CHALMERS

Impacts of implementing paperless practices at shop floor level on the information flow and the working processes

Master of Science Thesis
in the Supply Chain Management Programme

Robin Müller

Department of Technology Management and Economics
Division of Innovation and R&D Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018
Report No. E2017:137

MASTER'S THESIS E2017:137

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ROBIN MÜLLER

Tutor, Chalmers: Peter Altmann
Tutor, company: Michael Gegner

Department of Technology Management and Economics
Division of Innovation and R&D Management
CHALMERS UNIVERSITY OF TECHNOLOGY

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Department of Technology Management and Economics
Division of Innovation and R&D Management
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2018

Acknowledgements

This master thesis was conducted during the autumn semester of 2017 in the master program of Supply Chain Management at Chalmers University of Technology. The thesis project was realized in collaboration with an automotive manufacturer located in Germany.

First of all, I would like to thank Peter Altmann, my tutor at Chalmers University of Technology, for his invaluable and constructive feedback and the guidance throughout the project. I am very grateful for the time and the expertise that have provided crucial input for the thesis. Also, I would like to express my gratitude to Michael Gegner, my supervisor at the company, who provided me with all the resources I needed and contributed with his knowledgeable insights to the outcome of the thesis.

I would also like to thank all the employees who were willing to share their experiences and knowledge in interviews and informal conversations. Without these contributions, it would not have been possible to realize the thesis project.

Robin Müller

Gothenburg, January 2018

Abstract

Digitalization becomes an increasingly important factor for organizations in order to realize potential process improvements that have an impact on efficiency, quality and flexibility. The study comprises the analysis of two use cases where the shift towards digital devices at the shop floor level is planned or has already taken place to eliminate paper-based processes. This thesis investigates how the adoption of the digital devices affects the information flow and the working processes.

The findings are based on a case study that was conducted at a car manufacturer where the digital solutions are implemented as a step towards highly flexible and reconfigurable factories. This development accommodates the customers´ demand for a high degree of customization. To assess the impact of digitizing processes on the information flow and the working processes, interviews were conducted with employees from different departments to get detailed information on the workflow. The outcome of the interviews was validated through field observations and informal field conversations. The findings were analyzed against the background of Organizational Information Processing Theory (OIPT), which emphasizes the need of a good fit between information processing requirements and information processing capability in order to achieve a good performance.

The data show that the shift towards paperless practices at shop floor level increases the information processing capability of the organization. The information flow and the working processes are streamlined by the implementation of digital devices. The implementation represents an important measure towards the goal of highly flexible factories that are needed to cope efficiently with the strategy of mass customization. However, the data also indicate that the processes that benefit from the paperless approach are not necessarily connected to increased information processing requirements. Various interrelated processes can be improved even if the performance in the paper-based environment does not exhibit an immediate misfit of the requirements and the capability.

Keywords: digitalization, paperless practices, electronic shelf label, Organizational Information Processing Theory (OIPT), mass customization

Table of contents

Table of figures

1 Introduction

In the following chapter the background of the thesis is presented, depicting the relevance of the topic. The purpose of the study is shown, which leads to the research questions that are supposed to be answered in the thesis and the limitations of the study are described. The introduction ends with a brief overview of the chapters that are comprised in the thesis.

1.1 Background

Digitalization has changed the way how industries have worked for decades prior to the implementation of digital technologies and will continue to do so at an accelerating pace (Zhou, 2013, Tihinen et al., 2016). Customers´ expectations have shifted over time as they demand customization of products to a very high degree and the industries have to adjust their processes to that because what was known as best practice years ago is already overaged and does not provide the companies with the most efficient processes anymore (Blecker & Friedrich, 2006).

There has been a trend towards mass customization with wide portfolios of different products that are offered by single companies and a great variety within specific product groups to cope with that demand (Blecker & Friedrich, 2006). In order to be able to provide that, companies have looked into possibilities to gain flexibility regarding the manufacturing processes and the concept of smart factories that incorporate a manufacturing system, which stands out in terms of flexibility and reconfiguration has gained much attention (Wang et al., 2015). These improvements however come at a cost of increased information processing requirements as it is presented by Trentin et al. (2012) who study the development of mass customization against the background of Organizational Information Processing Theory (OIPT). They state that the increasing demand for customization leads to a business environment that becomes more complex and dynamic and it comes along with a need for better operational performance resulting in a mismatch between the information processing requirements and the information processing capability of organizations. The concepts of information processing requirements, capability and the fit between them form the basis of OIPT (Galbraith, 1973), which is applied as the theoretical framework in the thesis.

The implementation of smart factories is largely based on a seamless connectivity that includes e.g. organizations, databases, sensors and devices that are used on the shop floor level (Harrison et al, 2016). In a report that was published by Capgemini (2017a), it is estimated that smart factories have the potential to nearly double the operating profit and margin of manufacturers in the automotive industry. It is stated that it is crucial for manufacturers to digitize processes that range from forecasting to the actual production in order to achieve higher efficiency and productivity in the factories (ibid).

Highly connected factories enable a paperless environment where the information that is needed for the manufacturing process can be provided in real time (Lee, 2015). Setting up smart factories is a process that takes time and that is still facing challenges but first steps towards the goal of implementing smart factories can be done by using the existent technology (Wang et al., 2015). Various technologies have led to an opportunity of creating a manufacturing environment where no paper is needed anymore to convey information (Mleczko, 2015). However, the shift away from paper-based processes comes along with considerable changes for the employees and their work. Updating information that is conveyed on paper involves process steps like printing, taking care that the paper reaches its destination and scanning the documents if they have to be archived. In the paperless environment, these steps are not needed anymore as the information is conveyed electronically. However, the new technologies have to be supervised so that a shift concerning the areas of responsibility can be expected in the course of the digitalization. Furthermore, the transparency of the processes will increase as more data will be available digitally, thus enhancing the possibility to analyze the performance (Parviainen et al., 2017).

The automotive industry is a prime example for the increased need of flexibility within the factories due to the high degree of customization and product variety that is asked by the customers (Khan & Haasis, 2016) and serves as the empirical context in this thesis. A case study at a leading car manufacturer is conducted in order to identify and assess possibilities and implications of establishing paperless practices on the shop floor level against the background of OIPT.

1.2 Purpose

The purpose of the thesis is to identify and assess use cases for implementing paperless practices on the shop floor level in the automotive industry. The assessment is done by looking into the information flow and the respective working processes that come along with this flow. The processes that are necessary to convey the information that is needed on the shop floor level will be compared for the paper-based approach and the paperless solution. This is done in order to get insights concerning the potential benefits that can be expected from implementing digital technologies. Transparency with regard to the current processes on the shop floor level is crucial to assess where and how paperless practices can contribute to a better performance. Characteristics of the process performance that are in the focus of this study are efficiency, flexibility and quality aspects, which are deemed to have a considerable potential of improvement. The goal is to evaluate how and to what extent the implementation of paperless solutions affects the processing of information and the respective work that is executed at the shop floor.

In addition to that, the thesis aims to analyze how the development of digitizing processes impacts the concepts of information processing requirements, capability and the fit between them. Thus, next to the rather practical implications presented above, the thesis also looks into the assumptions and approaches that form the basis of OIPT and how they might be affected by a shift towards paperless solutions.

RQ1: How are the information processing and the respective workflow on the shop floor level affected by the implementation of paperless practices in terms of process performance with emphasis on the efficiency, flexibility and quality aspects?

RQ2: How does a shift towards digital solutions on the shop floor level impact the concepts of information processing requirements, information processing capability and the fit between them with regard to the information flow and the working processes that are executed?

1.3 Delimitations

Subject of the thesis is the implementation of paperless practices on the shop floor level so that no other use cases within the company or across different organizations are considered. The study is conducted solely at one site of an automotive manufacturer that served as the case company. The thesis focuses on impacts of paperless solutions on the working processes and the information flow and it does not comprise insights about the detailed implementation of the devices that are needed for digitizing the processes. As the case study is only conducted at one site in Germany, the applicability of the results may differ considering that the ease of implementing new technologies and the working culture vary across countries.

1.4 Outline of the thesis

The second chapter provides context information to create a better understanding why the implementation of paperless practices is a relevant topic to research and what are current issues that are related to it. The chapter starts with an introduction to digitalization. The adaption of digital technologies is an important aspect for realizing the goal of smart factories. After the concept of smart factories is presented, the chapter ends with an introduction to the implementation of paperless practices in manufacturing companies.

The third chapter contains the theoretical background of the study. The OIPT is presented as it will be used for analyzing and interpreting the gathered data and to derive results from the findings that were made at the case company. The theory is based on the assumption that companies have the need and the ability to process information in order to reduce uncertainty and that a good fit is necessary in order to achieve a good performance.

In the fourth chapter of the thesis, the methodology is presented. It is described what data is used in the study and which approaches were applied to gather the data. The methodology chapter provides information about the research process in order to make the results comprehensible and reproducible for other researchers.

In the fifth chapter, the empirical findings that have been collected at the case company are presented. The chapter comprises two use cases where paperless practices have been implemented or where an implementation is planned. The first use case copes with the implementation of tablets to display work instructions for employees at the assembly line and to provide a digital solution for the process of stamping relevant working steps and reporting errors at the assembly line. The second use case deals with the possibility of adopting electronic shelf labels at the shop floor level.

The sixth chapter contains the analysis and the discussion of the gathered data. One focus of the analysis is how the information flow and the resulting work processes are affected by the shift towards paperless practices. It is analyzed what the impacts are regarding aspects like quality, efficiency and flexibility within the factory. Furthermore, the analysis copes with the question how the implementation of digital solutions affects the concepts of information processing requirements, information processing capability and the fit between them.

The thesis ends with the conclusions in chapter seven where the most important findings are summarized.

2 Contextual information

In the following chapter, contextual information is given to enhance the understanding of the concept of paperless solutions on the shop floor level and the respective implications. To achieve this, the trend of digitalization is presented that serves as an enabler for companies to realize the goal of establishing smart factories. The smart factories in turn are realized by implementing highly automatically operating machines that do not require any interaction with humans and a high connectivity by generating and distributing all the data that is needed for the manufacturing process to the according recipient (Lee, 2015; Wang et al., 2016). This development of creating a highly connected environment in the factories enables the manufacturing process to become paperless as the data will be available and displayable digitally. As the path towards smart factories has to be undertaken gradually, one step is to look into possibilities of establishing paperless practices, which is done in this study. This context is depicted in Figure 1 and will be further elaborated subsequently.

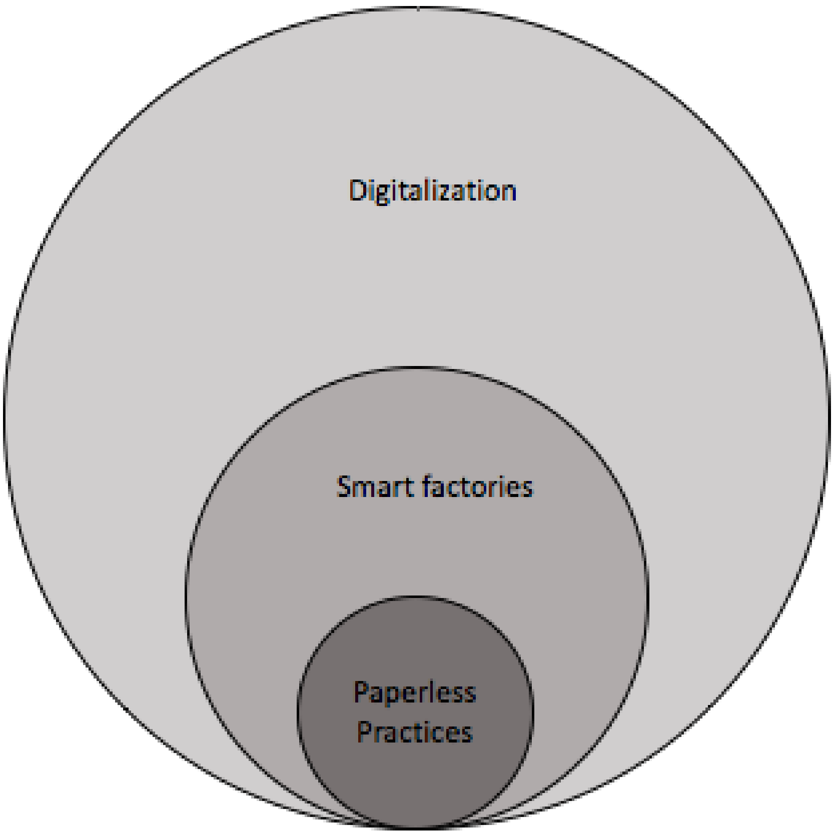

Figure 1: Paperless practices in the context of smart factories and digitalization

2.1 Digitalization

Digitalization can be described as the process of the implementation or the increased usage of digital technologies in organizations, countries or other entities (Brennen, Kreiss, 2014). The manufacturing industry faces radical changes due to the transition towards digitized processes that are enabled by the internet, internet of things, cloud-computing, big data and other trends (Zhou, 2013). These changes take place in several dimensions including the process level, the organizational level, the business domain level and the society level (Parviainen et al., 2017). The focus of the thesis will be on the process level that describes the adoption of digital technologies in order to achieve a better performance of the processes that require less or no human interaction at all. The society level, that includes the changing working conditions for the employees, will be considered in the discussion but it is not the main concern of this study. The organization level and the business domain level are not relevant for the thesis as it will be looked into possibilities to implement paperless practices on the shop floor level. It is not the scope of the thesis to look into new service models that arise in the course of digitalization and changing roles of companies and industries.

The process level focuses on the improvement of the internal efficiency by eliminating manual steps and thus increasing the efficiency, quality and consistency of the processes (Parviainen et al., 2017). Digitalization is seen as the key issue for companies to realize internal efficiencies and its importance will only enhance in the future, which makes it crucial for businesses to be proactive and look for possible use cases among their processes along the entire value chain (Bogner et al., 2016). Not doing so will give competitors a head start in this area, which can lead to severe consequences for the future position and development of a company (Parviainen et al., 2017). To exploit the potential that comes along with the digitalization, companies should not only transform existing processes into digitized copies but they should assess possible improvements that can be realized by implementing digital solutions (Bogner et al., 2016). Great potential is manifested in advances that include both the manufacturing processes and the respective planning and management referring of them (Zhou, 2013).

According to a report that was published by Capgemini (2017b), the actual implementation of digital technologies is still a considerable challenge for the companies. It is stated that 75 per cent of CIOs indicated in a survey that they had the assignment to strengthen the digitalization within the company. However, the CIOs often complained about inadequate frame conditions.

The scarcity of employees with knowledge in the areas of internet-of-things and big data was reported to be problematic as well as stiff structures within the organizations that make it difficult to introduce innovative technologies that have a great impact on existing processes and working routines. In addition to that, the CIOs experienced a lack of cross-functional planning and clear distribution of responsibilities. Another point that is highlighted in the report is the IT infrastructure that has come into the focus again since the digitalization sets new requirements for the infrastructure in terms of capacity and flexibility.

Parviainen et al. (2017) present a model that is supposed to help practitioners to cope with the digital transformation. They say that the first step is to assess the potential impact of digitalization on the business and the role the company desires for itself in this context. The second step is to evaluate the current state against the background of the desired future position in order to determine the gap and the need for action. In the third step, the organization develops a plan how to close the gap by formulating concrete activities that are necessary and the fourth step includes the implementation and validation of the designed activities.

2.2 Smart factory

The basis for establishing smart factories is the application of technological advances like the internet of things and smart analytics technologies to enhance the quality, performance and transparency of the processes in the factories (Lee, 2015). The goal of a fully connected environment can only be achieved by enabling the corresponding devices and machines with web technologies (Harrison et al., 2016). The needed connectivity within the factory comprises aspects like databases, software environments, shop floor level devices, sensors and people (ibid). In the smart factory, all the data is available digitally and through analytics technologies it is possible to organize the data and assess which data is relevant for certain devices and machines in order to fulfill the task (Lee, 2015). This enables the company to create a paperless environment where information is processed and provided in real time (ibid). Achieving a seamless connectivity in the factory is not a goal in itself but it is essential in order to realize highly flexible and reconfigurable factories, which in turn are needed to cope with the demand of high customization (Wang et al., 2016).

Key advantages of smart factories are, that it will be possible to produce various types of products using the same machines and that also the introduction of new products can be realized with less efforts compared to the practices in current factories (Wang et al., 2016). If there is a need for new machines, they can be established in the processes easily and thus the company will be able to respond to changing market demands in a quick and efficient way (ibid). According to a report that was published by Capgemini (2017a), it is estimated that the implementation of smart factories has the potential to almost double the operating profit for an average automotive manufacturer. In line with other researchers, they expect considerable improvements in efficiency, productivity and labor cost. It is reported that manufacturers in different industries have already started to take advantage of the potential of smart factories evidenced by improved productivity and quality.

The digitalization and the development of smart factories will have a deep impact both on the industries and on the lifestyle and the work that will be done by the employees in the factories. Routine processes on the shop floor level will be done automatically by machines so that no workers will have to be involved in these working steps anymore (Wang et al., 2016). In spite of technical challenges that still remain regarding the establishment of smart factories, companies strive to apply existing technologies and look into future developments that can be included in the factories (ibid).

2.3 Paperless Practices

As the broad trend of digitalization and the implementation of smart factories as an industrial application of digital and smart technologies have been briefly presented above, there is some contextual information on paperless practices in the following. The transformation of current factories towards smart factories is a gradual process but existing technologies already make it feasible for companies to detect processes that can be shifted from paper-based to paperless solutions in an affordable way (Weber, 2007). The developments of various technologies are the enablers of an infrastructure where paperless processes can be realized as a starting point towards smart factories (Mleczko, 2015).

The potential benefits of a shift towards paperless practices have already been discussed in the 1990s with the aerospace industry is a prime example of an early adopter of paperless approaches on the shop floor level as they expected considerable cost savings and better performance in areas like quality and customer satisfaction (Aldred, 1998). They realized that a lot of time was needed to gather all the documents that were necessary for the workers´ handling of the manufacturing processes. Tablets could be used to give clearer instructions by using photos, mechanical drawings and different colors without any additional effort and thus improving and facilitating the manufacturing process for the employees (Aldred, 1998; Forrester, 1999). At the same time, the use of tablets increased the efficiency in terms of providing the work instructions and always keeping them updated (Aldred, 1998). Typically, the manufacturing documentation, including work instructions, was available digitally before being printed on paper so the goal was to avoid the step of conveying the information on paper and directly communicate it electronically to the respective device (Forrester, 1999).

Even though the use case of digital work instructions might not be the optimal solution for all processes on the shop floor, many manufacturers see that they can realize a positive return on investment by reducing the handling of paper and accomplishing a faster information flow (Weber, 2007). Using paper as a conveyor of information slows down the process as the paper needs to be printed and has to travel to its destination whereas digitized solutions can show the data that is needed immediately without prior processing (Mleczko, 2015). In addition to the described process improvements that can be realized by the implementation of paperless practices, handling the data in a digitized way also enables companies to automatically gather data that can be valuable to get a deeper understanding of the performance and the cost drivers of the processes (Parviainen et al., 2017).

3 Theoretical Framework

The findings of the case study are analyzed against the background of OIPT. The theory describes organizations as systems that have both a need to process information and the ability to do so in order to reduce uncertainty (Galbraith, 1974). Information processing includes the collection of data, interpreting it and synthesize the gained information (Tushman & Nadler, 1978). There is a difference between data and information as "information refers to data which are relevant, accurate, timely and concise" (Tushman & Nadler, 1978, p. 614). Information leads to increased knowledge while data does not necessarily have that impact, thus data does not always account for information (ibid). Information processing can be described as the transformation of relevant data into information, which is then stored and distributed to the respective recipient in the organization (Egelhoff, 1991).

The three main concepts of OIPT are the information processing requirements of an organization, the information processing capability and the fit between them that affects the organization´s handling of uncertainties and the resulting performance of the processes (Galbraith, 1973). The information processing requirements represent the information that is needed by the organizations to cope with uncertainties (Tushman & Nadler, 1978). The greater the uncertainty of a task, the greater is the requirement for information that is processed during the task execution since it cannot be planned in advance sufficiently (Galbraith, 1974). Uncertainties can result from different factors including environmental dynamism, task interdependence and task complexity (Tushman & Nadler, 1978; Gattiker, 2007). Information processing capability comprises the ability to gather, interpret and disseminate the information in order to be able to deal with the different shapes of uncertainty (Tushman & Nadler, 1978). Achieving a good fit between the information processing requirement and capability is important for an organization in terms of realizing potential process improvements (Galbraith, 1977).

OIPT is a useful approach to gain insights regarding the organization´s handling of information to improve their performance (Galbraith, 1973). It provides a basis for assessing the benefits that come along with a coordinated collection and distribution of information (Hsu et al, 2016). Organizations can improve their handling of uncertainty by reducing their information processing need or by enhancing their ability to process information in order to achieve a better fit between those two components (Hsu et al., 2012). In the following, the concept of uncertainty, the resulting information processing requirements, the information processing capability and the respective fit are presented in more detail.

3.1 Uncertainty

Generally speaking, uncertainty can be defined as a state where only limited knowledge is present that does not allow to precisely predict future developments and outcomes (Hubbard, 2014). OIPT characterizes uncertainty as a disparity of information that is available to an organization and the information that is needed for the completion of tasks and processes (Downey & Slocum, 1975). In the literature that deals with information processing theory, various sources and shapes of uncertainty have been presented and discussed. Two important aspects that were identified with regard to uncertainty are complexity and dynamism (Duncan, 1972). Complexity includes the number of factors that are included in a task and how they are connected with regard to the process of decision making while dynamism accounts for the frequency of changes of those factors and the possibility to plan for these changes in advance (Premkumar et al., 2005). Tushman and Nadler (1978) define three sources of uncertainty that the subunits of an organization face when completing their tasks, which are the task characteristics, the task environment and the task interdependence. Figure 2 illustrates these aspects that form the basis for the framework that is considered in the thesis in the context of uncertainty.

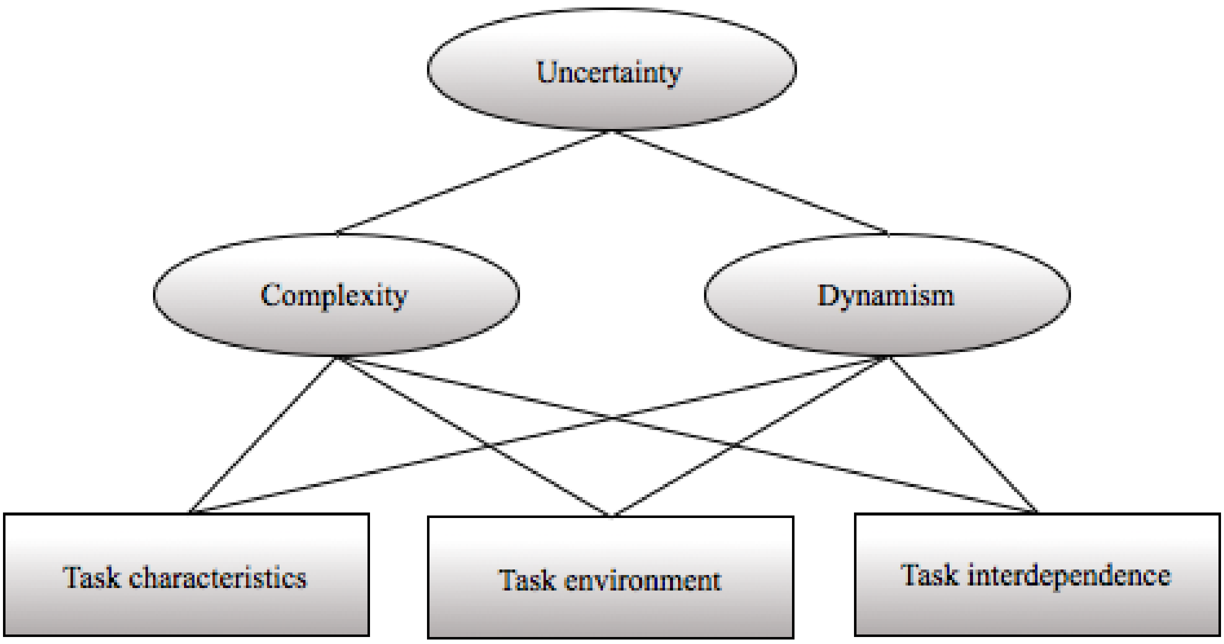

Figure 2: Interrelated aspects influencing uncertainty

Task characteristics include both task complexity and the interdependence within the subunit as sources of uncertainty (Comstock & Scott, 1977). As tasks differ regarding their predictability, the uncertainty that the units face also deviates accordingly (Galbraith, 1974). Routine tasks that do not underlie significant changes and that do not require a high level of interdependence within the unit can be planned well in advance, thus accounting for a minimal uncertainty concerning the task and the information that has to be processed (Tushman & Nadler, 1978). Accordingly, tasks that come along with an extensive need for interdependence or that are complex and can hardly be predicted lead to a high degree of uncertainty (ibid).

The task environment affects the uncertainty since it can be assumed that the units are not in control of the events in the environment outside their organization that have an impact on the tasks (Tushman & Nadler, 1978). Considering the task environment, the dynamic dimension is of great importance since a dynamic environment that is prone to frequent changes leads to a high level of uncertainty (Duncan, 1972). When the units operate in a stable environment, it is easier to establish routines that do not have to be adjusted frequently due to changing environmental conditions (Tushman & Nadler, 1978). However, such routines do not lead to efficient processes and a good performance if the units are facing an unstable environment (ibid).

The third source of uncertainty is the task interdependence. It describes the existing dependencies among different units that have to collaborate to fulfill a task (Tushman & Nadler, 1978). The greater the task interdependence, the more information has to be processed between the involved units in order to achieve an efficient performance (ibid). A high degree of interdependence comes along with a greater task complexity that has to be managed to perform the task successfully leading to an increased uncertainty (Melville & Ramirez, 2008).

To cope with the presented sources of uncertainties that depict the dynamic and complex character of tasks and processes in organizations, information processing is a major aspect that is considered to enhance decision-making processes (Cegielski et al., 2012). Trentin et al. (2012) state that the ongoing trend towards mass customization tends to leave the organizations with higher task uncertainty, which underlines the importance of effective approaches for processing information within and between units and organizations.

3.2 Information processing requirements

The information processing requirements that arise to perform tasks efficiently are connected to the uncertainty that the units face since the greater the uncertainty is, the greater are also the information processing requirements (Tushman & Nadler, 1978). When tasks are prone to uncertainty, routine tasks that were preplanned have to be complemented with processes for the handling of exceptions that strain the hierarchy (Galbraith, 1974). The information processing requirements have to be met in order to prevent the hierarchy from becoming overloaded, which would result in a poor performance (ibid). An increasingly dynamic environment makes it a necessity for organizations to cope with new requirements as the information that were gained through prior experiences and assessments cannot be assumed to be reliable and constant information in a dynamic environment (Galbraith, 1977).

The demand for highly customized products has an impact on the requirements for both mass producers and custom manufacturers (Trentin et al., 2012). For a custom manufacturer, a shift towards mass customization leads to an increased need of information exchange between the different departments of the organization to make sure that the demanded products can be manufactured and delivered on time (Salvador & Forza, 2004; Chen & Tseng, 2010). A mass producer who want to adapt the strategy of mass customization will encounter changing information processing requirements as well due to an increased degree of environmental complexity and dynamism that is relevant for the manufacturing activities (Trentin et al., 2012). The company will have to offer a larger variety of products, which in turn leads to an increased amount of information about each variant that has to be processed, stored, updated and communicated within and across the organization (Flynn & Flynn, 1999).

In the past, a common approach chosen by manufacturing companies to cope with uncertainty and thus, to account for the information processing requirements, was to reduce the need for information processing by using slack resources (Rosado Feger, 2014). However, this is a costly strategy if there is a high level of uncertainty involved in the tasks because the greater the uncertainty, the greater is also the extent of additional inventory, and buffers regarding lead time and budget that is needed (Galbraith, 1974). Holding additional inventory ties capital that could be used for other investments otherwise, increasing the budget leaves the company with less profit and buffers in the lead time might lead to delayed deliveries to the customers, resulting in an overall lower performance of the organization (ibid). Another approach to minimize the information processing requirements is the establishment of smaller working groups that work more autonomously to provide a certain output, which decreases the need for information processing when exceptions occur (ibid). The described approaches to cope with the information processing requirements lead in the first case to an inferior performance and in the second case to a new distribution of the labor, which are consequences that may not be acceptable for an organization.

3.3 Information processing capability

Information processing capability can be described as an organization´s ability to gather and distribute relevant information to the respective recipients in order to deal with both external and internal sources of uncertainty (Tushman, Nadler, 1978). According to OIPT, the capability of an organization must lead to information processing mechanisms that are tailored for the respective context to achieve an effective handling of the data (Galbraith, 1974; Tushman & Nadler, 1978). The capability is generated through both organizational and technological resources that need to be combined adequately considering the necessary information for the respective decisions that have to be made in order to perform the task (Kowalczyk & Buxmann, 2014). The shift towards highly dynamic business environments has made it a crucial task for organizations to establish new approaches for processing more information with IT as a key enabler for such a development (Melville & Ramirez, 2008).

IT-based information processing leads to the transmission of more accurate information since it can be collected and distributed in real time resulting in a better communication and cooperation both between organizations and within an organization between different units (Bharadwaj et al., 1999). Especially tasks that exhibit a high level of interdependence have a great potential of improvement if the data is processed electronically (Gattiker & Goodhue, 2005). In general, IT is seen as a crucial enabler of operational agility, which is characterized by an efficient communication that enhances the decision-making processes (Sambamurthy et al., 2003). Operational agility is an important quality of organizations to cope with uncertainties and the necessary flexibility can be achieved through the quick communication of the relevant information (Mithas et al., 2011). The enhanced information processing capability by implementing IT-based systems also has a considerable effect on an organization´s ability to handle the demand of mass customization (Trentin et al., 2012). Information systems that are set up adequately to support the operations of a company can be an essential enabler to exploit the existing capacities to manufacture a rising numbers of variants and avoid slack resources (Steger-Jensen & Svensson, 2004; Dean et al., 2009) that were mentioned above as a mean to reduce information processing requirements.

Mithas et al. (2011) emphasize that it might not be sufficient for organizations to set up an extensive IT infrastructure, which facilitates to gain the needed IT capability, but that companies have to put effort into leveraging their IT capabilities to exploit the potentials in terms of information processing. They refer to this leveraging as information management capability, which they define in line with Marchand et al. (2000) as the ability to provide accurate and reliable data on time that is processed through a highly connected environment and an infrastructure that is tailored for the respective business needs. This definition is conform to the commonly applied definition of information processing capability that is also used in the thesis. Achieving a high level of information management capability enables organizations to enhance the transparency of various processes and their impact on the performance (Kalakota & Robinson, 2003). This transparency is also beneficial in terms of acting responsively to changing business conditions or environmental uncertainties that might require a reconfiguration of the manufacturing processes (Mithas et al., 2011).

3.4 Fit between requirements and capability

A good fit between information processing requirements and the information processing capability is crucial for organizations to reduce uncertainties, which is typically achieved by decreasing the requirements e.g. by generating buffers or alternatively by enhancing the capability of processing information e.g. through the implementation of computer-based information systems (Premkumar et al., 2005). Venkatraman (1989) presents in his study various characteristics of different perspectives of fit. Among his taxonomy, fit as matching is an appropriate perspective for the thesis since it is described as the fit between two variables that are independent of a fixed reference point, which is the case when the fit between information processing requirements and capability is examined.

The concept of fit is an essential component of OIPT (Premkumar et al., 2005) and it is presented in Figure 3 to depict the interrelation of information processing requirements and capability against the background of the performance of a company. Organizations need to strive for a good fit to optimize their performance since misfit leads to an opposing development (Galbraith, 1977). To cope with an existing misfit, organizations ought to adapt the internal processes even if the uncertainty emanates from the business environment since the internal processes are easier to influence than environmental conditions (Sousa & Voss, 2008). According to this, a promising approach to achieve fit is to invest in appropriate information systems that allow organizations to match the information capability with the requirements (Busse et al., 2017). It can be distinguished between use cases of high and low uncertainty. Whereas it may be sufficient to establish rules and hierarchical support for processes that are connected to low uncertainty, tasks with high uncertainty require means like e.g. the implementation of advanced information systems, establishing more autonomously working units or the adoption of slack resources (Galbraith, 1974, 1977).

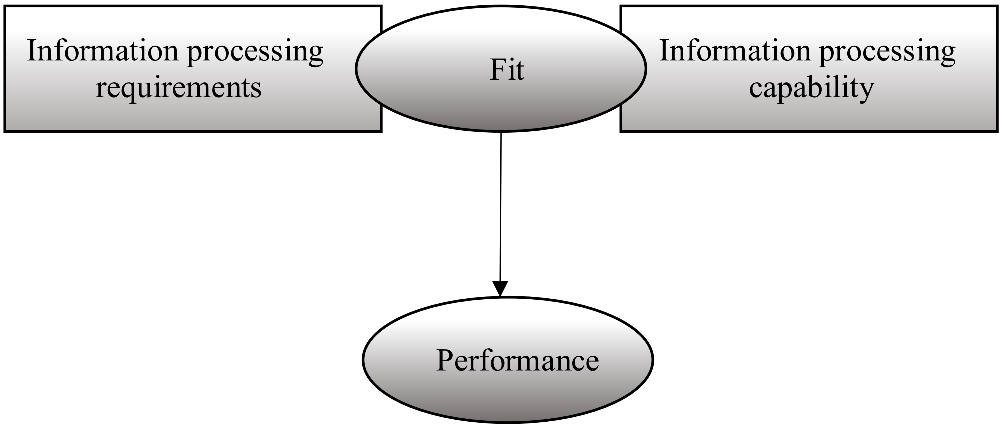

Figure 3: The concept of fit against the background of OIPT

If organizations decide to follow the development of mass customization, it is common that a mismatch between information processing requirements and capability arises due to a higher level of operational performance that is needed and a business environment that becomes more complex and dynamic (Trentin et al., 2012). As it has already been presented above, establishing slack resources comes at a high cost in terms of firm performance and the redesign of units to achieve higher degrees of autonomy is an elaborate and costly task on the shop floor level of a manufacturing company. That is why the thesis focuses on the possibility to implement paperless practices by utilizing computer-based information systems. It is analyzed how the information flow and the respective working processes are affected by the digitized solutions and how this has an impact on the handling of uncertainties that afflicted to the tasks.

4 Methodology

In the following chapter, the methodology that has been applied for the thesis is presented. It is described, what research design has been chosen and what methods have been used in order to generate and evaluate the data. Finally, the implications of the methodology that is used in terms of reliability and validity of the results are discussed.

4.1 Research design

The research design that is applied in the thesis is a descriptive approach used in a single case study at an automotive manufacturer. To answer the research questions, it was important to gather detailed information on the processes at the shop floor level and how these are affected by implementing paperless practices. Thus, a single case study was an appropriate approach as it enabled a deep understanding of the studied subject in a certain setting. Based on these results, it can be assessed to what extent the conclusions drawn from the case study apply to other settings and their respective circumstances.

In the course of the thesis, both findings from the literature of other researchers and the gathered data were used and reviewed from the beginning and matched to one another. Applying this approach, the literature reviews showed findings of former studies that were considered when gathering the data at the case company in order to get insight whether findings from academia were in line with the data from the case company. Examples for this practice include challenges when implementing digital technologies that were found by other researchers, that were discussed in interviews and the expected or already realized improvements by implementing paperless practices.

4.2 Research method

The research method describes the tools that were applied to generate the data that was used to answer the research questions. In the thesis, most of the data that was gathered at the case company was qualitative in nature. It was collected through semi-structured interviews, field observations and informal field conversations. For one of the use cases that is part of the thesis, next to the qualitative data, quantitative data was imposed as well.

4.2.1 Literature review

As a starting point of the thesis, literature was reviewed that gave insight about studies of other researchers with regard to the transition towards digital technologies in an industrial context. As the information processing and the workflow are the main topics of interest against the background of implementing paperless practices, keywords like "digitalization", "smart factory", "paperless factory", "technology adoption", "information processing" and "organizational information processing theory" were searched in the Chalmers Library Database and statista. While the Chalmers Library Database includes numerous online libraries and databases for academic literature, statista is an online portal that encompasses data that has been imposed by market research institutions and economic reports.

By reading the abstract, it was assessed whether the paper had the potential to contribute to the thesis or whether the authors had different objectives with their paper that were not relevant for this study. The papers that were found valuable for the thesis were studied in detail and references of these papers provided further input for a well-founded theoretical background. The theories, approaches and results of other researchers served as guidelines to assess what data needs to be collected at the company. Thus, the literature review was an important input for the interviews as it contributed to the set of questions and topics that were discussed with the respective interviewees.

4.2.2 Interviews

Interviews were conducted with employees from different departments of the case company who were either involved in planning the implementation of paperless practices or whose tasks were affected by it. The initial contact to the first employees that were interviewed was established due to recommendations of the supervisor at the case company and then the interviewees provided other contacts with relevant areas of responsibility. In addition to the recommendations given by the employees, interviewees were also found by searching the intranet of the company for employees who had "Paperless Factory" listed as one of their responsibilities. This was done in order to get a deep understanding of the considerations that were made prior to the implementation of digital technologies and how the processes on the shop floor level changed by the shift towards paperless solutions and what the target state looked like.

The data was collected through semi-structured interviews, where a set of questions and topics were prepared in advance. The interviews were carried out in person if it was possible or by a phone call if the interviewee was not available for a personal meeting. For all interviews notes were taken and discussed with the interviewees afterwards to make sure that a mutual understanding of the statements and their implications was given. If the interviewee agreed to it, the interview was also recorded, which decreased the risk of losing any detail. The semi-structured nature of the interviews made it possible to keep a flexible development of the discussion by only setting the frame conditions with the topics and questions asked. This was valuable as in the course of the interviews aspects like additional use cases for the digital approaches arose that were followed up in the project.

The questions and the topics that were discussed, differed in some parts as the interviewees had different backgrounds in the company and thus they also had different expertise, and experiences they could share. The set of questions that were used in the interviews is enclosed in the Appendix 1. The areas of responsibility of the concerned employees ranged from innovations management and standardization to the planning of assembly processes, IT and the actual operations on the shop floor level. This diversity made it possible to get a holistic picture of the viewpoints and experiences of different actors that are involved in the process of planning and implementing paperless practices and it reduced the risk of compiling biased results. When it was possible, e.g. for the descriptions of the processes at the shop floor and how they are affected by paperless solutions, the statements that were made in the interviews were validated by field observations. These field observations were combined with informal field conversations as well, which were held throughout the period of the project.

4.2.3 Quantitative data

In addition to the collection of qualitative data, which has been described above, quantitative data has also been considered to a small extent. As one of the use cases was the implementation of electronic shelf labels, the efforts made for changing the shelf labels when the information on them has to be updated, was of interest. There was no documentation of how many times the shelf labels were changed and interviews with the employees who are responsible for the task could not provide the needed information. That is why in this case the data was gathered through the company´s ERP system. The analysis of the data was done in close collaboration with employees who were involved in the process of changing the shelf labels. That was necessary since the data was used to give a well-founded estimation on the effort that is made in the plants to keep the shelf labels updated.

4.3 Discussion of Methodology

In the following, the methodology that was applied for the thesis is discussed. It is assessed whether and why the methodology was appropriate to answer the research questions and where possible weak spots are.

Conducting a single case study allowed the author to acquire a deep understanding of the relevant processes for the use cases of implementing paperless practices on the shop floor level. Although this approach gave valuable insight in terms of understanding the changing processes and challenges that come along with them, it has to be considered that the results from a single case study mainly based on qualitative data might lack reliability. Using qualitative data to a great extent makes it difficult to replicate the study expecting to get the exact same results.

The internal validity of the results was taken into consideration as employees from various backgrounds have been interviewed so that it can be assumed that the results are not prone to biased viewpoints of a certain group or department within the company. Furthermore, the results from the interviews were verified by field observations and conversations with other actors involved in the processes when possible. This decreased the risk of gathering data that does not reflect the reality, which would lead to results that are not in line with the actual processes at the case company. With regard to the external validity, it has to be considered, that a single case study always represents a certain set of processes and a business culture that might differ from other companies, making it hard to generalize the findings. However, it is possible to draw conclusions from the study even if other settings are of interest since the transparency concerning the investigated processes is given. This enables the reader to assess to what extent the results of the study might be applicable for his case.

5 Case Findings

The case study was conducted at an automotive manufacturer and it is concerned with the implementation of paperless practices at shop floor level. The presented results were mainly detected through interviews with employees from the departments of IT, planning and operations. In addition to that, field observations and informal field conversations provided an important input for the findings.

According to the interviewees of the planning department and IT, the goal of implementing digital technologies on the shop floor level is to achieve an increased connectivity between devices and applications and leveraging the possibility to connect machines in order to improve the manufacturing processes. Manual processes are supposed to be reduced or abolished, especially for the purpose of documenting and conveying information. These measures are expected to have a considerable effect on both the quality, the efficiency and the flexibility of the processes. The case study comprises two use cases where paperless solutions are planned to be implemented or where they already have been established as a pilot.

5.1 Shift towards digitizing assembly processes

The first use case that is considered deals with the shift from paper-based working instructions and stamping processes at the assembly line to tablets or stationary monitors at the working stations. These tablets and monitors contain the instructions for the manufacturing process and serve as a mean for digital stamping and error tracking. The goal of this shift towards a paperless approach is an enhanced data transfer within the organization that is achieved by seamlessly connecting the backend information systems with the devices at shop floor level. That is expected to lead to an improved information flow that comes along with more transparency and an enhanced process performance.

5.1.1 The paper-based approach

In the paper-based process, the work instructions are printed and mounted on the bonnets. The information for the instructions come from the production planning system where the order of the cars that are manufactured is determined. In the production planning system, the characteristics of the cars are specified so that the respective instructions for the assembly process can be derived from it. The employees who are responsible for adapting the assembly instructions if changes occur stated, that the applied software for handling these changes is outdated and has not been changed significantly over time. The employees have to type in every character separately if changes have to be integrated as it is not possible to copy or shift the characters.

Changes of the instructions can occur e.g. due to repositioning of the shelves that can cause a change of the order of the working stations and thus the order of the tasks that have to be executed. If the employees who are responsible for planning the assembly processes report that there is supposed to be a change concerning the order of the working stations at the assembly line, the working instructions have to be adapted accordingly. To cope efficiently with the demanded changes, the requirements from the planning department are collected and the respective work instructions are prepared over the course of one week. Once a week the planned changes at the assembly line can be realized and the updated working instructions are activated, which means that the updated information is printed on the instructions from that moment on. The process is handled this way because when an employee who is adjusting the work instructions activates these changes, all the changes that are currently worked on, including the ones that other colleagues are working on, are activated. Thus, a date was set once a week when the employees agree to have finished all the changes that were demanded so that these changes are activated consolidated and the arrangements at the assembly line can be done accordingly. Other cases that require an adjustment of the working instructions are e.g. the adoption of new material in the assembly processes or the introduction of new models or variants.

The working instructions that are mounted on the bonnets comprise the information, which parts have to be assembled at the respective working stations. Due to the high number of working stations, only a minimal amount of information can be displayed for each station. Therefore, abbreviations are used and it is required that the employees at the assembly line derive the necessary working steps from the abbreviations and general information that is given e.g. that the car is powered with Diesel. On every paper that contains work instructions, the unique production number of the respective car is written as a mean of distinct identification so that the instructions can be related to the cars at all times.

If an employee encounters a problem while assembling the parts, it can be caused by a number of factors, e.g. missing material that was not supplied to his working station, faulty parts and material than cannot be assembled, problems with the tools or an insufficient assembling pace of the employee. If such a problem occurs, the employees who work at the assembly line have the possibility to pull a cord. By doing so, a supporting employee gets a signal that his colleague encountered a problem and he goes to the respective working station to find out what caused the problem and how it can be fixed without delaying the following processes.

For critical working steps that are e.g. safety relevant for the customers like the work that is done to assemble the brake system, the employees have to stamp a piece of paper (not the working instruction) that travels with the car that is assembled through the plant. On the paper, the working steps that have to be stamped are listed. Every employee has his own stamp so that it can be identified who did the working steps. At the quality gate, an employee monitors whether all the required working steps are stamped. If that is not the case, it is communicated to the respective employee who was in charge of the working step where the stamp is missing to find out what has caused the error. When all the relevant working steps have been stamped, the paper is scanned and archived both digitally and as a hardcopy form.

The presented practices at the assembly line depict the processes that take place in a paper-based environment. The processes include providing the employees at the assembly line with the working instructions, performing the stamping process for the relevant working steps and reporting and fixing problems that the employees encounter during their tasks. The following chapter provides insight on how these processes can be handled when a paperless approach is realized.

5.1.2 The paperless solution

The shift from the paper-based processes at the assembly line towards a paperless environment is realized by implementing tablets at the working stations. The information that is displayed on the tablets to provide the employees with the instructions originates from the production planning system as it is the case for the paper-based process. However, a different software is used to adjust the work instructions if changes are demanded by the employees who are planning the assembly processes. With the software, changes can be adapted easier compared to the work instructions that are printed on paper and the design that is displayed on the tablets can be chosen from several templates. The instructions can be adjusted for each tablet separately so that there is no need to schedule a fixed date when all changes have to be processed so that they can be activated consolidated.

Since the tablet only displays the instructions for the respective work station, there is more space to provide the employees with clearer instructions and illustrate them with pictures or colors if it is desired. In addition to that, besides the car that is currently assembled at the working station, the employees can also see the instructions for the following cars by scrolling on the touch-sensitive tablet. By looking at the instructions of the next car, the employee can already prepare the working steps and the material that is needed so that he can use his time more efficiently. If he is done with one car, he does not have to wait for the next car to read the work instructions mounted on the bonnet, but he can already see the instructions on the tablet whenever he needs them.

If there is no interaction on the part of the employee at the assembly line, the tablet always shows the work instructions for the car that is located at the working station. That is realized through a localization of both the cars and the tablets. The tablets are either attached on mobile carts or they are mounted at a fixed place if the employees at the working stations do not operate with a mobile cart that carries the material. If a mobile cart is used, the employees place the material that is needed for their working steps on the cart and then they position it next to the car. Independent of the place where the tablet is mounted, the tablet shows the work instructions for the respective work station and the car that is located in a certain range of this work station. Thus, if a mobile cart with the material is moved from one car to another, the work instructions on the tablet will change accordingly and if the tablet is mounted at a fixed place, the work instructions will change as the cars move forward on the assembly line.

Besides showing the work instructions, the tablets can also serve as a surface for stamping the relevant working steps and reporting problems that might occur at the work stations. Instead of stamping a piece of paper that travels with the respective car through the plant, the stamping process can take place by touching a field on the tablet and it can be saved and archived automatically without further processes. In order to be able to retrace who stamped the working step, the employees register on the tablet at their work station when the shift starts. If a relevant working step is not stamped but the car is moving to the next work station, the employee at the quality gate will be notified on a display so that he can contact the responsible worker and clarify why the stamp is missing and how this error can be fixed in the most efficient way. Analogous the employee who is responsible for supporting the workers at the assembly line is notified if problems occur. Instead of pulling a cord, the workers have the opportunity to choose on the tablet between several reasons why they need support. Thus, the supporting employee already receives a rough indication what causes the problem and what might be needed in order to fix it. Furthermore, this process makes it possible to keep track of the problems that occur at the assembly line without an additional effort of documenting them.

The tablets are powered with rechargeable batteries that are charged after each shift so if there are two working shifts per day, there are two sets of batteries and the employees are responsible for charging them when the shift ends so that they have a fully charged battery for the tablet when their next shift starts. The information is transmitted over wireless LAN using the frequency of 2,4 GHz.

5.2 Implementing electronic shelf labels

The second use case that is considered in the thesis is the implementation of electronic shelf labels (ESL) instead of the commonly used paper-based shelf labels. The motivation for this approach has mainly been derived from a high frequency of changing locations of the shelves along the assembly line and changing storing positions of the material within the shelves. These changes come along with the requirement to adjust the shelf labels so that the employee, who is supplying the shelves with the material, is provided with the correct information on the label. In addition to changing locations and storing positions, information like the number of carriers in the shelf and the building where the material is stored can change and require an update of the shelf label. For the site where the case study took place it was calculated that over the course of one year, on average more than 2200 shelf labels had to be updated in the manufacturing plants every month. This number shows the potential of avoiding manual working steps for updating the shelf labels by implementing ESLs.

Next to the process improvements that can be realized by ESLs when updated shelf labels are needed, another use case of ESLs is to support the employees regarding the processes of picking and supplying the shelves with material. The support can be provided by including an LED in the design of the ESL that flashes when the respective material has to be picked or supplied. A constant information flow between the ESLs and both the Enterprise Resource Planning (ERP) system and the production planning system can enable such a process. The ESLs receive the information regarding the material that has to be picked or supplied and they can display it by flashing the LED accordingly. However, this feature is not subject of the following comparison between the processes that take place in a paper-based environment and the paperless approach.

This is due to the circumstance that it depicts an additional use that can be derived from the implementation of ESLs but it does not affect any processes that occur in the paper-based setting. Thus, the comparison is solely done with regard to the processes that take place when updates of the shelf labels are needed.

5.2.1 The paper-based approach

Regarding the process of updating the shelf labels, it can be distinguished between the updates that are demanded by the employees who are responsible for the assembly and the updated information that is not connected to the assembly processes. The information on the shelf labels that is connected to the assembly encompasses the location of the shelves and the storing position of the carrier within the shelf. This information is also critical for the correct supply of the shelves with the material. If the employees of the assembly plan to relocate shelves or material, they forward this information electronically to the employees of the operational logistics because the employees of logistics are responsible for executing the relocation including the updates of the shelf labels. The employees of both the assembly and the operational logistics schedule a date when the changes will be realized and then the shelf labels are updated accordingly although at this stage it is not the final form of the updated label that is placed on the shelves.

The shelf labels are generated over night with a computer-based tool that monitors whether relevant information has been updated in the ERP system. The following morning, employees of the operational logistics use the tool to print the updated shelf labels and distribute them to the shelves. If the information that has changed is critical for supplying the shelves with the material, it is not an option to leave an outdated label on the shelf and wait until the updated labels are distributed jointly the next day. Critical information is the location of the shelf and the storing position of the material within the shelf so that these updates have to be put on the labels immediately. If that is the case, the employees write the correct information with a pen on the label or a temporary label is printed directly from the ERP system and the following day the updated shelf label that is generated with the tool replaces it. If the updates concern information on the labels that is not critical for the process of supplying the shelves with material, it is not necessary to adopt the updates immediately but it is possible to wait until the shelf labels can be printed on the following day.

The process of replacing shelf labels is illustrated in Figure 4. Both the processes that take place when the changes are demanded by employees of the assembly and the processes that occur when the changes do not affect the assembly are considered.

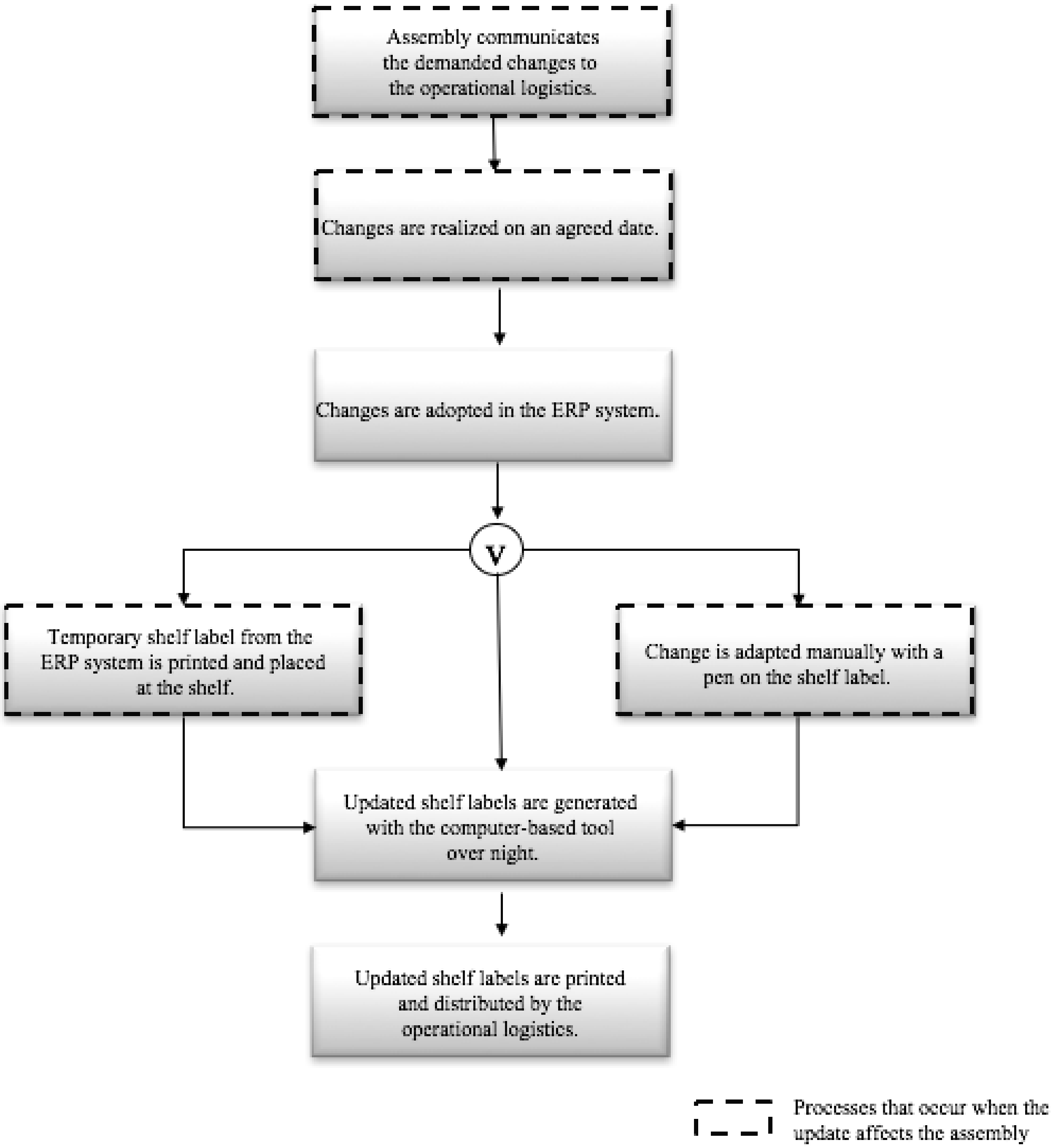

Figure 4: Updating shelf labels in a paper-based environment

5.2.2 The paperless solution

The abolishment of paper-based shelf labels can be realized by implementing ESLs that can be introduced using different approaches. One possibility is to supply the ESLs with both power and data through wires at the shelves. This might be a feasible option if the shelves are already wired, which could be the case if e.g. electronic devices for the process of picking material have been installed. However, it may not be an economically reasonable solution for a general substitution of paper-based shelf labels if the shelves do not include any technological components yet. Another option is the implementation of battery-free ESLs that receive the data and the power via Near Field Communication (NFC). NFC is operated with a sending device that has to be brought closely to the receiving device, in this case the ESL, in order to transmit the information. For the process of updating shelf labels, the goal is to eliminate the human interaction, which is difficult if NFC is used due to the close distance between the sending device and the ESL that is needed until the information is transmitted. That is why the thesis focuses on the possibility to implement ESLs that are powered with batteries and where the communication takes place over gateways that commonly communicate in the range of 2,4 GHz or 868 MHz.

The ESLs are connected to a certain storing position of a shelf and if the information, which material is placed on that position is changed in the ERP system, the change is automatically communicated to the ESL, which then displays the updated information accordingly. Thus, there is no need for human interaction in the process besides updating the information in the ERP system. If the changes concern the location of the shelf or the storing position of the material, it is still the employees of the assembly who communicates the demanded change to the operational logistics and a date is set when the changes are realized. The updated information on the shelf labels is adjusted in the ERP system as soon as the operational logistics have completed the relocation of the material or the shelf and this information is then directly communicated to the respective ESL. The process steps that occur when a shelf label has to be updated if ESLs are implemented is depicted in Figure 5.

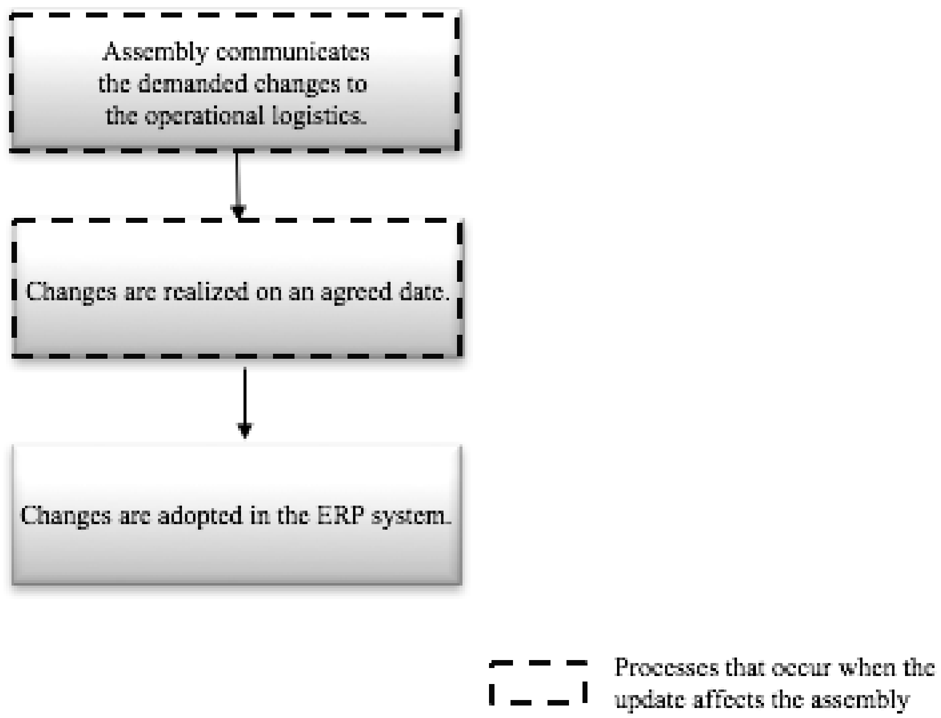

Figure 5: Updating ESLs

The use of batteries to power the ESLs makes an effort to change the batteries at some point inevitable. However, considering this effort, the implementation of ESLs can still depict an improvement compared to the processes that are needed if paper-based shelf labels are used. This depends to a great extent on the usable time of an ESL before the battery has to be changed. Suppliers of ESLs like Opticon (Opticon, 2018), Displaydata (Displaydata, 2018) or Ubiik (Ubiik, 2018) commonly indicate a usable time of around 5 years before the batteries have to be replaced, which would enhance the process of updating shelf labels considerably with regard to the number of more than 2200 shelf labels that were updated on average every month over the course of one year.

5.3 Challenges of implementing paperless practices

Next to the potential process improvements that come along with the implementation of digital solutions at shop floor level, several challenges emerged in the interviews with the employees of IT, planning and operations. These challenges include areas like adapting responsibilities of the employees to the new processes, arranging that the needed hardware and software is working in the given IT infrastructure and training the employees to ensure a smooth transition towards a paperless environment.

If new technologies are supposed to be introduced at shop floor level, the interviewees of the different departments agreed on the statement that it is important that the employees of operations are involved from the very beginning. If that is considered, the operational workforce can influence the outcome of the project and support the process with own ideas, which increases the willingness to adapt the new technologies. In the case company that approach is handled through periodic meetings where all the involved departments are represented and where the progress and further approaches of the project are discussed. Even though these efforts are made to ensure a close collaboration of the different departments that are involved, the employees of the operations stated that it would be good to already include them in the planning processes at an earlier stage since their daily experience concerning the operational processes could provide valuable input to determine the requirements for the paperless solutions.

Another challenge that is connected to the employees of the operations is the circumstance of changing responsibilities that result from a shift towards paperless practices. Areas like the transparency of the information flow and the flexibility are enhanced by implementing e.g. the tablets that display the work instructions and provide the possibility to automatically stamp relevant processes. However, there are tasks like charging the batteries that have to be included in the workflow. For the employees at the assembly line it is calculated what time they need for the activities that are necessary for completing their tasks. Activities like charging the batteries at the end of the sift have to be considered when such a calculation is done as well as the quicker handling of stamping processes. An adjustment of the calculated times for the activities is needed in order to retain a comprehensible basis of the expected tasks and the referring times.

With regard to the IT as a key enabler for the implementation of digital technologies at shop floor level, the given IT infrastructure depicts a challenge as the number of smart devices increases continuously. Even though the case company has not encountered problems concerning the infrastructure, it is an aspect that has to be considered for the future development of digitizing the manufacturing processes since many of the devices transmit the information on the frequency of 2,4 GHz, which is also the case for wireless LAN. Other frequencies like the 868 MHz that is partly used for transmitting the information from the gateways to the ESLs are not as developed and the companies face a lack of knowledgeable employees who supervise devices that operate on these frequencies.

Even though the digital approaches of the presented use cases come along with considerable potential process improvements, it has to be assessed which frame conditions are needed in order to exploit those potentials and how a smooth transition towards a paperless environment can be achieved. In this regard, it is important to consider the role of the employees of the operations because their willingness to adopt the technologies is crucial for a successful implementation.

6 Analysis and discussion

The following chapter comprises the analysis and the discussion of the case findings. The findings are analyzed against the background of OIPT in order to answer the research questions:

RQ1: How are the information processing and the respective workflow on the shop floor level affected by the implementation of paperless practices in terms of process performance with emphasis on the efficiency, flexibility and quality aspects?

RQ2: How does a shift towards digital solutions on the shop floor level impact the concepts of information processing requirements, information processing capability and the fit between them with regard to the information flow and the working processes that are executed?

First, the findings are analyzed with regard to the impacts of the paperless solutions on the information flow in 6.1. Thereafter, in 6.2 the focus is on the adaption of the working processes that could be detected in the paperless environment. While these aspects account for the first research question, the analysis of the concept of fit when the paperless approach is applied in 6.3 aims at answering the second research question. The chapter ends with a reflection on the results in 6.4.

6.1 Impacts on the information flow

The comparison of the paper-based solutions and the paperless processes, that are supposed to substitute them, depicts a changing information flow that is aspired to cope efficiently with the market requirements. Conveying the information on paper slows down the process compared to a communication that is handled electronically. Thus, the paper-based approach is adverse for the requirements of creating responsive and flexible processes in the organization. Both use cases reflect this circumstance. In the paper-based environment, the information that is needed at shop floor level is available electronically and is printed on paper and distributed in order to communicate it to the recipients. The handling of the paper does not add value and adds uncertainty to the tasks as human interactions come along with a risk of errors and increase the number of employees that are involved in the process.

Creating an information flow that is not dependent on paper as a medium is beneficial for organizations that are facing high customer demands, e.g. with regard to aspects like customization, quality and availability of products. To handle this demands efficiently, setting up an infrastructure that enables organizations to communicate the relevant information to the recipients quickly is an important measure. The presented use cases show how the implementation of paperless practices at shop floor level can represent a step towards an improved handling of environmental complexity and dynamism, which is of particular interest for the organizations if the strategy of mass customization is applied. Increased complexity and dynamism lead to augmented information processing requirements since the uncertainty rises for the organizations in terms of manufacturing products that satisfy the demand on time, in the right quality and in a cost-efficient manner.

In the automotive industry, the adoption of a mass-customization strategy leads to an increased number of variants of the manufactured cars, which comes along with a greater amount of information of the respective variants that has to be stored and communicated. On the shop floor level, the implementation of tablets at the working stations enables a quicker transmission of the information if adjustments concerning the working instructions are desired because the employees who take care of the adjustments can control the tablets at each station separately. The shift towards the tablets changes the way the information is displayed and communicated to the employees.

While the working instructions that are printed and mounted on the bonnets contain all the instructions for the employees at every station of the assembly line, the information on the tablet only concerns the respective working station. Thus, the employees who use the tablets do not have to filter, which information is relevant for them and it is possible to give clearer instructions as the tablets provide more space for the instructions of the single working stations. This accounts for an increased information processing capability that enables the organization to provide the employees of the assembly with an improved presentation of the working instructions. Since the increasing numbers of variants lead to a higher task complexity for the assembly, the implementation of the tablets is an appropriate measure to support the employees in their workflow, achieving a better fit between the information processing requirements and capability for the assembly processes.

Next to the display of the working instructions, the tablets serve as the medium for stamping the relevant working steps and calling a supporting employee if problems occur in the assembly process. The information flow with regard to the stamping process changes since the use of the tablets enables the electronic gathering and storing of the stamps. In the paper-based environment, the information is conveyed on paper where the tasks are stamped and have to be scanned in order to archive the information electronically. The handling of the stamping process with the tablets also enables the direct communication to the employee at the quality gate if stamps are missing. This communication is not possible when the stamping is performed on paper so the employee at the quality gate has to look through the list of stamps in order to assess whether all the stamps have been made. Thus, the improved information processing when tablets are used comes along with an easier detection of missing stamps resulting in an enhanced process performance and quality.

The possibility of transmitting information with the tablet if problems occur at the assembly line represents an increased information processing capability as well. On the tablet, the employees can give a rough indication what causes the problem which is not possible if the employees pull a cord to demand support. The use of the tablets for reporting problems at the assembly line enables the organization to keep track of these problems and analyze them in order to assess the causes and diminish or terminate them. The use case shows how information flows can be generated that have not existed before but that enhance the processes on the shop floor by providing additional information to the employees and increasing the transparency of the processes.

The implementation of ESLs is another use case of paperless practices that comes along with an altered information flow. The source of the information that is displayed on the shelf labels remains unaffected since the information is derived from the ERP system, both for the paper-based shelf labels and for the ESLs. When the shelf labels are printed, first of all the updated information is adjusted in the ERP system and a programmed tool screens overnight whether the information that has been updated is relevant for the shelf labels. The information that is extracted from the ERP system is filtered and if the updates concern relevant changes, the labels are printed and placed at the shelves. In this case, the information flow includes the ERP system where the updated information is inserted initially, the programmed tool where the information is filtered with regard to its relevance and the process of printing the shelf labels and placing them at the respective shelves.

If ESLs are used, the information flow is reduced to the communication of the updated information from the ERP system to the ESLs, which is then displayed accordingly. The reduction of steps for updating the information on the shelf labels compared to the paper-based approach accommodates the vision of smart factories that are highly flexible and reconfigurable. Such a flexibility comes along with frequent changes of shelves and material along the assembly line to cope efficiently with an increasing number of variants that are manufactured. That in turn increases the information processing requirements as the dynamism leads to a higher degree of uncertainty that is afflicted to the task of updating the shelf labels. The goal of flexible factories emphasizes the potential process improvement that can be realized by implementing ESLs. The implementation accounts for an increased information processing capability that enhances the fit between information processing requirements and capability, leading to an improved process performance.

Both use cases that are considered in the thesis represent an enhanced information processing capability that is achieved by adopting paperless practices. For the process of updating the shelf labels, the information flow is streamlined and in the use case of implementing tablets at the assembly line, the shift towards the paperless solution enables the consolidation and improved handling of different information flows with the tablet as the central device. The adjusted information flows serve as a mean to reduce the uncertainty that is attached to the tasks and thus result in more efficient processes that improve the quality and flexibility due to an enhanced information processing.

6.2 Impacts on the working processes

The analyzed adjustments of the information flow when paperless practices are implemented come along with a changing workflow. On the one hand, these changes concerning the working processes are caused by the elimination of paper as a medium to transmit information so that the handling processes that come along with it are abolished. On the other hand, the workflow is also affected due to adjusted processes where the handling steps are not eliminated but where they differ compared to the paper-based environment. One example that illustrates the elimination of working processes by implementing paperless practices is the use case of ESLs since the process of printing and placing the shelf labels can be abolished. The use case of the tablets at the assembly line is an example that depicts the case, where working steps are partly eliminated but also adjusted against the background of the introduction of digital devices.

Eliminating working steps reduces the uncertainty that is afflicted to the respective tasks since the task complexity and also the interdependence both within a subunit and between subunits is decreased. One example in this regard is the implementation of ESLs since they eliminate the need for the employees of the operational logistics to handle the shelf labels on paper. That reduces both the risks of errors that can occur when updated shelf labels are placed and it affects the task interdependence, especially when the location of the shelves or the storing position of the material is affected. If that is the case, the employees of the operational logistics only have to schedule a date with the assembly when the repositioning takes place and then the shelf labels are updated according to the ERP system once the updated information is inserted there. The double handling of the process of updating shelf labels on paper, which requires more communication and efforts within the department of operational logistics, can be avoided. Thus, the elimination of the working steps serves as a countermeasure to cope with an increasingly dynamic environment that results in the need to adapt the assembly processes more frequently.

The use case of implementing tablets at the assembly line illustrates both the elimination and the adoption of working steps. The opportunity to abolish the handling of the paper streamlines the working processes and creates an increased information processing capability as it has already been discussed above. The working instructions do not have to be printed, mounted and removed from the bonnets and the paper where the relevant working steps are stamped is not needed as the stamping process takes place on the tablets. Even though the process of assembling the parts is not influenced itself, the working instructions on the tablets are more detailed, thus providing a better assistance regarding the assembly processes against the background of an increasing number of models and customized features. The working process if the employees at the assembly line need support is improved as well. The employees can give an indication on the tablet why they need support so the necessity for additional communication is reduced and the supporting employee can undertake the required working steps quicker.

Both use cases that are considered in the thesis show the potential process improvements that can be realized when digital solutions are adopted at shop floor level and when the workflow is adjusted accordingly. In the case of implementing ESLs, the workflow is adjusted automatically because the manual handling of the shelf labels that are printed on paper is eliminated. The introduction of the tablets at the assembly line not only terminates the handling of the paper but it also improves the working processes regarding the execution of the instructions, the stamping of the working steps and the call for the supporting employee.

6.3 The concept of fit in the paperless environment

The fit between information processing requirements and information processing capability is an essential component of OIPT. Galbraith (1974, 1977) emphasizes the variation of tasks concerning their information processing requirements that lead to different levels of capabilities that have to be provided in order to achieve fit. Even though the trend of mass customization comes along with a more complex and dynamic environment that increases the uncertainty that is afflicted to the tasks, the analysis of the use cases indicates that it is not only a mismatch of information processing requirements and capability that drives the adoption of digital solutions on the shop floor level.

Considering the use case of implementing ESLs, it can be argued that the shift towards the digital approach is necessary to cope with the goal of establishing highly flexible and reconfigurable factories. Changing locations of the shelves along the assembly line and changing storing positions of the material are continuous processes if the assembly line is supposed to be flexible. Shelf labels that have to be printed on paper and placed at the shelves do not serve as an adequate mean to cope with this development so the information processing requirements and capability would not be in line anymore. Arguably, there is already a mismatch in this regard in the current state considering the number of more than 2200 shelf labels that had to be updated on average per month over the course of one year. Introducing ESLs at shop floor level is likely to result in a good fit between requirements and capability that could not be achieved with the paper-based approach.

Besides the display of the information that is needed on the shelf labels, ESLs might also be used to support the employees of the operational logistics who have to supply the shelves with material. This support can be realized in the shape of LEDs that are included in the design of the ESLs and that flash when the respective material is supposed to be delivered to the shelf. This function facilitates the supply of the material since the respective storing position can be identified easier, resulting in a quicker process that is less prone to errors. In this case, it is not a certain information processing requirement that would lead to the implementation of the LEDs. A mismatch of the information processing requirement and capability could not be detected for the process of supplying the shelves with the material. However, the approach of including LEDs is considered since the implementation of ESLs provides the organization with the opportunity to improve processes even if there is not an immediate need to do so with regard to the information processing requirements. The approach is not derived from a need to cope with a misfit between requirements and capability but it is developed as a possibility that comes along with the implementation of ESLs. Figure 6 illustrates this circumstance as it depicts the information processing capability as the determining factor that on the one hand has to fit the requirements. On the other hand, it can also lead to the realization of potential process improvements that are not connected to a certain requirement that has evolved from increasing uncertainties.

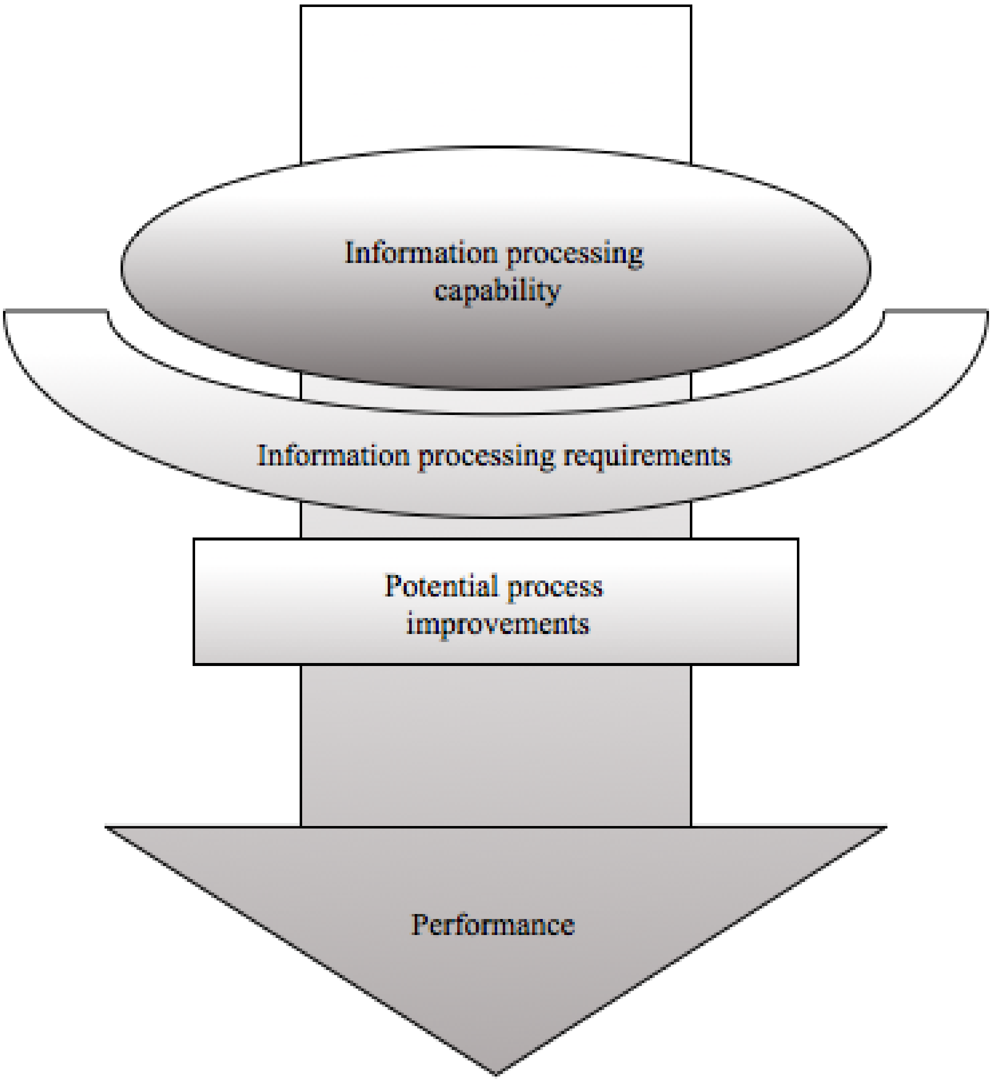

Figure 6: Information processing affecting the performance

The implementation of tablets at the assembly line depicts another example of increased information processing capability. This capability is used to provide the employees with more detailed information about the assembly processes, which helps them to cope with an increasing number of models and customized features and thus creates a better fit. The other two aspects that are included in the use of the tablets, i.e. the process of stamping relevant working steps and asking for the supporting employee, are not directly connected to an increasing uncertainty or information processing requirements. Nevertheless, as it has been discussed above, these functions account for considerable process improvements that can be realized because of the implementation of the tablets.

The two use cases show that there might be a shift away from considering the single tasks with the respective information processing requirements and the information processing capability that has to be provided in order to achieve a good fit. Abstract requirements like the need for flexible processes that are efficient in terms of time and costs are considered when new processes are designed with the help of digital solutions. In the presented use cases, the paperless practices enhance the information processing capability and it is assessed how the devices that are implemented can contribute to achieving better process performances for the workflows that can be connected to the digital devices. The starting point for the realization of process improvements is not necessarily the identification of an increased uncertainty that is afflicted to a task, which leads to a misfit with regard to the information processing capability. The digital solutions come along with extensive possibilities to enhance the processes of various interrelated activities, which have to be realized in order to fully exploit the potential that lies in the digital approaches.

6.4 Reflection on the results

The results of the analysis give a clear indication on the impacts on the information flow and the working processes that come along with the implementation of paperless practices at shop floor level. A brief summary of the results is given in Table 1. The study shows how the use of digital devices can help to increase the information processing capability, which in turn helps manufacturing companies to cope with the strategy of mass customization. The use cases illustrate the effort that is made by the company to develop the means to handle the customers´ demands of a high availability of high-quality and customized products. Thus, the possibility of digitizing processes is a promising approach as it provides the potential to streamline the information flow and the working processes. These findings are in line with e.g. the findings of Wang et al. (2015), who emphasize the efforts of companies to establish a better-connected environment that enables them to take advantage of the digital technologies that are already available. These measures represent an important step towards the goal of smart factories that come along with a great potential in terms of efficiency and flexibility as it is stated by Capgemini (2017a).

Use case	Benefit	Area of improvement	Reasoning
Implementing ESLs	Information from the ERP system is displayed automatically on the ESL.	Efficiency, Flexibility	Highly flexible and reconfigurable factories come along with frequent changes of the location of the shelves and the material along the assembly line. Thus, the shelf labels have to be updated more frequently as well so that an efficient process is important to cope with the increased dynamism.
Tablets at the assembly line	Display of the working instructions on the tablets.	Quality, Flexibility	The working instructions for the employees are more detailed on the tablets and changes can be adopted easier. This accommodates the need to assembly an increased number of variants and customized features.
	Stamping relevant working steps on the tablets.	Quality, Efficiency	The stamps are set and stored electronically, which facilitates the processes. Missing stamps are reported automatically so that the quality is additionally secured.
	Reporting problems at the assembly line via the tablets.	Transparency, Efficiency	The employees can give a rough indication on the tablet what has caused the problem. That decreases the need for further communication to fix the problem and the problems can be tracked and analyzed easily to assess possible causes and solutions.

Table 1: Summary of the results

Furthermore, the results suggest that OIPT alone may not be capable of explaining all the developments of the shift towards a digital environment that could be detected in the use cases. OIPT proved to be a valuable theory to assess the change towards paperless practices but it seems like the concept of information processing capability becomes the central aspect that affects the adjustments of the processes, which is not anchored in Galbraith´s (1973) OIPT. The assumption that the information processing capability is the determining factor in the OIPT framework is derived from the analysis of the use cases. However, even though the information processing capability is an asset of the organization that is likely to increase continuously against the background of digitalization, more case studies and quantitative data is necessary to validate or to neglect the assumption.

In general, the combination of interviews, field observations and field conversations provided detailed information about the processes both in the paper-based environment and when the digital solutions are implemented. However, it has to be considered that the results are solely based on a single case study comprising two use cases where digital solutions have been implemented or are supposed to be implemented. Thus, the results may differ if the study is conducted at other companies whose workflows might lead to different information processing requirements and whose initial investments that are needed to establish a certain information processing capability can also vary.

7 Conclusions

The analysis of the findings of the two use cases that were considered in the course of the thesis allowed a well-grounded evaluation of the results with regard to the formulated research questions:

RQ1: How are the information processing and the respective workflow on the shop floor level affected by the implementation of paperless practices in terms of process performance with emphasis on the efficiency, flexibility and quality aspects?

RQ2: How does a shift towards digital solutions on the shop floor level impact the concepts of information processing requirements, information processing capability and the fit between them with regard to the information flow and the working processes that are executed?

The results of the analysis show that the shift towards paperless practices at shop floor level streamlines the information flow and the working processes. The findings of the two use cases indicate potential improvements with regard to efficiency, flexibility and quality aspects. The introduction of ESLs illustrates the possibility to eliminate working steps that are executed in a paper-based environment to transmit the information to the recipient. Abolishing these non-value-adding tasks increases the efficiency and accommodates the goal of highly flexible and reconfigurable factories. The reduced human interaction that is needed to convey the information decreases the uncertainty that is afflicted to the task and thus increases the quality of the process as errors are less likely to occur.

The implementation of the tablets at the working stations also enables the elimination of working steps. Furthermore, the data show that the use of the tablets leads to an improved handling of different information flows that are consolidated with the tablet as the central device. By using the tablets at the assembly line, the organization is able to collect more data that can be analyzed and archived easier, resulting in an enhanced process efficiency and quality. Moreover, the tablets improve the information flow of the working instructions that are communicated to the employees at the shop floor. The tablets provide the employees with more detailed instructions and if changes are demanded, they can be adopted in a quick and flexible manner.

With regard to the second research question, the data show that the adoption of paperless practices at shop floor level leads to an enhanced information processing capability of the organization. As the information processing requirements increase due to a rising number of variants and the goal of establishing smart factories that are highly flexible, the shift towards a paperless environment is an important step to achieve a good fit between the requirements and the capability that leads to a strong performance. However, the analysis also shows that the implementation of paperless solutions is not always necessarily connected to increased information processing requirements that have evolved due to rising uncertainties. The paperless approach comes along with the potential to improve various interrelated processes that are not prone to a misfit with regard to the information processing requirements and capability. Realizing these potentials, as it is illustrated with the implementation of the tablets, has a significant impact on the performance of the organization and is a step towards the goal of seamless connected and highly flexible factories.

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Appendix

Appendix 1: Set of question for the interviews

General questions:

- What is your business operating area and how are you involved concerning the implementation of paperless practices on the shop floor level?
- Have you already had experiences regarding a shift towards paperless practices in prior projects?
- What does the collaboration between the different involved departments like IT, planning, standardization and operations look like?
- What impact does the implementation of paperless solutions have in terms of information flow and the respective workflow?
- What are the main challenges for a smooth transition from a paper-based towards a paperless environment on the shop floor?

Planning:

- What were the criteria for choosing the processes that are supposed to be (or that have already been) digitized?
- At what point does the planning department contact e.g. IT and operations about future plans regarding the implementation of paperless practices that might be realized?

IT:

- Is the current IT-infrastructure sufficient for the plans of digitizing the processes at shop floor level? If that is not the case, what arrangements have to be made in order to ensure an adequate infrastructure?
- How is the interface handled between the displays and the ERP and the production planning software that provide the information that has to be displayed?

Operations:

- Will the implementation of paperless solutions change your working steps? If that is the case, how will the newly arising working steps be distributed among the employees?