contributes to the innovativeness of company D by 100%. Company D does not have any paper documents and physical systems and the work is digitized.

During the first 3-4 years after the start of the company, the focus of Company D was on technology and product innovation. However, it ended up being too new or too smart, which made it less consistent with the current way of working in their organization. Therefore, they changed their products to be less smart. Company D also created process innovation that was new to the market and maybe the first one in
Europe. In short, Company D implemented the Smart Industry in two steps; first it was too smart and therefore too disconnected to the state of the art in the industry. It was more like bringing technology into business and then business into worldwide business. Nowadays, they also focus on marketing innovation.

Challenges

My interviewee believes that defining the concept for the Smart Industry is very important. So, compared to 10 years ago the Smart Industry promises better opportunities for the companies. However, the Smart Industry concept still is in the phase available only for innovators and early adapters (prototype phase). Lack of openness of the customers is a very serious challenge to the Smart Industry concept. The whole supply chain should participate in order to fully implement the Smart Industry concept.

Each organization has its specific challenges on the way to the Smart Industry. If small companies change a lot, they will not have enough routines for documenting to pay off. One difficulty in big companies is the current work culture. Sometimes the employees with higher experience in an organization believe in the principles that they have used for years and that makes it sometimes difficult to accept new ideas. The big companies assign the task of implementing the Smart Industry to specific employees and departments and neglect to use it in their operation process. Moreover, complexity of the big organization may make it difficult to implement the Smart Industry concept. The more employees a company has, the more management layers it has. It takes lots of time to react when lots of people coordinate in the organization (or translate the business goals from the management layer to the layer in which they actually do the action). In some cases, the big companies produce really smart products, but the process of manufacturing is not based on the Smart Industry.

The more people are involved in the operation of company and influence it by adding value to company, the more impact the Smart industry concept has. It is important to affect the bottom line of the company if you aim to succeed in implementing the smart industry. Otherwise, the smart industry concept will probably only bring secondary benefits to the organization. Based on my interviewee, those companies that only see the secondary benefits of the Smart Industry concept will be less receptive to it. Actions like data generation and implementation of a new business model are at the second phase of the Smart Industry concept.
Middle sized companies may be ideal for using the Smart Industry concept. In general, the number of employees who can easily integrate people into their organization is growing in medium sized companies. They are more receptive to the Smart Industry concept.
3.3.5. Case Study E

Introduction

Company E is a big company specialized in innovative products and services in the field of IT and document management. So, the idea is that IT is a base for every company and without that it is difficult to perform well.

Smart technologies

My interviewee helps the customer companies to adapt IT solutions in their organizations. She explains to customers that there are several layers of IT (the definition of Gartner) including software, hardware, devices, data center, connectivity, storage, backup, operating backup offices, 24/7 data, device mesh and, ambient user experience and application. If the customer companies do not implement every layer of IT in the right way, they will have problems somewhere at some point. There are certain actions for connecting and coupling those layers of IT. She explains those layers to the customers and based on their specific working condition and environment.

My interviewee believes that it is not sometimes lack of knowledge of the IT manager that stops technical innovation, but cost cuts, priorities or the fact that IT solutions are implemented across different departments.

Human Capital

The customer adaption to IT solutions is very important issue. The traditional companies do not change, because they don’t see the sense of urgency or do not have the knowledge to innovate. That is because of the fact everything works well in their organization. Explaining the opportunities in digitalization for entrepreneurs is not enough. They should see concrete example of it. As long as they do not see the problem, they will not invest in IT solutions. It is not only about the sector or size of the company, but also about the knowledge of people who operate the company and their objectives that determines their awareness about IT.

Without willingness and cooperation of employees in the customer companies the IT solutions will not succeed, because that is the difference between now and the past. In the past, managers used to make almost all decisions. Now, the employees have a bigger share in defining the whole strategy of their company. So, there is a whole shift from employer to employees. The
employees, especially young staff have other ways of thinking. They expect their organization to provide them high quality IT facilities.

**Innovation Output**

Company E is very active in rapid development of office automation by offering their customers innovative solutions. The services include not only hardware and software, but also training. Company E looks through the eyes of customers to the problems, because every problem is different. This is actually another way of thinking. Every company has a different mindset and goal from using IT, for example, saving money or evolving in the business. Three categories of services are offered to the customers.

The first one is IT services (everything in IT that you need such as cable, plugs, software, hardware, VDI, etc.). The second service is to help the customers with other ways of communication. IT has changed the office atmosphere during recent years. Less paper office is going towards a paperless environment. It is called in the Netherlands as “Plaats, tijd en device onafhankelijk zijn” (mobile working environment). The idea is to digitize all the paper flows and share them at the right moment with the right people. So, the whiteboards, communication ways, and projectors become digital using the services. All the information flow, communication, data and usage of the cloud will be affected by the digital revolution. Cloud is new way of sharing and storing the information and allows employees not be in the office all the time. As performing the tasks are getting less hardware dependent and parties want to share information quicker, workspaces are optimized. Working in the cloud is something that we currently do, because we have storage access everywhere now. You do not see the cloud, but it makes our everyday living and activities much easier. It provides 24/7 data access. The cloud is basically another way of communication, distribution and sharing of information. It helps companies to reduce their costs, because it saves time. By using the cloud you access the information faster, but you need to secure it as well. Currently, free cloud services are used by many people. They do not realize, however, that their information is public and can be used by owner of service. If they pay for these kinds of services, they make it safer because they are the sole owner of the cloud. Moreover, they have now a backup of their data. It is unbelievable that many companies currently do not have any backup of their information. The problem with the current way of storing information is that in case of an accident like fire in their local server room, all their information is gone.
The third category of services is Smart Building solutions using IoTs and atomization approach.

**Challenges**

It is very difficult to implement ecosystem thinking in practice, unless the number of companies that implement the Smart Industry internally increases. After many companies have adapted to the new business model, you can talk about collaboration in supply chain and about sharing knowledge.

Although big companies understand that they have to adapt IT solutions and have IT operational strategic directors, human capacity and money to implement the IT solution, they are afraid of change. If they want to make changes even if it is necessary, they have to pull the plugs and they have to put new plugs in the systems. Therefore, their system will be down. It means that they have to take one step back in order to take five steps forward. Taking the step back is very difficult for them if everything is working well in their organization. The most important challenge is to make people understand that if they do not change now, they will lose their market share very soon.

SMEs are less interested in IT solutions. The most serious obstacle in small companies is lack of knowledge. Organizations with less than (roughly) 500 employees do not have usually a perfect model for implementing IT solutions.

Providing a clear definition of the Smart Industry is another challenge, because there is no stable factor. The only stable factor is that there is a change, but the changes become faster and more difficult every year. Actually, it is very difficult to implement the whole strategy, because as a company whether you are small or big, if you implement something now, it is good step forward because the mindset is there. But, all the things you are doing now, within for example 3 years will lose their effect and you have to move again, because the market and technology is changing so fast. That is the difficulty of the whole reality that we are living now. Two years ago, for example, tools on the device was a hot topic, but now even on the device the issue is no longer a matter of bringing tools, but a matter of security and integration. We do not care if you bring it yourself or a company provides it for you. That has changed within 2.5 years. We do not know what will happen, but it is a given that we need to change.
3.3.6. Case Study F

Introduction

Company F is a medium-sized company which is part of a big enterprise group. The head office of the group is located in a foreign country. The core competency of the family group is hard- and software facilities for motion, automation and robotics for innovative machines. They offer also engineering, training and services for the customers. Therefore, the services include the entire engineering process for the automation of customers’ machines.

Smart Industry is not a new concept in company F. Company F has helped customers to implement the Smart Industry concept for years. According to company F, the Smart Industry concept is very easy to use by companies due to smart validation of data.

Human Capital

My interviewee believes that disruptive changes in the markets are the reasons for the companies to change their current approach toward partnership and collaboration in supply chains.

The employees are the most important asset of the company. Investment in knowledge and skills of employees is a must in order to implement the Smart Industry concept. Both high academic and working skills are required to implement the Smart Industry concept. The work culture of company F is unique. The company organizes very good training activities for the staffs. The Smart Industry is not only about IoT and IoS, but the engineers need to have high communication skills and learn to think cross sector and cross discipline. The company organizes weekly brainstorming sessions to encourage multi-disciplinary working culture.

Smart technologies

The company takes advantage of IT technologies including actuator, NFC, RFID tags, M2M communication, modular hardware and software, communication portals, advance machine learning and smart apps for remote control. Moreover, robotics is important technology for the company. However, company F has not taken advantage of 3D printing technology yet. The focus is not only on product innovation and end products, but on improving the interplay of applications and systems. Connected hardware and software is very important for the Smart Industry solutions.

The local IT department is responsible for the implementation of IT at company F. The bottom-up approach is very common in company F.
Innovation output

The results of using Smart Industry in company F are increased productivity, flexibility and higher quality products and services. Moreover, the Smart Industry reduces the cost, especially the engineering costs of manufacturing and decreases risks in machine engineering. Company F does own R&D, production and worldwide sales of their portfolio itself.

The workload of employees at company F, however, has been increasing as a consequence of business growth. Therefore, restructuring the organization is an important activity to balance the workload of the staffs.

Challenges

According to my interviewee, fear from disclosure of business information is the most serious challenge to implementing the Smart Industry concept in the industry. Trust and communication between parties within the supply network and commitment can address the problem effectively. The high costs of secure and safe IT systems and other advanced manufacturing technology is another challenge that makes it difficult to implement the Smart Industry concept.

3.3.7. Case Study G

Introduction

Organization G is a big public organization that has been active in Information Technology business for some time.

Smart technologies

The organization uses SCM, CRM, ERP software’s, and service oriented architecture in order to improve the processes. In general, the use of identification and communication technologies like RFID tags, M2M communication in organization G is in the early stage. Moreover, the organization has not used real time data in collaboration with other parties yet.

Traditionally, the central IT department is an early adapter of IT solutions. Nowadays, the organization tries to get employees involved in that process more than before. The ideal approach is to have a mixture of centralized and decentralized IT for implementing the IT process.
There has been a revolution in data science at organization G because of special kind of data named X. This is good example that explains the creation of so called “Big Data” concept. The data X was used in the past for only specific purposes. However, nowadays the data X can be used for multiple purposes because the relationship between different data has become closer and more complex. For more information about this date see the confidential appendixes.

**Human capital**

Two factors help the organization to invest on the Smart Industry. The first factor is the people who come to the organizations with new ideas. The second factor is pressure from customers to reduce administrative processes and to become more cost-effective.

In general, the organization is proud of the knowledge of employees about ICT. However, the observed problem is that the average number of years that people work at organization G is high. That may be a barrier in adapting to new techniques and skills. It can be improved by increasing influx and outflux of the staff. It means there should be a higher percentage of people who start to work at organization G. So, the idea is that the new people are more interested to change the routines and processes than those who have been working in the organization for a long time.

In general, the organization has two kinds customers. The first group is the people whom data are collected by the organization. The second group is the users of outcome. It is important to have good relationship with the both groups in order to improve the quality of the services.

Co-creation is difficult in practice. A few years ago, organization G collected information on specific group. There was a lot of opposition against it, because it was very time consuming for the customers. Therefore, organization G invited them in order to discuss the benefits of collecting those data. They together found a way to improve the process by reducing the administrative process and the size of the sample. The experience showed that without high benefits for the different parties it is very difficult to co-create a process or product.

It is important to learn to co-create with other parties. There are groups of employees that are willing to participate in co-creation projects with other parties, especially the management and senior employees. However, organization G wants to speed it up and involve as many employees as possible. The groups of staff that are active in production are so busy with their tasks that they do not want to participate in other side activities. For example, they hesitate to participate in the presentation of their colleagues from other
disciplines, who have worked on an interesting topic for years. It is crucial that multiple disciplines communicate with each other in order to circulate the knowledge inside and outside of the organization. This helps the staff to have a broader perspective in their job.

The organization has learned that it is necessary to stimulate employee’s interaction with the customers. The best way to do this is to make the steps and targets as small and easy as possible. The organization tries to encourage staff to collaborate with other parties through participation in activities that are organized by a network organization (named Y) which has members from industry, university and governmental organizations. This provides a safe learning environment to prepare for co-creation with other parties. G organizes brainstorming sessions with the users in order to get a good understanding of their needs and address them in the best way. This is difficult and organization G is still in the early phase of the process.

Moreover, about three people in the organization work in an innovation lab. The aim of the innovation lab is to bridge the gap between invention and innovation. The innovation lab started five years ago. The innovation lab operates only inside of the organization and focuses on process innovation. There is only one other external organization that collaborates with the innovation lab. Inviting other external parties to collaborate in the innovation lab will be very useful.

Organization G has a number of Memorandums of Understanding with universities. About ten university professors have collaboration activities with the organization. Moreover, the organization exchanges knowledge within some joint projects with other information companies.

**Complementary aspect of human capital and smart technologies**

The organization currently faces new challenge with regard to investment in ICT. A few years ago, the approach in the organization was to reduce the workload of staff by investing in IT solutions. However, experience has shown that that approach has decrease the productivity. Moreover, that productivity of specific groups of staff decreases when their workload decreases. Therefore, nowadays the organization asks the staff to increase their productivity by improving the process and guarantees that necessary IT solutions will be provided based on request.

**Innovation activities**

A few number of staff (about ten people) work purely on innovation concepts. However, the bigger part of the organization works on implementing those innovative ideas. More than product innovations, the
organization makes always process innovation. The process of collecting data has changed compared to twenty years ago. Previously, the aim was to collect micro level data. Nowadays, the organization has the big data. They do not need to recollect data constantly, but only need to add the current information pool. The advantage of information pull or the big data is that it can be enriched and reused constantly for different purposes. For the examples of process innovation see the confidential appendix.

This process innovation requires redesigning the whole way of working in the organization, because it is important to make the whole chain internally consistent.

Organization G takes advantage of new media or techniques in product promotion by treating published data as a product. The aim is to have good news coverage about published data. Moreover, organization G renews the way of communication. Nowadays, publishing articles and tables is not enough, but visualization and storytelling as new ways of presenting the outcome are important.

Finally, organization G has increased cost-effectiveness by three per cent for seven years in row. Therefore, there is a constant balance between increasing the productivity and reducing the workload of the staff.

**Challenges**

The main challenge in the Smart Industry is the complexity of it. It is very important to be much disciplined about the steps and not lose yourself during the process by trying to solve everything. Not everything can be addressed at once.

Although brainstorming ideas and multidisciplinary work is done successfully inside the organization, it is still difficult to do so externally in collaboration with other organizations. The confidentiality of the data is another challenge in creating information pull. The unique information position of organization G makes it very attractive organization for other parties for collaboration. However, the organization has responsibility with respect to the confidentiality of the available information. It is not possible to allow other parties to access the information pull. They are only allowed to have limited access to the information pull, based on the request.

Finally, investment on the Smart Industry is a challenging issue. On the one hand the organization has changed the approach toward investment on pure IT as the main contributor to productivity. On the other hand, organization G has to invest in data science and new communication techniques in order to create the information platform.
3.3.8. Case Study H

Introduction

The municipalities in the Netherlands have been performing a facilitator role at the local level for a very long time. Organization H has around 350 people on staff.

They want to know to what extent their role in addressing the societal issues like education, regulation, culture will be changed in the coming years so, they can prepare well to perform their responsibilities in the coming years. The case of organization H is different from cases of profit organizations and manufacturing companies. One difference is that organization H has a fixed number of customers.

Smart technologies

Currently, coupling available sub data and using it in one unique country-wide system is an important goal for the municipalities. For instance, they want to couple all available geographical information of the land and use it for other purposes in the near future.

Organization H should address the demands of different parties, while there are not many software and IT options on the supply side. Most of the IT systems provided by the government are made inside of the Netherlands (nationally), because they are suitable for special applications. The available IT systems and software by the Dutch government offered to the municipalities are not customized. Customized IT system are only designed and supplied if they receive requests from more than one municipality. Therefore, it is very expensive for each individual municipality to have access to customized ICT software and systems.

Human Capital

Organization H does not need to hire new employees who have special skills in IT technologies, but has trained the current employees about new technologies and new ways of working. H collaborates with lots of other parties (like other municipalities) to extend the scale of digitized projects.

Complementary aspect of human capital and the smart technologies

Digitization can increase the services, the speed of work and reduce the workload of employees if the value chain and external parties collaborate effectively with organization H. It is not possible for municipality to allow other parties to log in to the central data system and input their data because of security concerns. Therefore, so far digitization has not lead to less workload for employees, but it has led
to more transparency. Another example is that organization H introduced new application to its citizens that allowed them to take photo of problems or defects in public facilities and send it to municipality, together with a description of the problem. It has facilitated the process, but has increased workload of the employees in municipality, because someone has to enter (or couple) the information from the app to the main information pull in municipality.

Sometimes, this kind of problems makes the employees uninterested to work with new IT systems. This is a matter of time (culture). Coupling the information of the app to the municipality’s data system can address the problem.

**Innovation output**

Since 2010 the digitization of work has been the top priority of the organization. My interviewees attributed about 80 per cent of innovation activities in their organization nowadays to the digitization. The output of digitization is less tangible on products like passports or driving licenses, but much more on the process innovation like work process and digitization of invoices.

**Challenges**

Low knowledge about digitization and complexity are serious challenges for organization H on the road to the Smart Industry. The municipality aims at digitization both internally and externally in relation with other parties. The municipality has a lot of critical sub data that can be coupled to be used for multiple purposes. The municipality collaborates with other municipality to implement the information platform. Multidisciplinary employees from each party have met in order to share knowledge between organizations. They were successful to some extent to share information based on their relationship and trust. However, it appeared to be very difficult in practice, especially when the organization wanted to share information in a formal way. Privacy issues and confidentiality of customer data are serious challenges in the process of coupling the data for creating information pull, because each organization has customers who do not allow using their data for additional purposes.

Another example of confidentiality issues is the use of Facebook and twitter information of citizens in collaboration with the police for security purposes, which raises concern about the private life of the citizens.
Finally, not all groups of people or citizens are able to use IT services offered by the municipality. Organization H needs to find alternative way for collecting the data of those groups; for example, elderly people.

### 3.3.9. Case study I

**Introduction**

Company I is a SME organization that has been developing customer apps since 2012, when Company I identified a huge opportunity in business apps, because companies did not know how to be efficient while they are mobile (not behind their desk). ICT is the main sector of the company. It does not have any other branches.

**Smart technologies**

Company I uses RFID chips, NFC, IP, M2M communication and other IoT technologies. My interviewee, however, did not have an example of using real time data in the supply chain. He only had an example of using real time data for a customer.

My interview gave the score of seven out of ten in the investment of his company in the Smart Industry, because they do not have advanced manufacturing technology yet. Company I is, however, planning to extend the technology to new realms like augmented reality.

**Human capital**

The knowledge of the employees is sufficient to use the Smart Industry concept. The age of employees, per se, is not an explanatory factor in using the Smart Industry. However, the younger generations, who have studied IT, expect a lot from the technology.

Company I is not a consultancy company. Therefore, the customers should come with an idea when they ask company I to make a concrete plan out of it. Company I thinks with the customers about the concept. Company I needs to collect not only customer information by organizing workshops and interviewing the stakeholders, and the engineers, but also information about the end users. The aim is to investigate the biggest opportunity for the customer companies. The stakeholders in customer companies always want to be sure that the new apps are profitable and address the demand of customer companies.
**Innovation output**

Innovation was defined as introducing significantly improved or new products and processes to the market according to my interviewee. Moreover, roughly 70-80 per cent of the innovations in company I is IT based. The aim of company I is to empower the customers to make the processes simpler and connect one IT solution to every backend process. The apps facilitate intensive information processing and provide an interface for different parties inside and outside of the customers companies. Therefore, it helps customers to improve their skill in supply chain management, resource planning, and customer relation management.

There are companies that are using a lot of different applications to perform a certain task, while it could be simpler if they connected different systems to one central IT system. Company I helps the customers to leverage the available technology and devices by remote control (without physical presence).

My interviewee mentioned number of examples of their innovation services to the customers. Company I made the software product of a customer's more user friendly. Moreover, the customer companies can use the developed app with their current back-end system. The result was new product innovation in Europe for the customer company. Another example of process innovation is developing a connected app for an airline customer. Company I helped the customer to make a cross platform app that facilitates the task of managing the traveler's seats, payment status etc.

Increased productivity, business growth, increased revenue and decreased the workload of the employees are the result of the Smart Industry concept in company I.

**Challenges**

My interviewee believes that financial issues and lack of time are not barriers for entrepreneurs in bringing Smart Industry into their companies. If the companies have sufficient knowledge of what the Smart Industry can bring to their companies, they are more likely to implement the Smart Industry concept. He defines the smart companies as those who have that knowledge.
3.4. Conclusion

This chapter aimed at investigating the result of literature study on nine organizations that are in different phase of implementing the Smart Industry solutions. The cases are chosen from various size, sectors and core business activities. The findings from these two chapters answer sub question one and two.

In some cases, the interviewees were not familiar with the terms like CPS and Big Data. Nevertheless, all cases use the Smart Industry concept in their organization. The age of Smart Industry initiative is different among the companies. While company A and G started since 2010 with the Smart Industry concept, the company B, F and I have been using the concept since long ago. Company D was founded based on the Smart Industry concept. Company C, D, E, F and I offer services for customers to help them implementing the Smart Industry. Therefore, they had good suggestions for my research based on the experience they had from their clients.

Each case has had its own path in implementing the Smart Industry. They do not have all technology domains of the Smart Industry yet, for example, the non-manufacturing organization like G does not need to use 3D printing at the moment. They, however, continuously invest in new technologies because of fast pace of technology change and new demands in the market. For example, company D wants to use sensor in everything to generate data and company A is considering using automated guided vehicles (AGV) as the next step in the Smart Industry. The result of case studies identified three domains of technology including ICT, IoT and manufacturing technologies that are important in the Smart Industry concept. Next chapter will explain them in detail.

New human-to-machine communication and machine-to-machine (M2M) communication are indeed a revolutionary aspect of ICTs in the Smart Industry. The new technologies like robotics do not replace workers. Instead, the companies invest on the knowledge of their staff to prepare them for new roles. The more a company has high skill staff, the easier the company can implement the Smart Industry solutions.

Moreover, human-to-human interaction still plays very important role in the Smart Industry concept. The whole organization should be ready to implement the Smart Industry solutions. Giving autonomy to the employees and involving them in the decision making process is necessity of the Smart Industry concept. Company A is a very good example for this claim.

The smart companies do not look at only the end products, but the whole process. The Smart Industry is not only for the high tech manufacturing companies, because its contribution is not only for the end
products. IoT integrates whole process of making products. So, the end product or product innovation is not anymore determinant of high tech and non-high tech sectors. There are examples of this kind in the case study C.

If innovation in the end product requires improved process in more than one company, then collaboration of supply chain is very important. That is why companies showed differences in collaboration activities with other parties. Company A for example, manages to do almost everything within the group currently, while the Smart Industry for company D means high proximity with the business partners. Even company A is aiming at designing new collaboration strategy with suppliers in the near future.

The result of organizational innovation is high quality and flexible process and products that are sometimes new in Europe and the World. The smart companies have increased capacity for production or service provision. This has led to business growth and increased turnover.

However, each company confronts with special challenges in the way to the Smart Industry. According to my interviewees, size of company is an important factor in adaption of the Smart Industry solutions. While access to finance and lack of sufficient knowledge about the Smart Industry solutions are common among small companies, complexity of organization, traditional way of work, and quick technology changes are perceived to be the serious barriers for the big companies. Other obstacles like lack of interest for collaboration among parties are common among all companies.

Small companies do not need to worry about lack of enough money if they want to start with the Smart Industry. If a small company has right and stable vision about the Smart Industry and defines target based on available (even limited) budget, the company will benefit from the investment. The solution for big companies lies in updating the knowledge of all staff about the Smart Industry. Moreover, ability of young and new knowledge workers appeared to be important factor in the implementation of the Smart Industry, especially based on case study D, E and G.

The key solution for addressing challenges like sharing data lies in enhancing staff’s skill. This includes not only technical skills, but also communicational skills. This facilitates collaboration among different parties (For example see case study H). Organization G and F also highlighted the importance of engaging all groups of employees in collaboration with other organizations. Participation of staff in networking activities, workshops and open lecture can make them ready in this respect.
4. Conceptual Model

4.1. Introduction

A conceptual model is developed using input from the literature study. The figure below indicates the conceptual model. Based on this model, human capital and new technologies are important elements of the Smart Industry concept. These two elements complement each other.

The Smart Industry is a new approach toward accelerating innovation activities. The case studies confirmed that the common definition of innovation is applicable to the Smart Industry concept. However, the definition of technology and human capital was still broad in the framework. I explored those elements of the conceptual model further during the case studies.

According to my interviewees, the Smart Industry will not work unless all of an organization is prepared for it. The staff needs to learn new technical and non-technical skills. Collaboration inside and outside of an organization is a necessity to share knowledge and implement the Smart Industry solutions.

![Figure 2: Conceptual Model of the Smart Industry.](image)

A general problem is that the definition of technological elements like CPS and IoT was not unique among the interviewees. A number of interviewees believed that those words are complex. A possible solution was to use sub elements of those technologies for the interviewees.

This conceptual model aims at investigating the possible effect of sector and size in adaptation of the Smart Industry. The interviewees provided more insight about the reason behind the differences among companies in their progress with the Smart Industry. Organizations are confronted with different challenges in their Smart Industry program.
The reliability of the model needs to be tested with quantitative analysis. This chapter describes the quantitative design of the research.

4.2. Quantitative Approach

The literature study and nine case studies were performed to develop the conceptual model for the Smart Industry. The evaluation of case studies could suffer from weak interview questions, bias in selecting the cases, and incorrect interpretation of the results. Conducting the survey study is a micro approach that collects data about input (for example: investment in ICT), process (cooperation and source of knowledge), and innovation output of companies who use the Smart Industry concept. The design of the survey questionnaire and the variables of each element in the conceptual model are described in detail in this chapter.

4.2.1. Survey Design

This section describes the content of the survey study. Using the conceptual model as the framework, a structured internet-based survey is designed. Regarding the research questions and the conceptual model the survey includes 5 groups of questions in the following order:

a) General information
b) Innovation activities
c) Collaboration activities
d) ICT and manufacturing technologies
e) Smart Industry

The content of the survey is available in appendix 2. I used a Likert-scale (as a measure of 1 to 5) in the design of questions. In order to fulfil the validity of responses, I provided definitions of concepts that could be ambiguous for the respondents.

General Information

As discussed before, differences among companies like type of company, industry sector, size and age may be explanatory variables in the adaption of the Smart Industry. Therefore, I collected this information in order to use as control variables in the conceptual model. I used the Dutch Standaard Bedrijfsindeling (SBI 2008) as the industrial classification in my survey. The Smart Industry changes the boundaries of the
industries as a consequence of collaboration between different parties. The smart companies increase their product range and enter new markets. So, choosing more than one industry sector was possible for the respondents. The 20 sectors are dummy variables with two categories (0 and 1 values).

The size of companies is measured based on the number of employees in 9 categories (see the survey). Using 9 dummy variables with two categories in the analysis is not the best approach. Instead, I used an ordinal variable from 1 to 9 because natural logarithm (Ln) of variable “size categories” has a linear shape.

**Innovation Activities**

I used Community Innovation Survey (CIS) for the definition of innovation activities. This includes questions about product, process, organizational and marketing innovation in detail. Thus, it covers all innovation activities of the companies. CIS is now conducted in most EU countries every two years. The use of CIS survey question has two main advantages. First, questions have already tested on other samples of companies. This minimized possible mistakes or faults in the survey questions. Secondly, the result of this study will be comparable with other survey studies because it harmonizes data collection as optimal as possible over sectors and countries.

Most of the data collected in CIS surveys are qualitative, subjective and censored. Using binary (yes/no) indicator for process, organizational and marketing innovation may make sense for innovators only and 0 is not always a good guess for non-innovators. Product innovation is measured as ordered categorical variables based on the level of novelty in the market (Likert scales 1 to 5).

**Collaboration Activities**

I used Community Innovation Survey (CIS) for collecting data about collaboration partners, information sources and output of innovation activities. The collaboration partner variable is an unordered categorical variable (with 4 categories: Local/Regional within the Netherlands, The Netherlands, Europe, and the World). The source of information was an ordered categorical variable (Likert scales 1 to 4).

Based on the Smart Industry concept, companies can go beyond their industry and co-innovate with actors outside of their supply chain. Thus, I added “non-competitors from other industries” to the Collaboration and Information Sources questions.
Effect of Innovation is an ordered categorical variable (Likert scales 1 to 5). I added “Closer relationship with customer” and “Closer relationship with business partners” and “Reduced workload of employees” to this question based on the case studies.

**ICT and Manufacturing Technologies**

Developing a list of Smart Industry technologies appeared to be difficult and subjective. However, the result of literature and case studies showed that the list of technologies can be divided in three general categories including common ICT for SMEs, IoT or CPS, and advanced manufacturing technologies. Besides, the case studies showed that companies do not have a unique interpretation of general words like ICT and complex words like CPS and IoT that are used in the Smart Industry report or other survey studies. Using these words in the survey could lead to collection of information with low validity. Therefore, I devised a list of technologies for each of the three categories.

1. **Common ICTs for enterprises**

There are various indicators for ICT. Organization for Economic Co-operation and Development (OECD) uses 15 indexes like broadband and telecommunication based on various publications and datasets. Moreover, Enterprise Architecture systems like CRM, ERP, and SCM that facilitate Business-Business and Business-Customer transactions are mentioned in the literatures. The list of variables in this survey is as the following Table 2:

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Variable Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet access</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Company’s website</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>E-commerce</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Business Intelligence: having right strategies</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>CRM: software for Relationship Management with Customer</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>SCM: Supply Chain Management software</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>ERP: Enterprise Resource Planning software</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
</tbody>
</table>

*Table 2. Survey Variables on Common ICTs for Enterprises.*
2. IoT

I used a definition of IoT based on the scientific articles about IT. The advantage of using more sub-technology or layers of IT is that the respondents are provided with more information. Moreover, if a specific technology has lots of missing values in the respondent data set, other relevant group technologies can be used as the variable in the quantitative analysis. More explanation about this technique is provided in next chapter (in section Principle Component Analysis).

It is worth mentioning that there isn’t even a unique definition of IoT and layers of IT among the technical articles (for example see articles by: Gubbi (2013), Li, Da Xu, & Zhao (2015), Atzori, Iera, & Morabito (2010)). Comparing and contrasting those definitions is not in the scope of this thesis. I used three layers of IT for the purpose of this research. The fourth layer is about the application of IT in the industry (Table 3).

<table>
<thead>
<tr>
<th>IT layers</th>
<th>Variable Name</th>
<th>Variable Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware/Identification &amp;</td>
<td>Radio-frequency Identification tags (RFID)</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Communication</td>
<td>Sensors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Actuators</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Near Field Communication (NFC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine-to-Machine Communication (M2M)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other IP technologies, such as IPv6</td>
<td></td>
</tr>
<tr>
<td>Wireless Sensor Network (WSN)</td>
<td>WSN hardware</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open sensor web architecture (OSWA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secure data aggregation</td>
<td></td>
</tr>
<tr>
<td>Big Data</td>
<td>Open Services Gateway initiative (OSGi)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semantic oriented middleware</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine learning methods like genetic algorithms, Deep Neural Nets (DNNs), etc.</td>
<td></td>
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<tr>
<td></td>
<td>Modular software &amp; hardware</td>
<td></td>
</tr>
<tr>
<td>Industry Application</td>
<td>Mobile apps</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td></td>
<td>24/7 real-time data in Supply Chain Management</td>
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<tr>
<td></td>
<td>24/7 real-time access to the Enterprise Resource Planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24/7 real-time data for Customer Relation Management</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Survey Variables on IoT technologies.

3. Advanced manufacturing technologies:

I used the Smart Industry report as a reference. The list of variables is provided in table 4.
The list of three technology domains of the Smart Industry is developed and used during the case studies in order to test its validity.

**The Smart Industry**

The questions in the survey were designed in order to introduce elements of the Smart Industry to the respondents in the first four pages. The last page was aimed to collect information about the Smart Industry initiatives of the respondent companies. The first question was about the target variable. To assist respondents in scaling their investment on the Smart Industry (from 1 to 10) in the time period from 2013 to 2016, a short explanation based on the Smart Industry report was provided. Question number two asked the respondents to determine to what extent the Smart Industry had contributed to their innovation output from 2013 to 2016.

I used the period from 2013 to 2016 in most of the survey question. This will help to compare the results of the study with other studies, especially those that are conducted in Germany about the Industry 4.0 program.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Variable Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>3D-printing</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Robotics, autonomous vehicles, virtual personal assistants</td>
<td>Independent variable (5 points Likert scale)</td>
</tr>
</tbody>
</table>

*Table 4. Survey Variables on Advanced manufacturing technologies.*

The next three questions were about the human aspect of the Smart Industry initiatives. I developed a list of predictor variables based on the literature and case studies. The table below summarizes those variables:

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Variable Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Product innovation by the Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Process innovation by the Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Organizational innovation by the Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Marketing innovation by the Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
<tr>
<td>Increased turnover by the Smart Industry</td>
<td>Dependent variable (5 points Likert scale)</td>
</tr>
</tbody>
</table>

*Table 5. Survey Variables on the Smart Industry*
The last question asked the respondents to mention the most serious challenges in their Smart Industry initiatives.

The draft version of the survey questionnaire was developed during the case studies. The survey questionnaire was tested on a small sample before sending it out to the main sample. The aim was to minimize possible mistakes and misunderstanding in the design of the survey questions.

### 4.2.2. Sample

After preparing the survey, the Program Office Smart Industry provided access to a sample of 2273 individuals who receive monthly news about the Smart Industry. Therefore, a probability sampling is used in which the respondents are randomly selected and each individual has exactly the same chance of being selected. It was a cross-sectional survey study in which I collected the relevant variables in one step. The sample study includes people from both SMEs and large companies active in all industry sectors and public organizations. Therefore, the sample is appropriate for the purpose of the research. However, the exact information of the sample is not available for in depth study.
5. Survey Results

This chapter is about the quantitative analysis of the data collected from the online survey study. First, some descriptive results concerning general tendencies in the data are described. Secondly, inferential results are outlined.

5.1. Descriptive Statistics

In the period from April 13 till June 1 2016, data was gathered from 219 respondents, of which only 78 responses were completed and submitted. The low rate of response is a limitation for quantitative analysis and reliability of the findings.

Unfortunately, detailed information of the 2273 individuals, for example, their sector, size and area of activities was not available for comparison with the respondent sample. A possible alternative was to investigate the incomplete responses as a rough estimate of the non-respondents population.

Only 90 out of 141 incomplete responses included information about the industry sector and size of the company. The next table compares the sectors and size of respondents and non-respondents group. Comparison of two samples shows quite a good similarity between them. Notice that it was possible for the respondents to choose more than one industry in the survey questionnaire. Actually, it is important for the companies to go beyond their traditional industry and work in multiple industries based on the Smart Industry concept.
<table>
<thead>
<tr>
<th>Industry Sector</th>
<th>Respondents</th>
<th>Non-respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, forestry and fishing</td>
<td>8.97</td>
<td>8.89</td>
</tr>
<tr>
<td>Mining and quarrying</td>
<td>1.28</td>
<td>4.44</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>55.13</td>
<td>28.89</td>
</tr>
<tr>
<td>Electricity, gas, steam and air conditioning supply</td>
<td>6.41</td>
<td>8.89</td>
</tr>
<tr>
<td>Water supply, sewerage, waste management and remediation activities</td>
<td>10.26</td>
<td>3.33</td>
</tr>
<tr>
<td>Construction</td>
<td>7.69</td>
<td>8.89</td>
</tr>
<tr>
<td>Wholesale and retail trade; repair of motor vehicles and motorcycles</td>
<td>3.85</td>
<td>2.22</td>
</tr>
<tr>
<td>Transportation and storage</td>
<td>11.54</td>
<td>8.89</td>
</tr>
<tr>
<td>Aviation</td>
<td>5.13</td>
<td>1.11</td>
</tr>
<tr>
<td>Accommodation and food service activities</td>
<td>2.56</td>
<td>3.33</td>
</tr>
<tr>
<td>Information and communication</td>
<td>16.67</td>
<td>14.44</td>
</tr>
<tr>
<td>Financial institutions</td>
<td>1.28</td>
<td>3.33</td>
</tr>
<tr>
<td>Renting, buying and selling of real estate</td>
<td>2.56</td>
<td>1.11</td>
</tr>
<tr>
<td>Consultancy, research and other specialized business services</td>
<td>29.49</td>
<td>18.89</td>
</tr>
<tr>
<td>Renting and leasing of tangible goods and other business support services</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Public administration, public services and compulsory social security</td>
<td>3.85</td>
<td>11.11</td>
</tr>
<tr>
<td>Education</td>
<td>5.13</td>
<td>13.33</td>
</tr>
<tr>
<td>Human health and social work activities</td>
<td>2.56</td>
<td>3.33</td>
</tr>
<tr>
<td>Culture, sports and recreation</td>
<td>1.28</td>
<td>3.33</td>
</tr>
<tr>
<td>Other</td>
<td>11.54</td>
<td>17.78</td>
</tr>
</tbody>
</table>

*Table 7. Industry Sectors of companies in respondents and non-respondents sample.*

Only the percentage of companies in the manufacturing sector is relatively different between those two groups.
<table>
<thead>
<tr>
<th>Group of companies</th>
<th>Number of Staff</th>
<th>Respondents</th>
<th>Non-respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 employee</td>
<td>14.10</td>
<td>6.67</td>
</tr>
<tr>
<td>2</td>
<td>2 – 4 employees</td>
<td>8.97</td>
<td>7.78</td>
</tr>
<tr>
<td>3</td>
<td>5 – 9 employees</td>
<td>3.85</td>
<td>6.67</td>
</tr>
<tr>
<td>4</td>
<td>10 – 19 employees</td>
<td>10.26</td>
<td>8.89</td>
</tr>
<tr>
<td>5</td>
<td>20 – 49 employees</td>
<td>8.97</td>
<td>5.56</td>
</tr>
<tr>
<td>6</td>
<td>50 – 99 employees</td>
<td>8.97</td>
<td>7.78</td>
</tr>
<tr>
<td>7</td>
<td>100 – 249 employees</td>
<td>8.97</td>
<td>12.22</td>
</tr>
<tr>
<td>8</td>
<td>250 – 500 employees</td>
<td>8.97</td>
<td>4.44</td>
</tr>
<tr>
<td>9</td>
<td>&gt;500 employees</td>
<td>26.92</td>
<td>24.44</td>
</tr>
</tbody>
</table>

Table 8. *Size of companies in respondents and non-respondents sample.*

Only the percentage of companies with one employee is relatively different between two groups.

The organizations that submitted a response are perceived to be relatively experienced in their business. The youngest organization has been in the market for 2 years and the oldest one is a public organization with 213 year of experience. The figure 3 shows the distribution of age among organization (Mean=42.3, Standard Deviation=40.02).

There are 3 start-up companies among 63 observations of the incomplete response sample. The oldest organization in this group is a supplier of Original Equipment Manufacturers that has been active in the market for 125 year. The figure below shows the distribution of age among organization (Mean=34.29, Standard Deviation=27.32).
Thus, the age variable of two groups is perceived to be different from each other.

Unfortunately, there is no other available variable, for example innovation or investment on the Smart Industry concept that can be used as comparison between the two groups.

All in all, the 78 observations sample seems to be a good representative of the original sample. So, the conclusion of quantitative analysis seems to be quite reliable. The next section presents more descriptive analysis of the 78 submitted responses.
Descriptive statistics of submitted response sample

Type of companies

26.92 % of companies are small companies\(^3\). 28.21 % of them are medium sized companies\(^4\). The majority of companies in the data set are large companies\(^5\) (44.87 %). 12.82 % of respondent are part of an enterprise group with a head office located in a foreign country. There are companies active in all industry sectors except “Renting and leasing of tangible goods and other business support services”. A high percentage of respondent companies is active in the “Manufacturing” (55.13 %) and “Consultancy, research and other specialized business services” (29.49 %) sectors.

Innovation Output

The respondents were asked to determine their innovation activities during period 2013 to 2016. 87.18 % of companies introduced at least one product innovation\(^6\) in this period. 84.62 % of companies introduced at least one process innovation\(^7\). 69.69 % of these companies with process innovation introduced the novelty for the first time to the market.

83.10 % of companies experienced at least one significant organizational change\(^8\) in the period. 77.63 % of companies significantly changed organizing procedures (i.e. supply chain management, business reengineering, knowledge management, lean production, quality management, etc.) in this period. 67.11 % of companies significantly changed work responsibilities and decision making (i.e. first use of a new system of employee responsibilities, team work, decentralization, integration or de-integration of departments, education/training systems, etc.) of their organization. 67.11 % of companies significantly changed organizing external relations with other firms or public institutions (i.e. first use of alliances, partnerships, outsourcing or sub-contracting, etc.). 62.86 % of companies had at least one significant marketing innovation in their organization in this period.

The conclusion is that the respondent sample is a highly innovative one.

---

\(^3\) Companies employing up to 10 employees (Definition of Central Bureau Statistics (CBS))
\(^4\) Companies employing 10 to 100 employees (CBS)
\(^5\) Companies employing 100 or more employees(CBS)
\(^6\) Definition of CIS, 2012
\(^7\) Definition of CIS, 2012
\(^8\) Definition of CIS, 2012
**Information Sources**

Information from “clients or customers from the private sector”, “suppliers” and “within enterprise or enterprise group” were in respect the most important information sources to the respondent companies in their activities in the period 2013 to 2016.

Surprisingly, 61.54% of companies answered that information from “consultants and commercial labs” was less important for them or they do not use it at all in their activities (score 2 and lower on the 4 points Likert scale). Information from “government, public or private research institutes” (55.13 %) and “non-competitors from other sectors” (52.56%) were other least important source of information to the innovation activities of respondent companies.

**Smart Industry**

The respondents perceived their companies as giving investment in the Smart Industry (based on their available budget) as high priority (Mean=6.35, Standard Deviation=2.78, Skewness= - 0.55, and Kurtosis=2.10). The figure below shows the distribution of the target variable among the respondents.

![Figure 5. Distribution of target variable.](image)

![Figure 6. Investment on the Smart Industry by company size.](image)
Figure 6 shows that almost every degree of “smartness” occurs in each size category. However, investment in the Smart Industry is perceived to be more important for the bigger companies.

None of the sectors, except ICT and “Wholesale and retail trade” is a significant predictor variable for the target variable. The reliability of this claim is questionable because of low observation in the sample study and diversity of sectors.

| smartindustry          | Coef.  | Std. Err. | z      | P>|z|   | [95% Conf. Interval] |
|------------------------|--------|-----------|--------|-------|---------------------|
| agriculture            | -1.919399 | 2.151353 | -0.89  | 0.372 | -6.136512          | 2.296635 |
| mining                 | -3.983848 | 4.372906 | -0.91  | 0.362 | -12.55454          | 4.856938 |
| manufacturing          | 0.565312  | 0.6166591| 0.92   | 0.359 | -6.430984          | 1.774161 |
| electricity            | -1.326222 | 3.326723 | -0.40  | 0.690 | -7.84648           | 5.194036 |
| watersupply            | 0.648154  | 1.026225 | 0.63   | 0.529 | -1.364549          | 2.65818 |
| construction           | 0.136977  | 1.041713 | -0.11  | 0.913 | -2.155419          | 1.928023 |
| wholesale              | -2.429658 | 1.234989 | -1.97  | 0.049 | -4.850209          | -0.009107 |
| transportation         | 0.955783  | 1.782907 | 0.52   | 0.604 | -2.568855          | 4.420012 |
| aviation               | 1.119263  | 1.175297 | 0.95   | 0.341 | -1.184277          | 3.422803 |
| accommodation          | 3.294012  | 3.654108 | 0.90   | 0.367 | -3.867909          | 10.45593 |
| financial              | 0.3485264 | 1.679242 | 0.21   | 0.836 | -2.942723          | 3.639776 |
| renting                | -1.270672 | 1.511947 | -0.84  | 0.401 | -4.234034          | 1.69269  |
| consult                | -0.218695 | 0.656719 | -0.32  | 0.747 | -1.499015          | 1.075276 |
| sectorpublic           | -3.341332 | 1.792611 | -1.86  | 0.062 | -6.854784          | 1.172120 |
| education              | -1.871484 | 1.023958 | -0.38  | 0.755 | -2.19407           | 1.819773 |
| humanhealth            | -0.4956436| 0.557464 | -0.32  | 0.750 | -3.54821           | 2.556922 |
| culture                | 17.39735  | 146.859  | 0.01   | 0.991 | -2857.594          | 2892.389 |
| sectorict              | 2.459972  | 0.886272 | 2.78   | 0.006 | 0.7229108          | 4.197034 |
| othersector            | -0.067254 | 0.718209 | -0.01  | 0.993 | -1.414391          | 1.40094  |

Note: 1 observation completely determined. Standard errors questionable.

Table 9. Industry sectors and the Smart Industry.

Table 10 summarizes the contribution of the Smart Industry to innovation activities and turnover of the respondent companies. It appears that the most important contribution of the Smart Industry is to process innovation of the companies. Surprisingly, 41.79% of the companies did not report increased turnover of their organization because of the Smart Industry concept.
The contribution of the Smart Industry

<table>
<thead>
<tr>
<th>The contribution of the Smart Industry</th>
<th>Significant Contribution (score higher or equal to 4 on the 5-points Likert scale)</th>
<th>Almost No Contribution (score lower or equal to 2 on the 5-points Likert scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased turnover</td>
<td>29.9 %</td>
<td>41.79%</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>53.63 %</td>
<td>31.88 %</td>
</tr>
<tr>
<td>Process Innovation</td>
<td>60.56%</td>
<td>23.94%</td>
</tr>
<tr>
<td>Organizational Innovation</td>
<td>40%</td>
<td>28.57%</td>
</tr>
<tr>
<td>Marketing Innovation</td>
<td>37.5</td>
<td>38.89%</td>
</tr>
</tbody>
</table>

Table 10. Contribution of the Smart Industry to Innovation Activities and Turnover.

Lack of time and cost of ICT systems are reported as the most serious challenges for the Smart Industry initiatives in the respondent organization (table 11). The numbers are based on a 5 points Likert scale.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time</td>
<td>3.25</td>
<td>1.29</td>
</tr>
<tr>
<td>The cost of ICT systems</td>
<td>3.18</td>
<td>1.36</td>
</tr>
<tr>
<td>Constantly adapting to technology changes</td>
<td>3.05</td>
<td>1.22</td>
</tr>
<tr>
<td>Lack of sufficient knowledge about the Smart Industry in our supply chain</td>
<td>2.80</td>
<td>1.22</td>
</tr>
<tr>
<td>Low knowledge about new technologies</td>
<td>2.75</td>
<td>1.11</td>
</tr>
<tr>
<td>Less relevance to our business (company)</td>
<td>2.67</td>
<td>1.31</td>
</tr>
<tr>
<td>Fear of disclosure of business secrets</td>
<td>2.33</td>
<td>1.18</td>
</tr>
</tbody>
</table>

Table 11. Challenges for Companies in implementation of the Smart Industry.

5.1.2. Conclusion on the Descriptive Statistics

Considering the fact that the companies in the sample study are highly innovative, it is not surprise that lack of knowledge is not reported as a very serious challenge. A number of interviewees in the case studies told that their organization had been investing on the Smart Industry in the years before 2014. Considering the short age of the Smart Industry program and the relatively high investment of the respondent companies on average (Mean=6.35) confirms that the companies in the sample study (78 observations) are early adopters of the Smart Industry concept.

Surprisingly, fear of disclosure of business secrets is reported as the least serious challenge among the respondents. This finding is not in line with the evidence of the case study companies.
5.2. Inferential Statistics

5.2.1. Regression Analysis

The small size of the sample makes it difficult for inferential statistics, especially hypothesis testing on the conceptual model. Using too many variables in a regression model with a low number of observations predicts the target variable very well, but increases the error terms in the model. Technology and human capital especially includes many variables in the survey. The possible approach was Factor Analysis (FA). Explanatory factor analysis is used because the theory did not provide enough insight about the number and loading of factors.

Thereafter, regression analysis is used to investigate the elements of the Smart Industry in the sample study to answer sub question three.

Principle Component Analysis for variables

I used Principle Component Analysis (PCA) to extract a few numbers of components that explain all the human capital (including employee and information sources) and technology variables. Observing the data, it appeared that there are a relatively high number of missing values in the responses. On one hand quantitative analysis is confronted with limitations due to the low response rate. On the other hand, PCA excludes observations with missing variables (“I do not know” answer) in the analysis. Therefore, I checked variables with the highest number of missing values and investigated the possibility of excluding them from PCA. Thereafter, I ran PCA on different combinations of variables to gather more observations for the cluster and regression analysis.

PCA on Human Capital Variables

Initial PCA analysis on 11 human capital variables and 4 components could be extracted from the data of 50 respondents that have eigenvalues over Kaiser’s criterion of 1. They are ordered from the largest up to the smallest portion of variance in the data (table 12). However, component 1 alone includes 58.3 percent of the variance among the human capital data. Orthogonal (un-rotated) PCA is used to extract the components from the variables. In this method, the components are not correlated to each other. Since standard deviation of variables is not different covariance method in PCA is used.

The correlation between items showed to be sufficiently large to perform PCA. The extracted factors fit very well to the model (KMO = 0.916, Kaiser-Meyer-Olkin measure indicates an adequate sample size).
It is worth mentioning that the variable “old employees” is excluded from the PCA because it has 19 missing values in the data set.

12 information source variables are not included in PCA for a number of reasons. First, this decreases the number of observations in PCA to 44 due to missing values in the information source variables. Secondly, leaving aside “information within enterprise or enterprise group” the loading factor of those 12 variables is low on component 1. Moreover, new component 1 explains 44.35% of all human capital variables. Therefore, information source and collaboration partners are used later in cluster analysis as control variables.

<table>
<thead>
<tr>
<th>Component</th>
<th>Eigenvalue</th>
<th>Difference</th>
<th>Proportion Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp1</td>
<td>10.46</td>
<td>8.55431</td>
<td>0.5836 0.5836</td>
</tr>
<tr>
<td>Comp2</td>
<td>1.90568</td>
<td>.575407</td>
<td>0.1063 0.6899</td>
</tr>
<tr>
<td>Comp3</td>
<td>1.33027</td>
<td>.44601</td>
<td>0.0742 0.7641</td>
</tr>
<tr>
<td>Comp4</td>
<td>1.18407</td>
<td>.349451</td>
<td>0.0561 0.8302</td>
</tr>
<tr>
<td>Comp5</td>
<td>.834617</td>
<td>.199544</td>
<td>0.0466 0.8767</td>
</tr>
<tr>
<td>Comp6</td>
<td>.635073</td>
<td>.152566</td>
<td>0.0354 0.9122</td>
</tr>
<tr>
<td>Comp7</td>
<td>.110046</td>
<td>.320407</td>
<td>0.0146 0.9268</td>
</tr>
<tr>
<td>Comp8</td>
<td>.386019</td>
<td>.123055</td>
<td>0.0215 0.9483</td>
</tr>
<tr>
<td>Comp9</td>
<td>.262963</td>
<td>.099551</td>
<td>0.0147 0.9624</td>
</tr>
<tr>
<td>Comp10</td>
<td>.163012</td>
<td>.106557</td>
<td>0.0091 0.9715</td>
</tr>
<tr>
<td>Comp11</td>
<td>.152359</td>
<td>.00885</td>
<td>0.0048 1.0000</td>
</tr>
</tbody>
</table>

**Table 12. PCA on Human Capital Variables.**

The variables “new employees”, “young employees”, “workshops” and “vocational training” have the highest loading factor on component 1. However, there is not a big difference between loading factors of variables on component 1. Although interpreting components with use of an oblique (rotated) method is easier, the extracted components are highly correlated to each other. Therefore, one component of rotated PCA does not have a high portion of variance anymore.
PCA for technology variables

With initial PCA analysis on three technology domains items, 8 components could be extracted that have eigenvalues over Kaiser’s criterion of 1. However, component 1 alone includes 47.73 percent of technology variables (table 13). Since standard deviation of variables is not different covariance method in PCA is used. IoT technologies especially actuator, sensor, and manufacturing technologies like robotics have the highest loading factor on component 1. The result of PCA confirms the claim that there is no single technology in the Smart Industry concept, but it is a group of technologies.

Orthogonal (un-rotated) PCA is used to extract the components from the variables. In this method, the components are not correlated to each other. The correlation between items showed to be not large. However, the extracted factors fit very well to the model as Kaiser-Meyer-Olkin measure indicates an adequate sample size, KMO = 0,954).
Table 13. PCA on Technology Variables.

Notice that the following variables are excluded from the PCA because of a high number of missing values in the data set (table 14).

<table>
<thead>
<tr>
<th>IT layers</th>
<th>Variable Name</th>
<th>Missing values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware/ Identification &amp; Communication</td>
<td>Near Field Communication (NFC)</td>
<td>19</td>
</tr>
<tr>
<td>Wireless Sensor Network (WSN)</td>
<td>Open sensor web architecture (OSWA)</td>
<td>22</td>
</tr>
<tr>
<td>Big Data</td>
<td>Open Services Gateway initiative (OSGi)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Semantic oriented middleware</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Machine learning methods</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 14. Technology Questions with high missing values in the data set.
This does not affect the result of PCA, because the excluded variables have high correlation with other variables in their technology sub-group. For example, three out of 4 questions about Big Data has high number of “I do not know” in the data set. Only question about “Modular software & hardware” has low number (7) missing value in the data set. There is high correlation between all these 4 variables in the data set. Thus, “Modular software & hardware” is considered as the representative of “Big Data” technology in PCA.

![Table 15, Correlation Coefficient between Big Data Variables.](image)

**Confirmatory Regression Analysis**

Considering the target variables are ordinal numbers from 1 to 10, ordinal logit regression is used. It is part of the family of Generalized Linear Models (GLM). The data is checked for the outliers and missing values. One by one regression analysis on 13 components of human capital and technology domains showed that only component one of each group is a significant predictor for the target variable. For convenience, component 1 of human capital and technology are called pc1 and pc6 in this report. Both of them are significant predictor variables.

The table below summarizes the result of the regression model using size, information source and age of companies as control variables.

Including different combination of control variables shows the human capital (pc1) is the most significant predictor variable for the Smart Industry. Moreover, IoT and the advanced manufacturing technology domain complement the human capital (Multi-collinearity between pc1 and pc7 (correlation coefficient=0.656)).
The low number of observations and high number of missing values makes it difficult to use regression analysis for hypothesis testing. For example, including sector dummies as control variables leads to a model with big standard errors. Regarding the typology of the sample study (early adopters of the Smart Industry), it is interesting to investigate any difference between groups of smart companies. Therefore, I used cluster analysis as an exploratory data-analysis technique on the extracted components.

### 5.2.2. Cluster analysis

Defining cluster analysis is difficult (Kaufman and Rousseeuw., 1990). Two common clustering methods are partition and hierarchical. The partition method makes distinct (non-overlapping) groups of observations. The partition-clustering approach is usually quicker than the hierarchical method.

Stata has implemented two partition methods, kmeans and kmedians. Kmeans is the more commonly used partition clustering methods. The kmeans method is used for pc1 pc7 as the most significant predictor variables for the Smart Industry based on the conceptual model. I specified 3 as the number of clusters. Stata created the groups in an iterative process, in which each observation is assigned to the group whose

### Table 16. Influence of pc1 and pc7 on the Smart Industry.

<table>
<thead>
<tr>
<th></th>
<th>(1)\textsuperscript{a}</th>
<th>(2)\textsuperscript{b}</th>
<th>(3)\textsuperscript{c}</th>
<th>(4)\textsuperscript{d}</th>
<th>(4)\textsuperscript{e}</th>
<th>(4)\textsuperscript{f}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient (odd ratio) of pc1</td>
<td>0.6624****</td>
<td>0.709***</td>
<td>0.7621****</td>
<td>0.6885****</td>
<td>0.7138***</td>
<td>0.7954****</td>
</tr>
<tr>
<td>Coefficient (odd ratio) of pc7</td>
<td>0.0984</td>
<td>.0127</td>
<td>0.3436*</td>
<td>0.1277</td>
<td>0.3614*</td>
<td>0.2975*</td>
</tr>
<tr>
<td>Pseudo R$^2$</td>
<td>0.2393</td>
<td>0.2463</td>
<td>0.3841</td>
<td>0.2455</td>
<td>0.3485</td>
<td>0.4037</td>
</tr>
<tr>
<td>LR chi2(3)</td>
<td>33.87</td>
<td>34.86</td>
<td>48.61</td>
<td>34.75</td>
<td>48.66</td>
<td>51.09</td>
</tr>
<tr>
<td>Number of observations</td>
<td>35</td>
<td>35</td>
<td>31</td>
<td>35</td>
<td>31</td>
<td>31</td>
</tr>
</tbody>
</table>

- \textsuperscript{a} linear regression including no control variables
- \textsuperscript{b} linear regression including size of company as the control variable
- \textsuperscript{c} linear regression including information sources as the control variables
- \textsuperscript{d} linear regression including age of organization as the control variables
- \textsuperscript{e} linear regression including size of company and information sources as the control variables
- \textsuperscript{f} linear regression including size, age and information sources as the control variables

* $P < 0.20$
** $P < 0.10$
*** $P < 0.05$
**** $P < 0.01$
mean is closest, and then based on that categorization, new group means are determined. These steps continue until no observations change groups\textsuperscript{9}.

Unfortunately, only 35 observations are included in the partition clustering because of high number of missing values or “I do not know” answers in the survey. Nevertheless, the shape of distribution is still similar to 78 observations (figure 7). Moreover, it has a normal distribution (pr=0.054 Shapiro-Wilk test for normality, pr=0.142 for sktest).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{smart_industry_distribution.png}
\caption{The distribution of the Smart Industry for 35 observations in the partition clustering.}
\end{figure}

Partition clustering led to three groups of smart companies showed in the table 17. Although the difference between three groups on investment on the Smart Industry is not statistically significant (Fisher Exact test=0.061), the average of target variables among three groups are hierarchically related;

Group 1: Very high investment in the Smart Industry (Mean=8.2, Standard Deviation=1.37)
Group 2: Relatively high investment in the Smart Industry (Mean=7.09, Standard Deviation=1.97)
Group 3: Low investment in the Smart Industry (Mean=3.88, Standard Deviation=2.26)

Since the relationship (similarity and dissimilarity) between groups is important for this research, a hierarchical method is used. Two types of hierarchical clustering method are agglomerative and divisive. The first method is used for the pc1 and pc7. However, there are various ways to do so; Single-linkage clustering computes the similarity or dissimilarity between two groups as the similarity or dissimilarity between the closest pair of observations between the two groups. Complete linkage clustering, on the other hand, uses the farthest pair of observations between the two groups to determine the similarity or

\textsuperscript{9} For more information see: http://www.stata.com/}
dissimilarity of the two groups. I chose average-linkage clustering that uses the average similarity or dissimilarity of observations between the groups as the measure between the two groups.

![Dendrogram for hierarchical cluster analysis](image)

**Figure 8.** Average linkage clustering (labels are groups of companies in partition clustering).

As shown in figure 8, the result of hierarchical and partition clustering are almost the same, except for three observations. Next section describes the differences between these three groups (partition clustering) based on the available variables in the survey study.

**Comparing three groups of companies**

The three groups of smart companies are different in respect to their size (Fisher's exact test = 0.000).

![Dendrogram for hierarchical cluster analysis](image)

**Figure 9.** Average linkage clustering (labels are size of companies).
This graph shows that the Smart Industry was more important for big companies than small companies during the three years 2013 to 2016. 67% of companies with lowest investment on the Smart Industry are companies with only one employee.

26.66% of companies in group 1 are part of an enterprise group with the head office located in a foreign country. The average investment of these companies in the Smart Industry in the three years period 2013 to 2016 was 8.5 (on the 10-points Likert scale). 9.09% of companies in group 2 are part of an enterprise group with the head office group located in a foreign country. All the companies in group 1 are Dutch companies.

Table 18 describes the age differences of the three groups. Running Multinomial Logistic Regression showed that the three groups of companies are not significantly different regarding the age of organizations (p-value=0.133>0.05).

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>61.86</td>
<td>43.95</td>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>Group 2</td>
<td>35.90</td>
<td>28.71</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Group 3</td>
<td>17.66</td>
<td>12.46</td>
<td>2</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 17. Age of Companies on 3 Clusters.

**Innovation output**

The groups of companies are not different in product. They are only different in supporting activities for their processes, such as maintenance systems or operations for purchasing, accounting, or computing.

The three groups of smart companies are perceived to be statistically significantly different in use of real time data for supply chain management. Table 19 summarizes the mean value of each group (based on the 5 points Likert scale measure).

<table>
<thead>
<tr>
<th>Real time data</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Chain Management</td>
<td>4.06</td>
<td>2.36</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Table 18. Used Real Time Data on Three Clusters of Smart Companies.

Innovation activities of more than 90% of companies in group 1 and 2 helped them to build closer relationships with their customers. However, 66.66% of the companies in group 1 built close relationships with their customers.
Innovation activities of 76.92% of the companies in group 1 has increased their capacity of production or service provision. 45.45% of companies in group 2 and 14.28% in group 3 have increased their capacity of production and service by the innovation activities.

50% of the companies in group 1 reduced environmental impacts or improved health and safety. 36.36% of companies in group 2 and 14.28% in group 3 have increased their capacity of production and service by the innovation activities.

Table 20 summarizes the contribution of Smart Industry to innovation activities and turnover of the three groups of companies. Contribution of the Smart Industry to innovation activities of group three during the three years 2013 to 2016 was very low. They have not increased any turnover by the Smart Industry in this period. The biggest difference between group 1 and 2 is the high contribution of the Smart Industry on organizational and marketing innovation activities.

<table>
<thead>
<tr>
<th>The contribution of the Smart Industry</th>
<th>Significant Contribution (score higher or equal to 4 on the 5-points Likert scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>Increased turnover</td>
<td>53.33%</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>53.33%</td>
</tr>
<tr>
<td>Process Innovation</td>
<td>73.33%</td>
</tr>
<tr>
<td>Organizational Innovation</td>
<td>66.67%</td>
</tr>
<tr>
<td>Marketing Innovation</td>
<td>60%</td>
</tr>
</tbody>
</table>

Table 19. Contribution of the Smart Industry to Innovation Activities and Turnover of three Clusters

Cooperation partners

The three groups of companies are only statistically different in cooperation activities with competitors or other enterprises in their industry. 66.66% of companies in group 1 have international cooperation partners, while 16.67% of companies in group 3 and none of companies in group 2 and only have international cooperation partners.

For 73.33% of companies in group 1 information from suppliers is highly important (score 4 on the 4 points Likert scale), while only 18.18% of companies in group 2 and 10% of companies in group 3 scored information from suppliers as highly important.
Challenges in the Smart Industry initiatives

Table 20 summarizes the challenges that are perceived to be different (Fisher exact test <0.05) among three groups of companies.

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Mean value (5-points Likert scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>The cost of ICT systems</td>
<td>3.4</td>
</tr>
<tr>
<td>Constantly adapting to technology changes</td>
<td>3.4</td>
</tr>
<tr>
<td>Secrecy</td>
<td>2.8</td>
</tr>
</tbody>
</table>

*Table 20. Challenges on Three Groups of Smart Companies*
6. Summary and Discussion

This research was aimed at exploring (1) the elements of the Smart Industry, (2) the effects of the implementation of the smart industry concept on innovation output, and (3) empirical evidence about the current stage of development of the Smart Industry in the Netherlands. A Mixed-methods approach is used to answer the research questions. The first step of the research was a literature study of published documents and scientific articles about the Smart Industry. In the literature survey part of the thesis, I studied scientific publications about the 4th Industrial Revolution in other countries especially Germany (Industry 4.0). This step of research provided some insight to answer the research questions theoretically. However, empirical evidence was needed to complement the theory and develop a framework to examine the implementation of the Smart Industry concept on a company level. This was done in two steps. First, case studies are done on 9 different organizations in terms of industry sector, size and development stage of the Smart Industry solutions. The findings were translated to a framework or conceptual model for the Smart Industry. So, this study introduced new definition for the Smart Industry. The Smart Industry is the balance between smart technologies and human capital to apply smart solutions to the core competency of an organization or company.

In order to test the framework an online survey was conducted on a sample of 2273 members of Smart Industry Program Office. The sample study includes people from both SMEs and large companies active in all industry sectors and public organizations. In the period from April 13 till June 1 2016, data was gathered from 219 respondents, of which only 78 responses were completed and submitted. Comparing sector, size and age of organizations in the 78 observations with 90 incomplete responses showed quite good similarity between them.

The first part of this chapter is a summary of the main findings of the research. Further, the conclusion, limitation and potential follow up research are discussed.
6.1. Summary

1. How important are new technologies, human capital (learning new skills and collaboration activities) for implementing the Smart Industry concept in theory and practice?

The result of literature study showed that investment in new technology especially ICT and human resources are two pillars of the Smart Industry concept.

Convergence of the Technology Domains

Human-human, human-machine and machine-machine communications are three important contributions of ICT to the Smart Industry. The latter (IoT or CPS) is known as the new revolutionary aspect of ICT. However, all three contributions of ICT are important in innovation activities of companies. Internet is the enabler of communication between humans as well as machines in CPS throughout large networks.

The literature study showed that the Smart Industry concept is not about a single technology domain, but it is about the convergence of multiple technology domains including digitalization, network and advanced manufacturing technologies.

The case studies demonstrated that each organization started the way to the Smart industry with use of specific technologies. However, they continuously extended their technology portfolio because of the fast pace of technology change and new demands in the market.

From the observed technology domain items (20 variables in the survey), a first component could be extracted which is a significant predictor of the Smart Industry concept (target variable). Not a single technology, but a group of IoT and advanced manufacturing technologies (especially sensor, RFID tags) have a high loading factor on this component. Commonly used ICT technologies like the internet, company website, and telecommunication have the lowest loading factor on this component. It shows that investment in IoT technologies is very important to implement the Smart Industry concept.

Having embedded IT capabilities within the organization (or decentralized IT) was attributed as a prerequisites for technology convergence in the literature. The survey was aimed to test the convergence theory by asking the role of different disciplines of organizations (like central IT, decentralized IT, innovation and R&D) in implementation of IT, but it did not lead to meaningful findings.
Human Capital (learning new skills)

Based on the literature, implementation of the Smart Industry requires knowledge workers with higher technical and non-technical skills. Non-technical skills include communication, multi-disciplinary working, problem solving and decision making abilities. Companies need to either train their current staff or hire new knowledge employees, especially young engineers. Participation of staff in relevant conferences, working groups and workshops are examples of vocational training that are given in the literature.

The case studies confirmed that the whole organization should be ready to implement the Smart Industry solutions. Moreover, it is found that vocational training is not only for workers, but managers may also need to update their skills, especially soft skills like communication. Smart Industry is not only about IoT but human-to-human interaction also still plays a very important role in the Smart Industry concept.

Schuch et al (2014) introduced an interesting framework for collaborative practices including three categories: cooperation, coordination and communication. Cooperation indicates that the involved entities recognize the importance of the overall goal and consequently work together in order to reach it. Coordination is defined as “managing dependencies between activities”. The change in labor work falls in this category. Communication is necessary to share information, as a value driver of new business models in the Smart Industry, with other parties.

The case study companies differed in terms of collaboration activities. A number of them managed to innovate almost completely internally, while some of them had products and services that needed added value from other parties. My interviewees believed that investment on soft skills of staff and engaging them in collaboration with other parties addresses many challenges in the Smart Industry. For example, sharing data between parties is not limited to technology progress, but it is about trust and communication skills. Participation of staff in networking activities, workshops and open lecture can make them ready in this respect.

From 11 employee and 12 information sources variables in the survey study only one component could be extracted that is a significant predictor of the Smart Industry. The loading of information sources items were low on the extracted component. Therefore, they are excluded from PCA analysis. It increased the number of observation in cluster analysis. The loading of “hiring new employees”, “young employees”, “workshops” and “vocational training” on the extracted component turned out to be the highest.
Complementary aspect of human capital and technology

The findings from literature were tested in case studies and then translated into a conceptual model to examine the implementation of the Smart Industry concept at the company level. Based on this model, human capital complements smart technologies in the Smart Industry concept. This is applicable for all companies regardless of size, type and industry sector of a company. The regression model included significant extracted components and a number of control variables confirmed the complementary aspect of human capital and smart technologies. Human capital is the most significant predictor variable for the Smart Industry concept. Moreover, these two components are significantly correlated with each other. This claim is tested by including a number of control variables such as size and age of companies in the regression model.

2. To what extent does the Smart Industry concept provide for higher innovation output?

Reviewing the literature showed that the common definition of innovation is applicable in the Smart Industry concept. The dynamics in the market have changed from mass to individualized production. Thus, manufacturing companies need to differentiate their product and services based on the demands of customers. Investment on the Smart Industry leads to increased capacity, reduced costs, reduced environmental impacts and real-time intelligence.

The case studies revealed that smart companies not only look at the end products, but also the whole process because of integration of manufacturing and delivery to customers by ICT. The result of organizational innovation is incremental and radical process and products innovation. The Results of implementing the Smart Industry concept are entering to new markets, increased capacity of production, reduced environmental impacts, business growth, and increased turnover. That is why the smart companies move production site from abroad back to the Netherlands.

3. To what extent are the Smart Industry solutions implemented in the Dutch industry?

The low response rate to the survey questionnaire made it difficult to answer sub-question 3. Moreover, hypothesis testing on a regression model with low observation is not highly reliable. Nevertheless, the available data was sufficient to test the main part of the conceptual model.

The 78 respondents of the survey turned out to be a heterogeneous group of organizations that are highly innovative and early adopters of the Smart Industry concept. The sample included various sizes of companies from all industry sectors especially the “Manufacturing” (55.13%) and “Consultancy, research and other specialized business services” (29.49 %) sectors. 12.82 % of the respondents are part of an
enterprise group with a head office located in a foreign country. Although almost every degree of “smartness” occurs in each size category, investment in the Smart Industry is perceived to be more important for the bigger companies in the sample.

Information from “clients or customers from the private sector”, “suppliers” and “within enterprise or enterprise group” were the most important. Information from “consultants and commercial labs”, “government, public or private research institutes” and “non-competitors from other sectors” were the least important information sources for the respondent companies in their activities in the period 2013 to 2016.

The most important contribution of the Smart Industry concept was to provide process innovation to companies. However, a considerable percentage of the companies (41.79%) did not succeed to increase their turnover by using the Smart Industry concept during the period 2013 to 2016. The most serious challenges for 78 respondent companies in the Smart Industry are lack of time and cost of ICT systems. Surprisingly, fear of disclosure of business secrets in data sharing was the least serious challenge for the participants in the survey.

Inferential statistics on 35 observations in the sample confirmed that human capital and smart technologies are significant predictor variables for the Smart Industry. Moreover, a high correlation coefficient between human capital and smart technologies showed that they complement each other.

Further, a cluster analysis was used to compare and contrast possible groups of companies that are in a different stage of investment on these two predictor variables. The majority of companies in the three groups were Dutch companies. The result of partition clustering methods on human capital and technology components clustered 35 observations in 3 groups. These three groups are different with respect to their investment on the Smart Industry in the period 2013 to 2016 (group 1: very high investment, group 2: relatively high investment, group 3: low investment). Interestingly the result of average-linkage clustering (hierarchical clustering) led to almost similar clustering, except for three observations.

The three groups of smart companies were found to be different with respect to their size. The Smart Industry was more important for big companies than small companies in this period. The age of organizations in the three groups was found not to be significantly (statistically) different.
The three groups of companies were found to be significantly different (statistically) in cooperation activities with competitors or other enterprises in their industry. The companies in group 1 have more international cooperation partners. Moreover, the “information from suppliers” was more important for them than for the other two groups.

The groups with higher investment in the Smart Industry concept used real time data for supply chain management more than other groups in this period.

Although, three groups were not found to be different in innovation activities (leaving aside supporting activities for their processes), the effect of innovation in increased capacity of their production or services, reduced environmental impacts, closer relationships with their customers were found to be significantly different.

The higher a company was scored as smart, the higher the contribution of the Smart Industry to innovation activities and turnover of a company was in the period from 2013 to 2016. Surprisingly, companies in groups 3 did not increase their turnover by the Smart Industry in this period.

6.2. Conclusions and implications

This study developed a simple framework for describing innovation activities of the smart companies which is applicable to all companies regardless of their size, industry and core business. According to this framework the Smart Industry has two important pillars: human capital and smart technologies.

The definition of smart technologies depends to some extent on the core business of a company. In general, it is a combination and convergence of ICT, IoT and advanced manufacturing technologies. However, IoT and advanced manufacturing technologies are perceived to be more important technology domains than commonly used ICTs like internet and telecommunication.

Innovation in the Smart Industry concept is not limited to the end product, but includes the whole processes. The adaptation of a whole organization to the Smart Industry concept is a necessity. Moreover, the integration of manufacturing processes requires more collaboration activities among different parties. Operation and organization of a smart factory needs staff with high knowledge of technology, but also with high soft skills for effective collaboration activities. Collaboration activities include communication, coordination and cooperation inside and outside of an organization. Therefore, investment in the technical and soft skills of staff is a must in the Smart Industry concept.
So, two elements of the Smart Industry complement each other. Smart technology in a company is not used by accident. A smart company has staff who are engaged in decision making, multi-disciplinary working, and communication with other disciplines to use smart technologies in the innovation activities.

Investment in human resources can be done by training current employees or hiring new employees. All groups of employees in an organization, especially new comers and young generation, are important in implementation of the Smart Industry.

Social innovation activities like organization of workshops are perceived to be very important to engage and motivate employees to implement the Smart Industry concept.

The result of cluster analysis in this research identified three groups of smart companies that all have product and process innovations. The smarter companies in the survey study (which are mainly big companies) are those that took advantage of the Smart Industry concept to generate more innovation. Moreover, they used real time data for their supply chain management more than other groups during 2013 to 2016. As a consequence, they generated more turnover by using the Smart Industry concept.

On the theoretical level, the study added new evidence to existing literature in the field of ICT, human capital and innovation by introducing the framework for the Smart Industry. This research can be a first step to invite more academic research into the emerging subject area.

On a practical level, this study is useful for the Dutch industry, especially for members of High Tech NL. Network organizations like HTNL always contribute to the Smart Industry solutions in the Netherlands. HTNL always looks at the Smart Industry through the eyes of the companies. Therefore, HTNL organizes many activities such as workshops, visiting tours to innovative companies, and open lectures in order to bring different parties inside and outside of the Netherlands together. The aim of these networking activities is not only to update the technical knowledge of participant companies, but also it is a great opportunity for their staff, especially engineers to experience collaboration activities with other organizations.

6.3. Limitations and Possible Future Research

As discussed before, the low rate of response to the survey was a limitation for the quantitative analysis. Although descriptive statistics showed that 78 observations are quite similar to non-respondent groups, the sample may not be a good representation of all 2273 members of Smart Industry Program Office.
The sample study includes every degree of “smart” company. However, reviewing the characteristics of the sample study showed that the companies seem to be the early adaptors of the Smart Industry concept. So, the result may not be reliable for later adopters of the Smart Industry.

Moreover, this research used a cross-sectional survey study in which the data was collected in one step. Therefore, it is not clear whether the relationship between human capital, smart technologies and the Smart Industry is a causal relationship or only a correlation. Conducting longitudinal survey questionnaire research on a big sample of companies is needed to confirm the finding of this research.

Another limitation of this research was the high number of “I do not know” answers or missing values in the data set that decreased the size of sample for cluster analysis to 35 observations. Missing values might be due to either lack of knowledge of respondents about the survey questions or weakness of the survey design. Customized design of survey questions can result in more observations and address the missing values to some extent.
References


Gartner. (2011). IT and Operational Technology: Convergence, Alignment and Integration


Appendix 1: Interview Questions

- Introduction of the Smart Industry and the research

- General information about the company

- Innovation activities
  How did the competitiveness of your company in the market improve in recent years by introduction of new or significantly improved products, processes, organizational methods, or marketing methods?

- Investment on the Smart Industry
  To what extent was the Smart Industry part of your company's strategy in recent years? When did you start with the Smart Industry?

  To what extent did the Smart Industry contribute to innovation activities in your organization?

- Technologies for the Smart Industry
  What were the important technologies in your company to implement the Smart Industry concept?

- Information sources and collaboration:
  To what extent did your success with the Smart Industry depend on your co-operation partners?

- Human Capital aspect of the Smart Industry
  What activities were important for your company in recent years to engage and motivate the employees in implementing the Smart Industry?

  Which actions would be necessary to assure the needed employee profile to implement the Smart Industry concept in your company?

- The effect of sector and size
  Do you think that implementing the elements of smart industry should be more realistic to small companies than bigger ones or the other way around?

  Why are some sectors lagging behind of the Smart Industry solutions?

- Challenges
  What was the most serious challenge for your company in implementation of the Smart Industry in recent years?

- Open question
  Is there any important point that you would like to add to this interview?
Appendix 2: Internet-based Survey

This research is undertaken by Technische Universiteit Eindhoven in collaboration with Program Office Smart Industry and High Tech NL. It aims at providing new insights into the competitiveness of the Dutch industry in the global race for “smarter” industry solutions (the so-called “Fourth Industrial Revolution”). As we expect that your company is at the leading edge of this radical change, we would be grateful if you could share your experiences in this area.

At the end of the survey, please indicate if you are interested in the results of the study. In this case, please provide us with your email address.

Completing the questionnaire will take approximately 15 minutes. While completing the questionnaire you can at any point: use the button ‘Resume later’. Then your answer will be automatically saved and you can resume the survey at a later stage.

Please do not click on the ‘Previous page’ or ‘Next page’ button of your internet browser while filling in the questionnaire.

Thank you very much for your time and your cooperation.

A note on privacy
The result of your survey response does not contain any identifying information about you, unless a specific survey question explicitly asks for it. If you used an identifying token to access this survey, please note that this token will not be verified with your responses. It is managed in a separate database and will only be updated to indicate whether you still (or do not) complete this survey. There is no way of matching identification tokens with survey responses.

General questions

In which kind of company (organisation or enterprise) do you work?

Check any that apply
- Original Equipment Manufacturer (OEM)
- Supplier of OEMs
- Public organization*
- Other:

The sector includes government-owned organizations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

Which kind of activities does your company perform?

Check any that apply
- Designing or processing
- Production of parts
- Assembly
- Engineering
- Consultancy
- Other:
What is your company's primary sector of industry?

Check any that apply

- Agriculture, forestry and fishing
- Mining and quarrying
- Manufacturing
- Electricity, gas, steam and air conditioning supply
- Water supply, sewerage, waste management and remediation activities
- Construction
- Wholesale and retail trade; repair of motor vehicles and motorcycles
- Transportation and storage
- Aviation
- Accommodation and food service activities
- Information and communication
- Financial institutions
- Renting, buying and selling of real estate
- Consultancy, research and other specialized business services
- Renting and leasing of transport equipment and other business support services
- Public administration, public services and compulsory social security
- Education
- Human health and social work activities
- Culture, sports and recreation
- Other: 

How long (years) has your company been active in that industry?

Only numbers may be entered in these fields.

What is the size of your company? Please indicate based on the number of employees.

Please select at most one answer

- 1 employee
- 2 - 4 employees
- 5 - 9 employees
- 10 - 19 employees
- 20 - 49 employees
- 50 - 99 employees
- 100 - 249 employees
- 250 - 500 employees
- >500 employees
- I do not know

In your company part of an enterprise group?*

Please select at most one answer

- Yes and the head office of our group is located in the Netherlands.
- Yes and the head office of our group is located in a foreign country.
- No
- I do not know

* A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as well as national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.
During the three years 2013 to 2016, did your company introduce the following product innovations?*

<table>
<thead>
<tr>
<th>The world</th>
<th>Europe</th>
<th>Country</th>
<th>Company</th>
<th>Yes</th>
<th>No</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods*</td>
<td></td>
<td></td>
<td></td>
<td>G</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Services*</td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

*A product innovation is the introduction of a new or significantly improved good or service that is the result of the company’s own capabilities, over new products, components or subsystems.*

*Innovations usually a tangible object such as a smartphone, but downloadable software, music and films are also goods. A service is usually intangible, such as retailing, financial services, educational courses, travel, consulting, etc.*

During the three years 2013 to 2016, did your company introduce the following process innovations?*

<table>
<thead>
<tr>
<th>Methods of manufacturing or providing goods or services</th>
<th>Yes</th>
<th>No</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics, delivery or distribution methods for your import or export services</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting activities for your processes, such as questions for purchasing, accounting, or computing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*A process innovation is the implementation of a new or significantly improved production process, distribution method, or supporting activity.*

*More any of your process innovations introduced during the three years 2013 to 2016 new to your market?* This question is mandatory. Please check at least one item.

*Please select at least one answer.*

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>I do not know</th>
</tr>
</thead>
</table>

During the three years 2013 to 2016, did your company introduce the following organizational innovations?*

| Organizational procedures (i.e., supply chain management, business reengineering, knowledge management, lean production, quality management, etc.) | Yes | No | I do not know |
| Work responsibilities and decision making (i.e., first use of a new system of employee responsibilities, team work, decentralization, integration of departments, education, training systems, etc.) |     |    |               |
| Organizing external relations with other firms or public institutions (i.e., first use of alliances, partnerships, outsourcing, or subcontracting, etc.) |     |    |               |

*A organizational innovation is a new organizational method in your enterprise’s business practice (including knowledge management), workplace organization or external relations that has not been previously used by your enterprise.*
During the three years 2013 to 2016, did your company introduce the following marketing innovations?*

This question is mandatory. Please complete all parts.

<table>
<thead>
<tr>
<th>Significant changes to the aesthetic design or packaging of a good or service (include changes that alter the product functionalities, characteristics, those are product innovations)</th>
<th>Yes</th>
<th>No</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>New media or techniques for product promotion (e.g., the first time use of a new advertising media, a new tested image, introduction of lottery cards, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New methods for product placement or sale channels (e.g., first time use of trafficking or distribution licenses, direct selling, e-commerce, new concepts for product presentation, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New methods of pricing goods or services (e.g., first time use of variable pricing by demand, discount systems, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from your enterprise existing marketing methods and which has not been used before.

---

During the three years 2013 to 2016, how important to your company’s activity were each of the following information sources?*

Please rank by placing a tick in the appropriate place according to the importance or tick the option “I do not know”.

<table>
<thead>
<tr>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Not used</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.
### Which types of co-operation partners do you use and where are they located?

<table>
<thead>
<tr>
<th>Local/Regional within the Netherlands</th>
<th>The Netherlands</th>
<th>Other Europe</th>
<th>All other countries</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other enterprises within your enterprise group</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Suppliers of equipment, materials, services, or software</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Clients or customers</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Competitors or other enterprises in your industry</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Consultants, commercial labs, or private R&amp;D institutes</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Universities or other higher education institutions</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Government or public research institutes</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Non-competitors from other industries</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

### How important were each of the following effects of your innovations that were introduced during the three years 2013 to 2016?*

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th></th>
<th>1 (Not important at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better closer relationships with business partners</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Better closer relationships with customers</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reduced extent of employees</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Increased range of goods or services</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Entered new markets or increasing market share</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Improved quality of goods or services</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Improved flexibility of production or service provision</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Increased capacity for production or service provision</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reduced costs per unit produced or provided</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reduced environmental impact or improved environmental performance</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Weet regulatory requirements</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Increased value added</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
To what extent are the following Information Communication Technologies (ICT) important for your company in the current business model?

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>1 (Not important at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet access</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company's website</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-commerce</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business intelligence:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>having right strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRM: software for</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>relationship management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with Customers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERP: supply chain</td>
<td></td>
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<td></td>
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<tr>
<td>management software</td>
<td></td>
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</tr>
<tr>
<td>SAP: enterprise resource</td>
<td></td>
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<td></td>
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<tr>
<td>planning software</td>
<td></td>
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</tr>
</tbody>
</table>

To what extent are the following big data, cloud computing and Internet of Things (IoT) technologies important for you company in the current business model?

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>1 (Not important at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification tags (RFID)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sensors</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Actuators</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Field Communication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NFC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine-to-Machine</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication (M2M)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Other IP technologies,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>such as (IPv)</td>
<td></td>
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<tr>
<td>Wireless Sensor Networks</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(WSN) hardware</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open sensor web</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>architecture (OSWA)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Secure data aggregation</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Open service software</td>
<td></td>
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<td></td>
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<tr>
<td>initiative (OSS)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Semantic related</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>knowledge management</td>
<td></td>
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<td></td>
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<tr>
<td>Machine learning methods</td>
<td></td>
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<td></td>
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<tr>
<td>like genetic algorithms,</td>
<td></td>
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<td></td>
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<tr>
<td>deep neural nets</td>
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<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile software</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart mobile apps</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>24/7 real-time data in</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24/7 real-time access to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the Enterprise Resource</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24/7 real-time data for</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Customer Relation</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Which of the following departments and disciplines are the main drivers of implementing ICT and IoT technologies in your company? Please rank by placing a tick in the appropriate place according to the importance of their role or tick the option "I do not know".

<table>
<thead>
<tr>
<th>(Not important at all)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central IT</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Innovation and R&amp;D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Management</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decentralized (Integr. IT)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other employees</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

To what extent are the following manufacturing technologies important for your company in the current business model? Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>(Not important at all)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3D printing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Robotics, autonomous vehicles, visual sensor-assisted</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Smart Industry

Smart Industry (or Industry 4.0) is driven by smart use of ICT to interconnect machines for smart operations. This is not only within factories but also between companies and between companies and customers. It involves a combination of the use of production technology, digitization, and a network approach.

To what extent was the Smart Industry part of your company’s strategy during the three years 2013 to 2016? Please rank your answer by using the following criteria:

1: NO INVESTMENT AT ALL
2: TOP PRIORITY OF MY ORGANIZATION & EMPLOYEES

Only numbers may be entered in this field. Your answer need be between 1 and 10.

To what extent did the Smart Industry contribute to your company in achieving the following objectives during the three years 2013 to 2016? Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>(No contribution at all)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very high contribution)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product innovation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Process innovation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Organizational innovation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Marketing innovation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Increased turnover</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Which actions would be necessary to assure the needed employee profile to implement the Smart Industry concept in your company? Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>(Not important at all)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing the current employees about the Smart Industry</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hiring new employees with special skills (for example, Delta specialist)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
To what extent were the following activities important for your company to engage and motivate the employees in implementing the Smart Industry during the three years 2013 to 2016?

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>1 (Not important at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocational training</td>
<td></td>
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<tr>
<td>Hosting workshops</td>
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<tr>
<td>Visiting other companies</td>
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<tr>
<td>Incentive education for</td>
<td></td>
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<tr>
<td>the current staff</td>
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<tr>
<td>Internal projects with</td>
<td></td>
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<tr>
<td>other “smart” organisations</td>
<td></td>
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</tbody>
</table>

To what extent were the following groups of employees in your company active in implementing the Smart Industry during the three years 2013 to 2016?

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>1 (Not important at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very important)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young generation</td>
<td></td>
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<tr>
<td>Middle age generation</td>
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<tr>
<td>Old generation</td>
<td></td>
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<tr>
<td>Employees with long and</td>
<td></td>
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<tr>
<td>working experience in the organisation</td>
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<tr>
<td>Employees who are new to</td>
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<tr>
<td>the organisation, regardless of their age</td>
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</tbody>
</table>

To what extent were each of the following issues a challenge for your company in implementation of the Smart Industry during the three years 2013 to 2016?

Please rank by placing a tick in the appropriate place according to the importance or tick the option "I do not know".

<table>
<thead>
<tr>
<th>1 (The challenge at all)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Very serious challenge)</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cost of IT systems</td>
<td></td>
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<tr>
<td>Less relevance to our</td>
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<tr>
<td>business (company)</td>
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<tr>
<td>Constantly adapting to</td>
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<tr>
<td>technology changes</td>
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<td></td>
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<tr>
<td>Lack of time</td>
<td></td>
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<tr>
<td>Lack of knowledge about</td>
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<tr>
<td>new technologies</td>
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<tr>
<td>Fear about disclosure of</td>
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<tr>
<td>business secrets</td>
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<tr>
<td>Lack of sufficient</td>
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<tr>
<td>knowledge about the</td>
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<tr>
<td>Smart Industry in our</td>
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<tr>
<td>supply chain</td>
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</table>

This is the end of the survey questionnaire. If you are interested in the result of this study, please provide us your email address in the text box below.