Linköping University | Department of Management and Engineering
Master's Thesis | Industrial Engineering and Management – Economic Information Systems
Spring term 2016 | LIU-IEI-TEK-A–16/02597–SE

Identifying Potential Effects of Using ERP-Connected Mobile Devices in Manufacturing Companies

Gustav Blomér
Claes Kallström

Tutor, Özgün Imre

Examinator, Alf Westelius

LINKÖPING UNIVERSITY

Abstract

Smartphones and other mobile devices are a common sight in our daily lives. The improvement in technology has given us small and portable devices that have the performance only found in desktop computers and more high-end devices less than a decade ago. An industry that has been quick to adopt technologies in the past is the manufacturing industry, examples of these adoptions are the conveyor belt and robots, which both are innovations of their time. Aside from hardware technologies, there are software technologies that the manufacturing industry has been using, e.g. complex information systems to manage materials and resources in the production. With the developments in mobile technology, a question arises whether the information systems can be combined with it in the manufacturing companies.

One of the technologies that has become popular in the past years is the use of mobile devices such as smartphones and tablets. These kinds of devices can improve communication and flexibility. This leads us to the purpose of identifying how the use of ERP-connected mobile and mobility-supporting devices can affect processes among shop floor and production management personnel in large manufacturing companies.

Using a qualitative approach, case studies of eleven companies were conducted using semi-structured interviews and direct observations. Personnel with different roles were interviewed to identify applications and devices that would reduce execution time, improve quality, or improve the flexibility of processes and tasks. These eleven companies were analysed with a model that focus on the dimensions complexity, specificity, and dynamism of a company's production structure, as well as a model that focus on the same dimensions in the roles of production personnel.

The result was six applications and corresponding devices that could improve the effectiveness and efficiency of a process in a significant way. The analysis showed that the management in companies had similar needs in mobile or mobility-supporting devices. Similarly, the assemblers and machine operators also had similar needs. No connection was found between the production strategy and the need for mobile or mobility-supporting devices.

Preface

The report you are reading is the finished product of our master's thesis, the final report in the final project to get our master's degree in industrial engineering and management. The project was conducted over the span of 20 weeks, and it was our full-time employment for the spring term of 2016.

We would like to use this space to thank the people who have helped us in getting this project to the finish line. We would like to thank our tutor Özgün Imre for giving us continuous feedback and helpful insights. We would also like to thank our examinator Alf Westelius for his valuable comments and help. Thanks to our two opponents, Olof Jarkman and Rasmus Kling, whose critique and feedback elevated this report and our work as a whole. Moreover, we would like to thank the eleven companies and the twenty-eight persons whom we have interviewed. Finally, we would like to thank IFS, who aided us by providing a place to work and gave us the opportunity to conduct this project. Last but not least, a thank you to our supervisor from IFS, Martin Gustafsson, who helped us along the way and to whom we are very grateful.

Our warmest thanks go out to all of you!

Linköping, 25th June 2016

Gustav Blomér

Claes Kallström

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List of Abbreviations

AUDE	Application-User-Device-Environment
CSD	Complexity-Specificity-Dynamism
ERP	Enterprise Resource Planning
ISIC	International Standard Industrial Classification of All Economic Activities
IT	Information Technology
MRP	Material Requirements Planning
MRPII	Manufacturing Resource Planning
P-C CSD	Personnel-Centric CSD
RAM	Random Access Memory
RFID	Radio-Frequency Identification

1 Introduction

This introductory chapter presents the background of the thesis and the subject on which it focuses. The purpose is presented followed by the limitations applied to the study. The chapter ends with sections on the conceived audience and the structure of this report.

1.1 Background

Smartphones and other mobile devices are a common sight in our daily lives. The improvement in technology has given us small and portable devices that have the performance only found in desktop computers and more high-end devices less than a decade ago. An industry that has been quick to adopt technologies in the past is the manufacturing industry, examples of these adoptions are the conveyor belt and robots, innovations of their time. Aside from hardware technologies, there are software technologies that the manufacturing industry has been using, complex information systems to manage materials and resources in the production. With the developments in mobile technology, a question arises whether it can be combined with the information systems in the manufacturing companies.

1.1.1 Enterprise Resource Planning Systems

One of the predecessors of the Enterprise Resource Planning (ERP) system has its roots in the 1960s when the first Material Requirements Planning (MRP) system was created and taken into use at a manufacturer of construction machinery. The technological change that opened the door for the MRP system was the availability of Random Access Memory (RAM), which allowed for more than one-dimensional calculation that had been difficult or impossible to perform with magnetic tape as storage. In the 1970s, the MRP system became a popular tool for material planning as the availability of mainframe computers with RAM grew. (Jacobs and Weston Jr, 2007)

In the 1980s, the MRP systems had evolved to include more functions than those that initially gave it its name. The new functions were focused on the other needs of the manufacturing company, e.g. shop floor reporting, cost reporting and procurement. The abbreviation MRP soon started to be used to refer to Manufacturing Resource Planning. Later Manufacturing Resource Planning became known as MRPII to distinguish it from MRP. During the 1980s, the focus for software developers shifted towards delivering software to cheaper computer systems aimed at small and medium enterprises. (Jacobs and Weston Jr, 2007)

The term ERP system was first used in the early 1990s, and by then the MRPII systems had grown together with functions like human resource management and accounting (Jacobs and Weston Jr, 2007). The definition of an ERP system today is a software system that integrates and exchanges data between and within the functions of an organisation (Kumar and van Hillegersberg, 2000; Jacobs and Weston Jr, 2007). The functions often include: reporting, accounting, manufacturing, inventory and supplies, human resource management, and sales and delivery (Davenport, 1998). All of these functions communicate to a common central database (Davenport, 1998).

Through their history, the ERP systems and their predecessors have evolved to be able to take advantage of the latest available technology. In the past years, one of the technologies to become popular is the use of mobile devices such as smartphones and tablets. This willingness to adapt to take advantage of new technologies made it interesting to study how mobile devices can be used in connection with ERP systems.

1.1.2 Mobile and Mobility-Supporting Devices

Recent developments in consumer-grade mobile devices have opened up opportunities for today's organisations. The improved mobile devices present the possibility for employees to access their company's ERP system on the go. (Prouty and Castellina, 2011) These possibilities stretch from the managers to the personnel on the shop floor. Both the shop floor worker and manager can utilise mobile devices to receive and send information at any place and anytime, and the devices can range from smartphones or tablets to wearables such as smart glasses (Huenerfauth, 2014). Opportunities are described, both in the academic study by Huenerfauth (2014) and in the white paper by the practitioner Turbide (2014), for a manager to send information proactively using their mobile device as well as to react to notifications sent to them, allowing them to wander around the facility without having to return to their office. The almost instantaneous receiving and sending of data allow for a more flexible process, leading to cost savings for the company employing these functions (Huenerfauth, 2014). One way of measuring if the business processes can become more efficient and effective by using mobile devices is by measuring the goal dimensions: quality, flexibility, and time (Hoos et al., 2014). If a mobile device improves one of these dimensions it will have a positive impact on the business processes (Hoos et al., 2014).

Among the Swedish population the access to smartphones and tablets has increased over the years, as seen in Figure 1.1. The highest rate of access being in the age demographic 16 to 45 years old and smartphones having a higher rate of access than tablets overall (Internetstiftelsen i Sverige, 2015). The high rate of access to mobile devices in the private lives implies that the users' knowledge of how to use mobile devices have surpassed the novice stage. Thus, the threshold for introducing and accepting mobile devices as part of the professional lives may have decreased and in some cases, the users might desire to use mobile devices in their profession. This possibility further impressed the question of how mobile devices could be used in a work setting.

Fallman (2010) examined mobile support systems in an industrial setting. One of them were wall-sized displays that could be used in connection to a mobile device. One reason cited for not using the mobile devices was that the displays were too small and it was difficult to collaborate using a personal mobile device. The wall-sized displays were placed in strategic places and provided a large screen for easier collaboration and usability, which removed the need to go to the office and instead the workers simply moved to the closest display. The information on the displays could easily be transferred to their mobile devices in order to support the workers mobility. This kind of mobility-supporting device that might be stationary itself was included in this study to incorporate more devices that might provide the personnel with the same benefits as a mobile device.

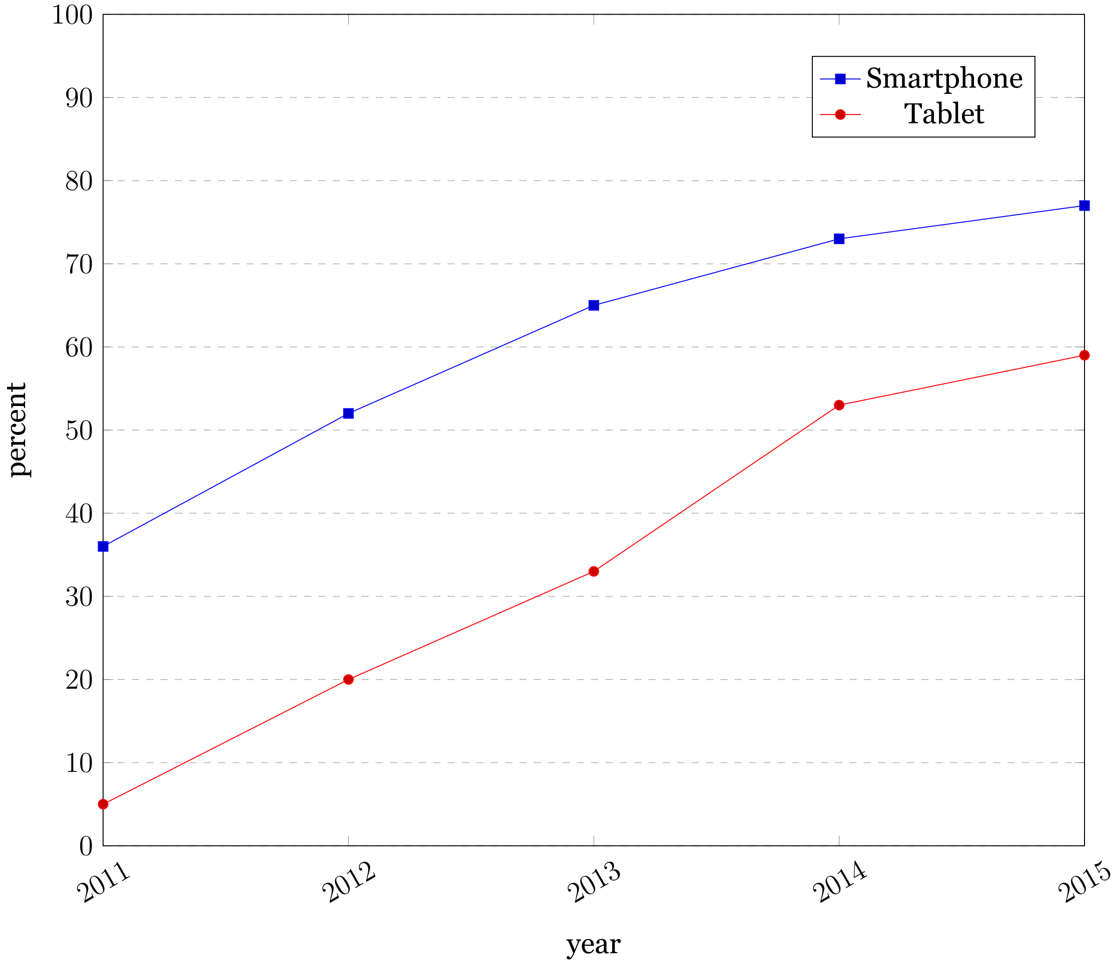

Figure 1.1: Access to mobile devices in the Swedish population (Internetstiftelsen i Sverige, 2015)

1.1.3 Manufacturing Industry

According to a survey conducted in Sweden by the Swedish government agency *Statistics Sweden* during 2014, 60 % of the surveyed manufacturing companies were using an ERP system, as seen in Figure 1.2. In total, 43 % of the surveyed companies were using an ERP system. (SCB, 2014a)

The manufacturing environment is growing increasingly complex, making the responsibilities of the shop floor personnel more difficult, and increasing the need for effective communication mechanisms (Morkos et al., 2012; Hao and Helo, 2015). Rapid changes in competition and the customers' expectations further reinforce the need to manage the uncertain environment (Zhang, Vonderembse and Lim, 2003). One way for manufacturers to stay competitive, in this uncertain environment, is to increase their flexibility (Zhang, Vonderembse and Lim, 2003).

The high rate of ERP system use in manufacturing enterprises, as well as improved technology, present opportunities to access the ERP system anywhere and anytime. Together with the changes in the manufacturing environment, these factors have lead to the appearance of a new area of research where little research has been conducted. In this study, the new area examining ERP-connected mobile and mobility-supporting devices in a manufacturing setting was selected be explored.

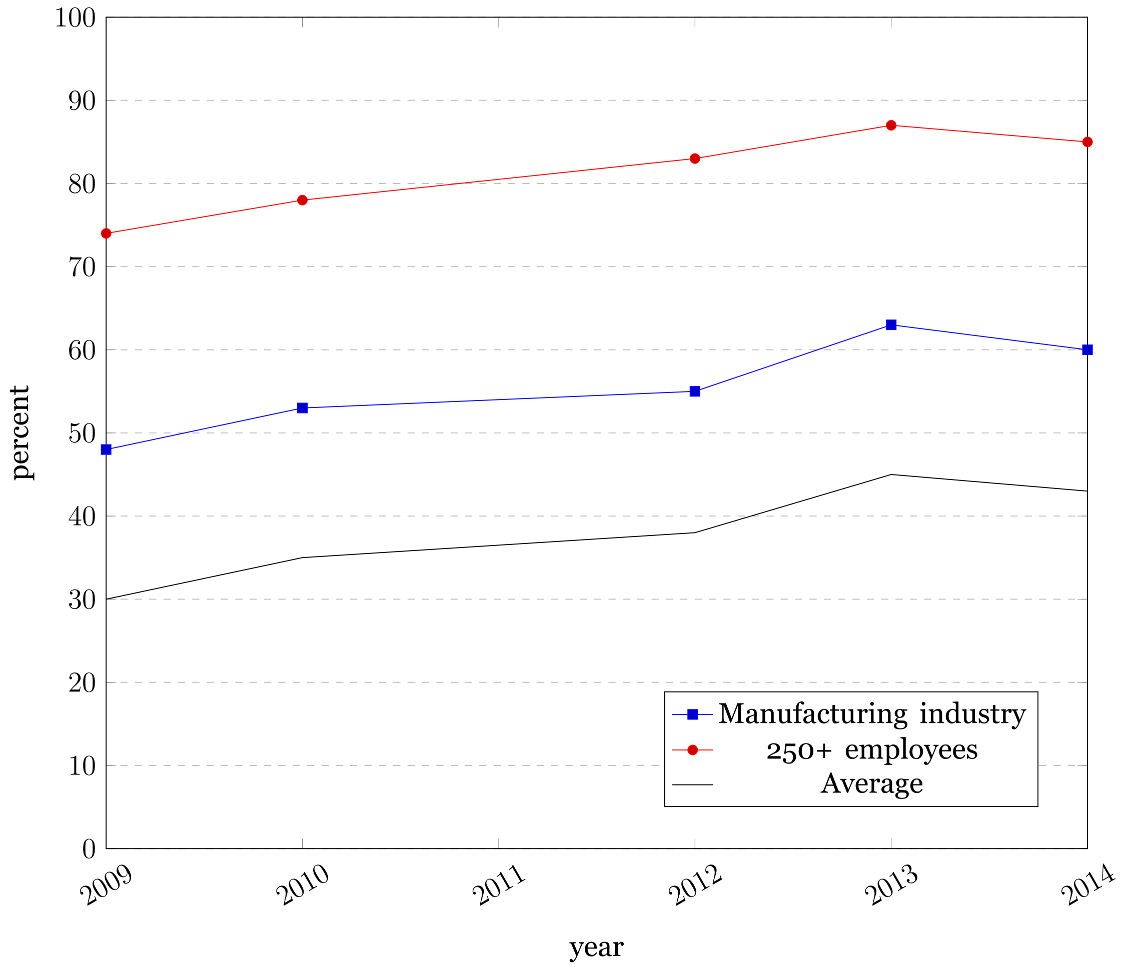

Figure 1.2: Use of ERP systems in manufacturing companies, companies with 250+ employees and average by year (SCB, 2014a; SCB, 2014b)

1.1.4 Large Enterprises

Large enterprises in this report refer to businesses that exceed the defining limitations for small and medium-sized enterprises according to the recommendation of the European Commission (European Commission, 2003). Thus, firms with a headcount of at least 250 employees, and a balance sheet total larger than € 43 million or a turnover larger than € 50 million are considered large enterprises.

According to the aforementioned survey, conducted by *Statistics Sweden*, 85 % of the surveyed companies with 250 employees or more were using an ERP system, as seen in Figure 1.2, compared to 43 % in average (SCB, 2014b). In 2013, *Statistics Sweden* surveyed how many companies provided their employees with Internet-connected mobile devices. The result showed that 95 % of large enterprises provided their employees with Internet-connected mobile devices, compared to 63 % in average (SCB, 2013).

The size of large enterprises was chosen to constitute the target demographic in this study due to the high use rate of ERP systems and rate of providing mobile devices to the employees compared to smaller firms.

1.2 Background of the Problem

Throughout the background, the basis for the purpose of this study was presented. History has shown ERP systems to evolve together with the technological development, and mobile devices as a popular technology would be an attractive part to examine in relation to ERP systems.

It is likely that the average knowledge regarding the use of mobile devices has risen, due to the increased use of mobile devices among the general public. This in turn may have led to lessening the opposition towards mobile devices in the workplace, and may have made people desire to use mobile devices in the workplace.

Large manufacturing companies have been studied in part for their above average use of ERP systems. Manufacturing companies have also been studied because both mobile and mobility-supporting devices may be used to improve flexibility and to affect shop floor and production management personnel in their tasks, which can be useful in a manufacturing setting where responsibilities are growing increasingly complex.

1.3 Purpose

The background concerning ERP systems, mobile devices, and manufacturing companies has led to the following purpose:

The purpose of this study is to identify how the use of ERP-connected mobile and mobility-supporting devices can affect processes among shop floor and production management personnel in large manufacturing companies.

ERP-connected mobile and mobility-supporting devices are, henceforth, referred to as ERP-connected devices in this report. In cases where other types of ERP-connected devices are referred to, it is made clear.

1.4 Research Questions

In order to fulfil the purpose different ways in which ERP-connected devices could be used to affect processes had to be identified. One approach to investigating the effects of ERP-connected devices on production processes involved analysing whether the processes would become more or less effective or efficient, as measured by the goal dimensions: quality, flexibility, and time.

1. How can ERP-connected devices affect effectiveness and efficiency in a production environment?

Within a manufacturing setting, there exist different roles both on the shop floor and in the production management, i.e. among all production personnel. The duties and responsibilities of the role may change the usefulness of ERP-connected devices in their daily work.

2. How does the role of the production personnel affect their need for ERP-connected devices?

The methods and configurations used in the production, aspects such as complexity of the products and the degree of automation, as well as the market the companies operate on are certain to vary. The strategies used in the production environment to manage these issues are sure to vary as well. There is a possibility that the production structure and production strategy can affect the duties and mobility of the production personnel which in turn may affect their need for ERP-connected devices.

3. How do the production structure and production strategy affect the need, in a production environment, for ERP-connected devices?

1.5 Limitations

In order to make the study manageable, it was limited only to companies with manufacturing facilities located in Sweden. This also had the added benefit of increasing the ecological sustainability of the study by reducing long travels.

1.6 Audience

This report is aimed at students, researchers and professionals in the fields of information systems and production. The language and structure of the report are that of an academic report, but the content is relevant for professionals as well.

1.7 Structure of the Report

In this section, the structure of the report is presented to help the reader get a better overview of the report and to get an insight into the focus and purpose of each chapter.

1. Introduction
   This introductory chapter presents the background of the thesis and the subject on which it focuses. The purpose is presented followed by the limitations applied to the study. The chapter ends with sections on the conceived audience and the structure of this report.

2. Methodology
   In this chapter, the decisions leading up to the choice of the methodology are presented, and the central aspects of the methodology used for the study are explained. In addition, the research process used for the literature study, and the gathering and analysing the empirical data is described.

3. Theoretical Framework
   This chapter presents the theoretical frameworks leading up to the analysis framework used in this study. The chapter is concluded by a description of how the theories were used to form the analysis framework and which research questions they were meant to answer.

4. Empirical Framework
   In this chapter, the empirical data gathered during the interviews and production tours while visiting the companies is presented.

5. Analysis
   The analysis chapter contains the analysis of the empirical data based on the analysis framework. The chapter is organised into three sections corresponding to each of the research questions.

6. Conclusions
   In this chapter, the answers to the research questions are presented and the conclusions of the study are drawn.

7. Discussion
   This chapter contains the discussion concerning the how the study has been conducted and recommendations for further research.

Methodology 2

In this chapter, the decisions leading up to the choice of the methodology are presented, and the central aspects of the methodology used for the study are explained. In addition, the research process used for gathering and analysing the empirical data is described.

2.1 Research Strategy

To lay the groundwork for the study, literature on methodologies and research strategies was examined. The information and descriptions of Bryman and Bell (2007), as well as Patel and Davidson (2011), were used as a starting point and basis for the search for the right research method.

In research methodology, there are two distinct and different strategies: quantitative and qualitative. These research strategies describe the method for generating, processing and analysing the collected data (Patel and Davidson, 2011, pp. 12-14). In practical research, the strategies employed often utilise aspects from both qualitative and quantitative research; the choice of strategy should be derived from what the research is trying to answer (Patel and Davidson, 2011, pp. 12-14). This study attempted to understand the production processes and duties by interviewing the production personnel and interpreting, as well as analysing, their responses. Thus, a mostly qualitative research strategy was settled upon for this study by the authors because it suggests that the researcher should get close to the subjects researched, trying to understand the subjects' point of view and explaining it in words (Bryman and Bell, 2007, pp. 28-29, 401-426). This choice was judged to be a good fit for the purpose of this study because interviewing personnel as a means to gather data instead of a quantitative method, e.g. a survey, opened up for immediate follow-up questions and better understanding of the production situations. A disadvantage of the qualitative research strategy is that the research may be harder to replicate compared to quantitative research (Bryman and Bell, 2007). This problem was handled in this study by explaining the method and theory used, as well as by keeping a case study database as suggested by Yin (2009), which is brought up further below in section 2.5.

2.2 Epistemological Orientation

Within research, there are several epistemological orientations, i.e. philosophical bearings of how knowledge is acquired, that researchers can adopt. One of these is that of positivism, where the methods of the natural sciences are adopted and used when studying the social reality with the aim of producing objective results, this bearing is more common in quantitative research. (Bryman and Bell, 2007, pp. 16-17)

Another approach is the one of interpretivism, an approach where it is recognised that the social sciences differ from the natural sciences and thus requires a different approach. In interpretivism, the researcher attempts to understand the subject's point of view to interpret the information gathered. (Bryman and Bell, 2007, pp. 17-21) One drawback is that the researcher's subjectivity will influence how the information is interpreted. During the gathering of information, the subjects are influenced by the researcher as the concepts are explained and introduced to them, further reinforcing that the information is subjective and open to interpretation. (Walsham, 1995) One criticism of interpretivism in case studies is that it is not statistically generalisable like positivism strives to be, the counter-argument to this is that the validity in interpretivist research is in the logical, convincing and plausible arguments made when analysing the empirical and theoretical data (Walsham, 1993, p. 15). Butler (1998, p. 297) says that ”proclaiming oneself as an interpretivist does not go far enough” since there are different approaches that an interpretivistic researcher can adopt. One of these approaches is the phenomenological hermeneutic, in the information systems research field there has been a marked trend towards this approach (Butler, 1998). Klein and Myers (1999) present a set of guiding principles when conducting interpretive studies in information systems of a hermeneutic nature, principles that encompass important insights in interpretivism. The argument for choosing interpretivism with hermeneutic features in this study was the fit with the purpose; the information gathered needs to be interpreted and analysed. An interpretivist approach will help in that regard, and the interpretivist will be of an hermeneutic nature and make use of the principles described by Klein and Myers (1999), which are further explained in the section below. The usage of this methodology among other information systems research studies lends further credibility to this choice of methodology. However, since the background and subjectivity of the researcher influence the interpretations, it was important to present thoroughly what laid the basis for the interpretations. This was done so that external researchers would be able to understand how the conclusions were reached and to validate the reasoning in the study.

2.3 Interpretivistic Principles

The hermeneutic circle is the foundation on which interpretivistic research of hermeneutic nature is built upon (Klein and Myers, 1999). Table 2.1 contain a summary of the seven principles of interpretivistic research, of which the hermeneutic circle is one of them, that Klein and Myers (1999) presents. These

Table 2.1: The Seven Interpretivistic Principles (Klein and Myers, 1999)

Principle	**Description**
The Hermeneutic Circle	The researcher iterates between considering the independent parts and the whole
Contextualisation	The object studied is part of a dynamic world and the social and historical context must be considered
Interaction Between the Researcher and the Subjects	Both the researcher and the subjects studied will be influenced by each other
Abstraction and Generalisation	To generalise in interpretivistic research the data should be abstracted and compared to theories that apply in multiple situations
Dialogical Reasoning	The researcher's own social context should be considered since this will influence the interpretations
Multiple Interpretations	Multiple subjects may interpret the same situation differently, the researcher should try to understand why they differ
Suspicion	Subjects can be influenced by power structures and similar aspects so that the answers might be distortions or disillusions

principles have more or less been followed due to varying applicability in this study.

The cases and their context were studied by iterating between analysing the independent parts, such as the interviewees, to analysing the whole of all the companies studied. The interaction with the interviewees was brief, which meant that the time frame to build a trusting relationship was short. In all interactions with personnel it was important to be truthful and open about what the study was about and what the data would be used for. Establishing a trusting relationship was important so that the interviewees would feel confident in diverging information they might deem sensitive but are important for the study.

Over the course of the study, we adopted some of the jargon that was common in the production environments, this sometimes altered the way questions were phrased and improved the understandability for the personnel. The interview subjects at each company was a shop floor worker and a manager, these two different points of view give multiple interpretations to one issue. It also allowed us to see if the views differed too much that it might point towards power structures influencing the results of the interviews.

2.4 Literature Study

The literature used in this study was collected by searching using Scopus, Google Scholar, and the search system provided by the library at Linköping University, which is operated by EBSCOhost. The searches used subject related keywords or combinations of multiple keywords. The keywords used were: ERP, mobile device, manufacturing, production strategy, information system, production, and mobility. During the literature study more keywords were discovered, for instance, flexibility being one of them. The articles were then selected based on the relevance of the title and summary, as well as the knowledge of the journal or place of publication. This was done in order to get breadth to the collected articles without risking the possibility of referencing research that had not been properly peer reviewed.

Another way literature was discovered was by examining the citations in other, previously collected, articles. The article itself was obtained using the tools mentioned above, and it was evaluated the same way as the other sources.

2.5 Case Study

To understand a real life phenomenon in its real life context, the case study is a valuable method. A case study can take several shapes; case studies can differ in time scope as well as the number of cases studied. Given that the researcher has enough resources it can be preferred to study several cases, a so-called multiple-case design. The multiple-case design can have improved analytical capabilities as well as conclusions holding more weight if the same conclusions are reached independently in several cases. (Yin, 2009, pp. 18, 35-39, 57-58) With an interpretivist approach the case study is a method that can yield interesting data. Using a multi-case design this report aims to increase the validity of the conclusions. Due to time limitations in the project the case studies were intensive with brief contact with the participating companies. A risk that was identified was that the short time periods of contact could limit the amount of data that could be gathered. To manage this risk, certain preparations were done such as schedules and interview protocols in order to spend as much of the time as possible gathering data from the case studied companies.

In a case study, it is important to gather data from several different kinds of sources to improve the validity of the study, this is called data triangulation and is the first of three principles of data collection presented by Yin (2009). Interviews are one on the most important ways of acquiring data in a case study; they can give the researcher important insights as well as new possible sources of information. Direct observation is another way of collecting data and can be performed when the researcher is doing a field visit to conduct interviews. (Yin, 2009, pp. 106-118) Both interviews and direct observation was chosen as the selected methods of data collection. The direct observations and the interviews were done at each case company's production facility. The direct observation consisted of a guided tour around the shop floor which gave the opportunity to ask more questions and to see if the answers from the interviews matched what was observed during the tour. How the interviews were structured is explained later on in this chapter.

The second principle of data collection is to create a case study database to store all data concerning a case. This data should be easily accessible so that other researchers can analyse the raw data and thus increase the validity of the study. The third, and last, principle is to maintain a chain of evidence; a reader should be able to trace the steps both from research questions to conclusions and vice versa as shown in Figure 2.1. (Yin, 2009, pp. 118-122)

This study aimed to follow the three principles presented by Yin (2009). The study used both interviews and direct observations to abide by the first principle of data triangulation. The data gathered was structured in a database for high

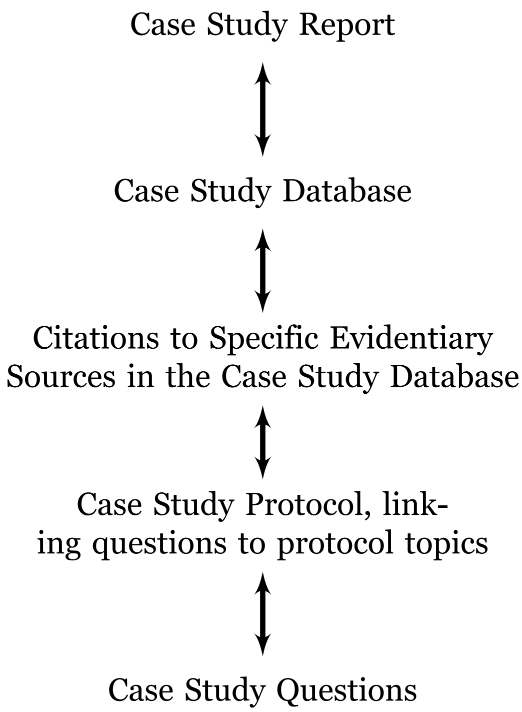

Figure 2.1: Maintaining a Chain of Evidence (Yin, 2009)

readability, the case companies and interview subjects are anonymous in the data in order to protect their integrity. The report was iteratively examined to ensure that the chain of evidence was maintained. This was conducted by linking the research questions to the interview questions, the interview questions to specific sources from the interviews in the case study database.

2.6 Research Ethics

When conducting research, it is important to have an ethical framework to lay the basis for how the research is conducted. The ethical framework should support the researcher in deciding what to do and what not to do, and also how to treat participants of the study. (Bryman and Bell, 2007)

According to Bryman and Bell (2007, pp. 132-133) and Enzer (1983), Diener and Crandall (1978) describe four ethical issues to observe when conducting research:

- avoid harm to the participants;
- get an informed consent from the participants;
- avoid forms of deception;
- avoid the intrusion of privacy and breach of confidentiality.

Bryman and Bell (2007, pp. 127-128) suggest that researchers look at the code of ethics of professional research associations. In our case, we looked at

Good Research Practice by the Swedish government agency: the *Swedish Research Council* (Swedish: Vetenskapsrådet). They take a wide look at ethics, norms and law, and the differences between them, and they summarise the ethical issues in eight rules, all of which can be categorised under the four ethical issues by Diener and Crandall (1978) above (Swedish Research Council, 2011, p. 12).

This study acknowledged these issues by getting consent from the participants, not spreading or publishing any data that can cause harm to the participants, and being truthful in both the report and during contact with the participants, which in this case means both people and companies.

One possible harm that could befall the interviewees would be if they divulged information or opinions they would not want other personnel in their company to know, because of this it was important to protect each interviewees confidentiality even inside the companies. Extra care was taken to not forward sensitive information to following interviews, even if it was interviews in the same company.

2.7 Case Study Companies

A business database of companies registered in Sweden was used to search for manufacturing companies matching the definition of large companies. The search result was used to select the companies to contact. Apart from the contact information found in the database, contact information to four additional companies was received from the supervisor at IFS. The companies that were received in this manner were looked up in the business database to ascertain their compliance with the definition of a large enterprise.

Apart from trying to find companies with different kinds of productions, the production structure was also of interest in order to build up the data for the third research question.

In total 27 companies were contacted. In those cases where the contact information consisted of the telephone number to the company reception, the receptionist was asked to connect the production manager. Of the 27 companies, the production manager or another person in a similar role was reached in 21 cases. The request was declined on five occasions. On five instances, the emails after the initial call were not returned. With the remaining 11 companies were visits scheduled and interviews during the visits planned. In most cases the interviews were planned with the production manager and a worker from the shop floor, e.g. a machine operator or an assembler.

All 11 case study companies manufactured different products, although some were more similar to each other. The companies were classified according to ISIC (International Standard Industrial Classification of All Economic Activities) Revision 4 (United Nations, 2008) which classifies the companies according to their line of business, as seen in Table 2.2. In ISIC Revision 4, the third section: C, is limited to manufacturing businesses and contains the divisions ranging from 10, manufacture of food products, to 33, repair and installation of machinery and equipment. The first two digits in the ISIC-classification represent the division. (United Nations, 2008)

Table 2.2: Basic Descriptions of Case Companies' Production

Co.	**ISIC Rev.4**	**Production**
C1	1010	Slaughter and butcher of animals
C2	1702	Manufacture of corrugated fibreboard and articles in corrugated fibreboard
C3	1702	Manufacture of articles in corrugated fibreboard
C4	2520	Manufacture of munitions
C5	2930	Manufacture of truck equipment
C6	2814	Manufacture of bearings
C7	3312	Refurbish and service of forklift trucks for rental and sale
C8	2811	Manufacture of turbines
C9	2824	Assembly of machinery for mining, quarrying and construction
C10	2819	Manufacture of heat exchangers, heating units and cooling units
C11	2732	Manufacture of electronic cables and wiring

Two companies: C2 and C3, shared the same classification as they both manufacture products in corrugated fibreboard, although the products the companies produce are different. On a similar note, four of the companies: C6, C8, C9, and C10, share the same classification division: 28, which indicates that they all manufacture machinery or equipment (United Nations, 2008).

In some cases, the study of the companies had been narrowed down to only cover a single business unit. This was a necessary limitation since some companies would have presented too large and dissimilar cases otherwise.

2.8 Interview Type

There are two major types of qualitative interviews: unstructured and semi-structured interviews. Both types offer much freedom for the interviewer to explore emerging insights and follow up on the interviewee's replies. In the unstructured interview, the researcher may start off with having just a single question written down as a starting point, probing the interviewee based on the responses and what areas that seem important to explore further. In the semi-structured interview, the researcher brings a list of questions to the interview but can still react to the interviewee's replies and ask questions that are not on the list. In multiple-case studies, the semi-structured interview is often the one used since the structure that the interviews have in common allows the researcher to easier compare the different cases and analyse the results while still being able to follow up the answers given. (Bryman and Bell, 2007, pp. 472-480)

This study used a semi-structured interview structure where the questions were constructed from the purpose and the theoretical framework. Before the first interview with a case study participant, a test interview was conducted with an ERP consultant who had many years of experience in the manufacturing industry. This test interview served as a way to check the understandability of the questions, and gave the opportunity for the consultant to suggest questions that they thought may be useful for answering the research questions.

The feedback from the test interview included both suggestions regarding the question and what to look for during the production tours where the direct observations were gathered. The suggestions about the questions were to:

- ask if and where in the production there are bottlenecks and critical areas,
- ask what the duties of the shop floor personnel involves,
- use the word rotation when referring to switching between machines,
- ask about how information is received from both internal and external sources,
- ask if mobile devices are used anywhere else in the company,
- ask if the shop floor personnel knows about how the production was measured or evaluated by performance indicators,
- ask about the nature of the workplace such as the work atmosphere and age diversity of the workers because a lower age could mean a workforce that is more accepting of new technology, and
- ask for contact details and for assent to contact them for follow-up questions.

The suggestions regarding the production tours were to:

- try to see how information is passed around (e.g. oral, paper, computers, etc.), because a lack of digital communication presents an opportunity to ask what the reasons are, and if this information could be transferred using ERP-connected devices,
- look for barcodes,
- look for computers and connected devices, and
- observe if the production work environment is dirty or noisy.

These insights increased the amount of valuable data that could be gathered from the case companies. Identifying these insights in an early stage before the interviews and observations meant that the data could be gathered from every case company.

2.9 Interview Technique

Before an interview, the researcher must consider the techniques to use. One important aspect is how the data should be captured. A recording device will capture the verbal part of the interview perfectly. However, a recording device may be intimidating, inhibiting the interviewee from answering questions to their fullest extent. The main alternative is to take extensive notes during the interview and expand on them when the interview is done. If the interviews are carried out in pairs, the researchers can critique each other and improve their interviewing technique. (Walsham, 1995)

Each interviewee was asked if they were comfortable with using a recording device during the interviews to which everyone consented. In order to lessen the risk for intimidating the interviewee as Walsham (1995) notes as a possibility, instead of using a traditional recording device to record the interviews a more common device was settled upon by the authors. Because of this, a smartphone was used to record the interviews since it is a device that the interviewees are familiar with, which also gave the interviewees a prop to use when explaining some of their answers. The recordings of the interviews were transcribed after the whole visit at each company was completed. The transcriptions were used, together with other data from the visits, to write the empirical framework.

Since the authors of this study, as well as all interviewees, spoke Swedish fluently the choice was made to conduct the interviews in Swedish. This would hopefully create a more relaxed interview situation, and the focus could be on the questions and not how to express their answers in a language they are less familiar with. In this report, the questions and the answers have been translated into English.

2.10 Interview Process and Questions

The interviews started by explaining the purpose of the study and the ethical guidelines it would be adhering to. This was followed, as mentioned above, by asking the interviewee if they were comfortable with having the interview recorded. After the recording started, the questions from the interview question manuscript were asked, as they can be found in Appendix A.

The questions were divided into three categories so that it would be easier to understand what the purpose of each question was. Each category contained questions that were constructed and structured to gather data for the analysis frameworks presented in section 3.6.

Depending on the role of the interviewee the questions took a different shape and focus. Interviews with shop floor workers focused more on the shop floor, what they themselves did in a workday and their interpretations of production strategy and market. The shop floor workers were an important source when discussing devices and applications since they would likely be the end-user and they had hands-on experience in the processes. They also gave a detailed picture of what their work role entailed. The production managers had a more detailed view of the production strategy and how the market behaved, besides app ideas for the shop floor they also gave valuable insight from a more overarching perspective of the production. The production managers were also questioned about the different roles that shop floor personnel could have in their production unit, and what their work processes were.

The end goal of the questions was to get an idea of how ERP-connected devices could be used in the enterprise to affect the effectiveness and efficiency, and to examine the function of the production strategy and production structure as well as the production role of the workers. As time progressed and interviews were completed, the interview techniques improved and more data could be gathered from the targeted enterprises. This was due to our knowledge base growing over time and because we got more comfortable doing the interviews and achieved a better connection with the interview subjects. The additional data and knowledge gained from the later interviews increased the understanding of earlier data as well, this added understanding was deemed sufficient, and the choice was made not to get back in touch with the earlier companies.

2.11 Direct Observations Process

At each company, the production area was shown to provide direct observations. When scheduling the visits, the plan proposed to the production managers was to let the interviews precede the production tour. On several occasions, this plan was altered to fit the studied companies' schedules. Alterations to the plan were made at C4, C6, and C11, where the production tour preceded the interviews. The observations were performed between the two interviews in the cases of C3, C5, and C7.

2.12 Process and Analyse Empirical Data

In between and after the interviews and visits to the production facilities, the data collected was processed. The process of going through the data involved discussing and writing down the observations and the impressions that the authors had gotten. Close after each visit, often the same day but at most within a week, the interviews were transcribed. The data was organised based on the company but was kept together with the data from the other companies.

The data was analysed as it is described in the next chapter, more specifically in section 3.6. The data from the analysis was organised in spreadsheets to make it easy to overview. These spreadsheets laid the ground for some of the tables found in the analysis chapter.

Theoretical Framework 3

This chapter presents the theoretical frameworks leading up to the analysis framework used in this study. The chapter is concluded by a description of how the theories were used to form the analysis framework and which research questions they were meant to answer.

3.1 Production Strategy

One of the research questions in this study was: how the production structure and production strategy affect the need, in a production environment, for ERP-connected devices. This presents the question of how to identify the production structure and strategy in a manufacturing company in a way that allows comparison between companies.

To better understand the strategic situation and potential in a manufacturing company or business unit, the production can be classified in a two-dimensional matrix by matching the process life cycle and the product life cycle, see Figure 3.1 by Hayes and Wheelwright (1979). The process life cycle indicates the way in which the production process is structured and how the product moves from process to process, from job shop where there is a high flexibility and the equipment can do general tasks, to continuous flow with specialised equipment and low flexibility. The product life cycle refers to both the standardisation and the production volume of the product, going from low volume production of highly customised products to high volume production of standardised products. Production tends to align along the diagonal or in proximity to it. When production moves away from the diagonal, it may be as part of a differentiation strategy to be used as a competitive advantage. However, in the far corners from the diagonal, where high volume products are produced in job shops and low volume products are produced in a continuous flow, the production is economically unsustainable. (Hayes and Wheelwright, 1979)

Even though Hayes and Wheelwright (1979) provide a general model, it does lack concrete empirical backing in the original article. Helkiö and Tenhiälä (2013) found that empirical studies that examined the article had mixed results. Helkiö and Tenhiälä (2013) reworked and extended the model, followed by testing their model with data from 151 manufacturing plants. They found evidence, in the literature that had followed the original article, that pointed towards three new dimensions instead of the two dimensions of Hayes and Wheelwright (1979).

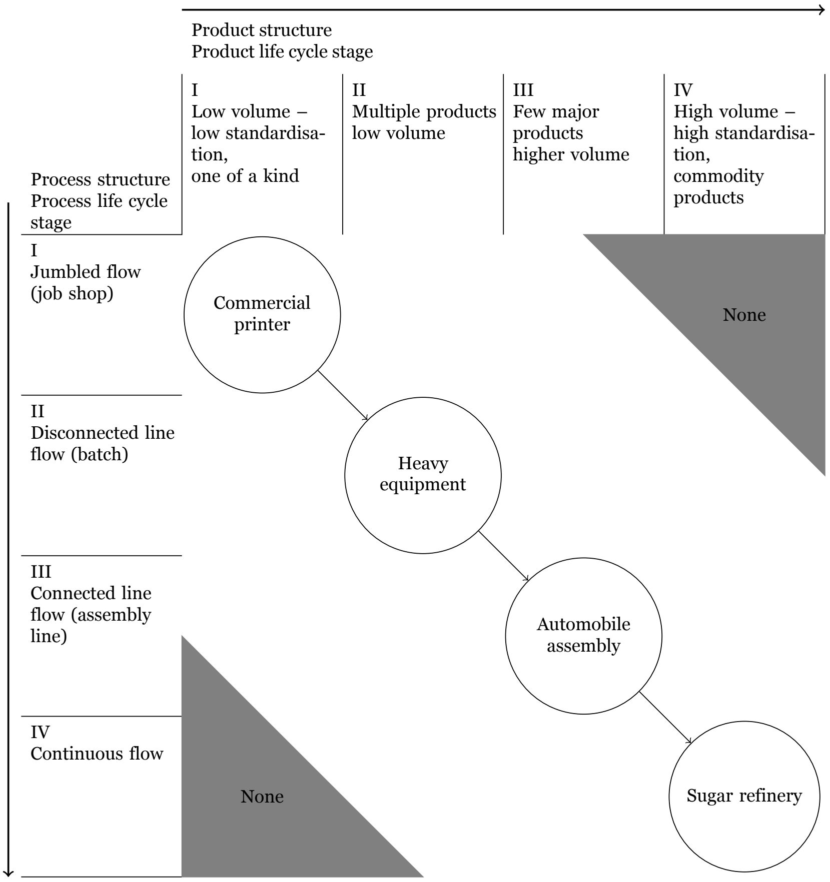

Figure 3.1: The Product-Process Matrix (Hayes and Wheelwright, 1979)

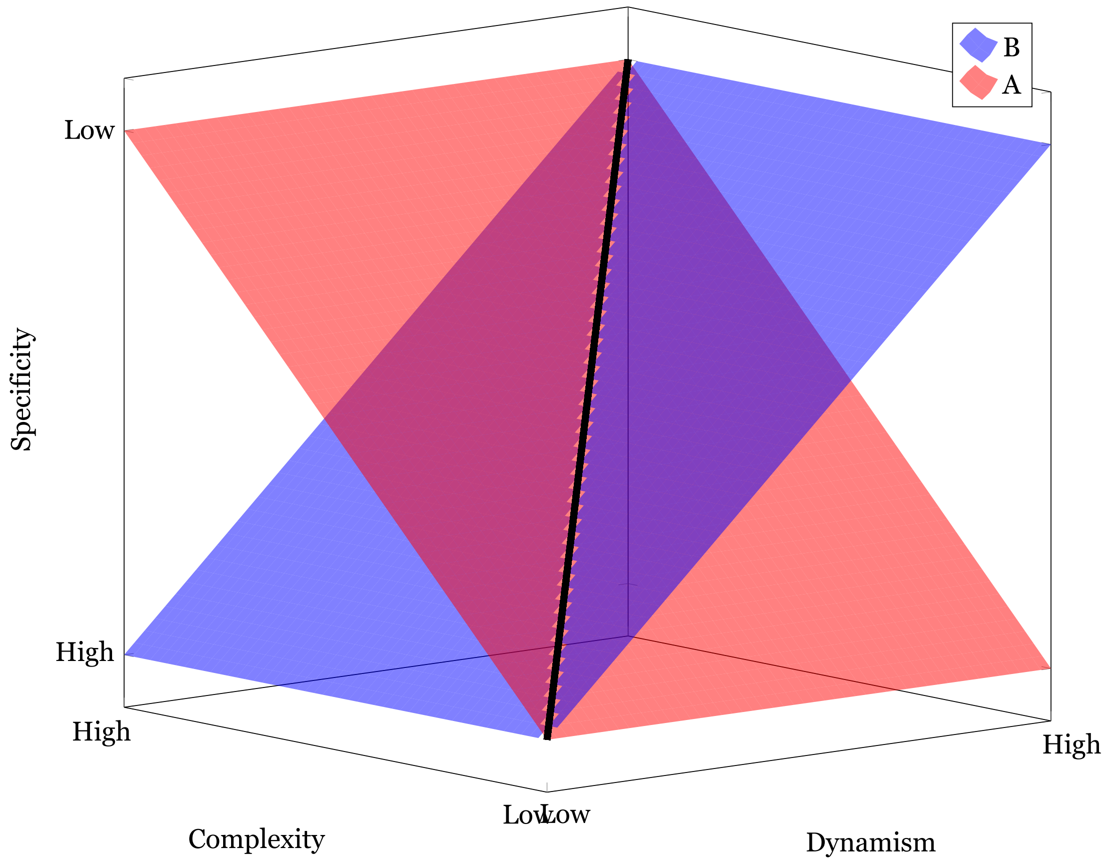

Figure 3.2: The CSD model (Helkiö and Tenhiälä, 2013)

The new model, known as the *Complexity-Specificity-Dynamism* (CSD) model, replaces the product dimension with the complexity dimension to account for how diverse and complex the products may be as well as the variety of the products manufactured. The value of this dimension can be decreased by simply decreasing the number of parts in a given product or by outsourcing some production in order to decrease the internal complexity. The model also exchanges the process dimension for the specificity dimension in order to take the flexibility of the production process resources into account, meaning how limited they are only to produce a certain product. Lastly, the model adds a third dimension, dynamism, which represents the rate at which the market requirements are changing. (Helkiö and Tenhiälä, 2013)

Complexity, specificity, and dynamism would, thus, cover the general characteristics of the products manufactured, the processes used in the manufacturing, as well as the influence the market has on the company, respectively.

The CSD model, as seen in Figure 3.2, has two planes in relation to the three dimensions. These planes are derived from a multiple regression analysis on the data from the study by Helkiö and Tenhiälä (2013). Companies on plane A and positions close by had good ”delivery performance”, and companies on plane B and positions close by had good ”product performance”. The equilibrium between ”delivery” and ”product performance” is found at the diagonal, where the planes intersect. Being in this equilibrium would maximise ”delivery” and ”product performance”, resulting in the most advantageous position in the model. (Helkiö and Tenhiälä, 2013) This would mean that companies that position themselves close to the planes are more likely to have competitive advantages concerning either ”product performance” or delivery performance”, compared to companies that are not close to the planes.

Helkiö and Tenhiälä (2013) builds upon the model by Hayes and Wheelwright (1979) and extends it, in order to take into account more factors that influence the production strategy. Using the CSD model, instead of the model by Hayes and Wheelwright (1979), has the benefit of taking these additional factors into account and adds more detail to the description of a company’s production strategy. The choice was made to use the CSD model in order to present a more comprehensive situation description for each of the companies. The CSD model also provides a comparative model of the production strategies at the participating companies.

3.2 Personnel-Centric CSD Model

The way Helkiö and Tenhiälä (2013) presents the CSD model, it introduces specificity as a dimension to define the versatility of the resources in the production. One resource employed in production is personnel. The authors of the current study, we present a modified CSD model to focus on the users of ERP-connected devices, i.e. the personnel in the companies. This personnel-centric CSD model, utilises the same dimensions as the CSD model by Helkiö and Tenhiälä (2013), with slight changes to what is analysed in each dimension. The purpose of focusing on the personnel in this model is that it opens up the possibility to compare the situation between and within companies and business units from a personnel-centric viewpoint.

The complexity dimension in the CSD model by Helkiö and Tenhiälä (2013) can be said to analyse the complexity in what the company is doing, i.e. the products and the work tasks. The complexity dimension in the personnel-centric CSD model analyses a person's complexity in their work processes, i.e. what they are doing. An aspect that is taken into account is whether their work is hands-on or monitoring, a person working more hands-on are likely to experience a more complex task. An increasing number of tasks and whether these tasks are standardised would also increase the complexity. Similarly a person with many responsibilities, for instance a manager, who has more responsibilities than say an assembler, would face a more complex workday. A greater amount of tasks and responsibilities that a person manages is comparable to a greater amount of production steps in a production facility; both would increase complexity.

When looking at the specificity dimension, the most influential aspects are mobility and whether the work tasks are recurring. A stationary person has a higher specificity due to the person's work being specific to one particular spot. If the person is involved in recurring tasks, the person can be seen as being specific to that task. It should be noted, however, that even if a task is recurring the task in itself can be more or less specific. A maintenance worker might always be performing maintenance tasks, how the maintenance is performed can vary greatly depending on the machines and errors that are present. The specificity in the personnel-centric CSD model differ a bit from how Helkiö and Tenhiälä (2013) defines specificity in their CSD model, the overarching aspect of flexibility is still present, however, the way one considers the flexibility of a person are different from how one thinks of flexibility for a company.

When looking at a person's role in a company using the personnel-centric CSD model, the complexity dimension analyses *what* the person does, the specificity analyses *where* and *how*. The final dimension is dynamism. In the model by Helkiö and Tenhiälä (2013), dynamism is how the market influences the company, how the market behaves is not something the company alone can influence and thus it has to adapt to the market's changes. Dynamism in the personnel-centric CSD model is similar in that it analyses the degree to which a person is affected by outside forces, which leads us to the following definition.

Looking at the dynamism dimension from a personnel-centric viewpoint the scope changes to include internal factors within the company, but only those that are outside the direct influence of the shop floor personnel. A high dynamism would correspond to a person whose work is often influenced by outside factors that are difficult to plan for; a low dynamism would be a person who always do the same work tasks no matter what happens around them. To give an example, a maintenance worker who is doing reactive maintenance and repairs, receives tasks when machines break, or they get notified from other shop floor workers. These are events that the maintenance worker can not plan for. Because his work day is entirely comprised of these events, his dynamism would be high.

The Personnel-Centric CSD model is henceforth abbreviated as the P-C CSD model. This modified version of the CSD model was intended to provide a means to compare the personnel situation between companies and business units as well as in different roles.

3.3 Flexibility

Flexibility was an aspect that occurred in several articles and in the goal dimensions used to evaluate the impact on effectiveness and efficiency. Articles regarding both ERP-connected devices as well as manufacturing companies discussed the impact of flexibility and ways to alter it, hinting that flexibility might be an aspect that influences both of those two subjects.

The manufacturing environment is growing increasingly complex, making the shop floor workers' responsibilities more difficult, and increasing the need for effective communication mechanisms (Morkos et al., 2012; Hao and Helo, 2015). With fast changes in customer expectations and competition, the need to manage the uncertain environment is further reinforced, with one option being to improve an enterprise's flexibility (Zhang, Vonderembse and Lim, 2003). Park (2015) says that personnel need accurate and timely data to manage unexpected events in the production process and that mobile devices offer the possibility to expedite this transfer of data.

Flexibility can be thought of as having three dimensions: range, cost, and time. The range in flexibility tells how many different states a system can take, the more states, the higher flexibility of the system. The cost dimension simply describes the cost of a state change and the temporal dimension concerns the speed of which the changes in states occur. (Slack, 1983) In a manufacturing environment, an example of flexibility can be the ability to produce two different items. In the example there are two states, the machines can be set to produce either item, the cost and time dimensions are the cost incurred and the time spent setting up the machines to produce the other item. Altered flexibility impacts the flexibility goal dimension presented by Reijers and Liman Mansar (2005). Using the definition of flexibility by Slack (1983) it could also affect the time goal dimensions, making it important to define how and to what extent flexibility affects the goal dimensions.

A strategy utilising flexibility is a topic discussed together with production strategy and production structure in a cross-sectional study of 47 companies by Theodorou and Florou (2008) where it seemed that flexibility is almost a necessity, and Ortega Jimenez et al. (2015) noted a trend in production strategy to increase flexibility. Gerwin (1993) also discuss flexibility as a way of managing uncertainty; he does, however, go on to warn about the costs of focusing too much on flexibility and that the academic literature may have neglected to consider the negative aspects of increased flexibility. A similar point is brought up in a literature survey by Reijers and Liman Mansar (2005) that also show how increased flexibility can affect the cost in a negative way.

To alter flexibility in a manufacturing enterprise Zhang, Vonderembse and Lim (2003) presents four manufacturing competencies geared towards flexibility:

Machine Flexibility

The ability to quickly change what to produce, to reduce downtime, and alter the rate of production.

Labour Flexibility
The ability of workers to quickly change and get up to speed when changing what to manufacture.

Material Handling Flexibility
The ability to alter the speed and method of moving products.

Routing Flexibility
The ability to find and use new routes in the production facility to use idle capacity and to increase output variety.

In a study with 273 manufacturing enterprises by Zhang, Vonderembse and Lim (2003) strong links were discovered between an improvement of the flexible competencies, and increased volume and product mix flexibilities. Increased volume and product mix flexibility in turn, had a strong relationship with improved customer satisfaction (Zhang, Vonderembse and Lim, 2003). Volume flexibility concerns the volume of products that the enterprise can produce within a time limit and the product mix flexibility is the breadth of products an enterprise can manufacture within a time limit (Slack, 1983).

The product mix flexibility influences the complexity dimension of the CSD model since increased product mix flexibility translates to a higher complexity. Gerwin (1993) discussed how enterprises that have a low product mix flexibility, and instead uses focused manufacturing would be vulnerable to changes in the market. This fits with Helkiö and Tenhiälä (2013) and the CSD model that proposes the optimal situation where complexity and dynamism has a similar value. The manufacturing competencies of machine, labour and routing flexibility presented by Zhang, Vonderembse and Lim (2003) relates to the internal manufacturing processes of an enterprise and the output of those processes, affecting the enterprise's position on the specificity axis. A high range in machine and labour flexibility gives a lower specificity since machines and shop floor workers can alter their processes to manufacture different products.

Åkerman et al. (2016) argues that there is a need for flexibility in the manufacturing industry and that one of the tools to achieve increased flexibility is through the use of Information and Communication Technology in the form of mobile devices.

3.4 Information Technology and ERP-Connected Devices

Investments in technology often fail to achieve what they set out to accomplish and are often criticised for it. For investments to be worthwhile, manufacturing plants must take into account the different aspect of the production practises. For instance, the production strategy appears to play a significant role when deciding if a technology should be implemented. (Garrido-Vega et al., 2015) Carr (2003) is a critic of IT expenditure in organisations, saying that companies should spend less on IT investments and follow the competitors instead of trying to have cutting edge IT. This view is disputed by Brown et al. (2003) that proposes that even though IT in itself does not give a competitive advantage, the knowledge of how to use it strategically can. Manufacturing companies with a clear linkage between their business strategy and production strategy have a greater chance of effectively implementing new technologies into their manufacturing plants (Garrido-Vega et al., 2015).

Mobile information systems can appear in many forms in an organisation; they can be ubiquitous through the use of wearable devices (Hao and Helo, 2015; Morkos et al., 2012; Thorvald, Högberg and Case, 2014; Fallman, 2010), they can take the shape of mobile devices such as handheld devices (Morkos et al., 2012; Valiente and Westelius, 2007). Information systems can also support mobility in the form of stationary technology supporting mobile work (Fallman, 2010). Originally the goal dimensions used by Hoos et al. (2014) cover one additional dimension apart from time, flexibility, and quality, and that is the dimension of cost. However, Hoos et al. (2014) goes on to say that a cost analysis would require a thorough investment analysis which is why in Hoos et al. (2014) research the cost is disregarded. This provides us with improvements in the three goal dimensions:

1. execution time,
2. the quality of activities or processes, or
3. the flexibility of an actor or process.

In a manufacturing environment, the actors within it may want different things from a mobile information system. Shop floor workers may be limited to information pertaining to their specific activity in a line, and a manager may want to have information about all processes and activities they are managing. (Fang, Huang and Li, 2013)

Several of the flexibility competencies in section 3.3 can be enhanced through the use of mobile information systems. Mobile devices present the opportunity to get notifications regarding machine faults instantly or to present updated information to both managers and shop floor workers (Müller, 2005; Thun, 2008). Faster reactions regarding machine shutdowns can reduce downtime and thus increase machine flexibility.

The labour flexibility can be increased through mobile devices as well. Shop floor workers can get instructions and support through the mobile device to aid in their learning and day to day work (Thun, 2008; Fallman, 2010). In a study by Thorvald, Högberg and Case (2014), it was discovered that the study participants produced items of a higher quality, as measured by amount of assembly errors, when using a mobile information source compared to using a stationary source further away, the participants were also more likely to use the information system when it was more accessible to them.

According to Kinauer and Müller (2014), to use mobile devices strategically an enterprise should ensure that the devices and applications are integrated into the back-end systems, such as ERP systems, and ensure that there are support systems in place for the devices.

3.5 Mobile Device Analysis Framework

When developing and using mobile IT, several aspects need to be considered that are not present in stationary IT (Andersson and Henningsson, 2010). Andersson and Henningsson (2010) present a framework called the AUDE framework, which stands for *Application*, *User*, *Device*, and *Environment*. The application aspect is the service or functionality that the application provides. The device aspect focuses on what mobile device best fit the task, along with the technical limitations and opportunities that present themselves. The user aspect concerns the user in terms of mobility and in what context the person require the mobile IT. The environment aspect looks at the organisational structure that exists around the user and the mobile devices. (Andersson and Henningsson, 2010)

The AUDE framework is first and foremost directed towards system developers, Andersson and Henningsson (2010) does, however, go on to say that these are aspects that need to be managed in order for mobile IT to be advantageous in an enterprise. There are enough similarities between the AUDE framework and other frameworks directed towards adoption and use of technology that the argument can be made that the AUDE framework can be useful for the adoption of new technology. DePietro, Wiarda and Fleischer (1990) present three elements that influence the adoption and implementation of new technology: the organisational, the technological, and the environmental context. The environment context is the environment around the enterprise, the situation in the industry and the forces that act on it (DePietro, Wiarda and Fleischer, 1990). The organisational context in turn is the context within the enterprise, the human resources and organisational structure (DePietro, Wiarda and Fleischer, 1990). Finally, the technological context is the technologies relevant to the firm, both technologies already in use and those that are available to them (DePietro, Wiarda and Fleischer, 1990).

Hoos et al. (2014) present three issues that are similar to what is brought up in the AUDE framework, and need to be dealt with in order for an implementation of mobile technology to be worthwhile:

Potential of mobile technology
: Does a business process have the potential to be improved by mobile technology?

Type of mobile devices
: What type of mobile devices is the best fit for the process?

Holistic point of view
: Are there any infrastructural or organisational issues that need to be considered?

When analysing whether the business process can be improved by mobile technology the aspects to look at are: how mobile the activity or actors are, if the activity has information requirements that are digital or can be digitised, and if the quality of the activity is improved from functionality in a mobile device (Hoos et al., 2014). When looking at which type of device to use, one of the more distinct difference from a stationary computer is the input and output methods, which can differ between mobile devices as well (Andersson and Henningsson, 2010; Hoos et al., 2014). The environment in which the mobile technology is to be used can present problems. These can come in the shape of infrastructural issues, policies or organisational rules that hinder the implementation (Hoos et al., 2014).

The environment presented by Andersson and Henningsson (2010) and Hoos et al. (2014) focuses on the factors inside of an organisation, similar to the organisation context by DePietro, Wiarda and Fleischer (1990). Both Andersson and Henningsson (2010) and Hoos et al. (2014) forgoes the environment around the organisation, which DePietro, Wiarda and Fleischer (1990) calls the environment context. The device aspect in the AUDE framework can be considered as a more narrow technological context.

The analysis in this study was structured using the AUDE framework. The three issues by Hoos et al. (2014) formed a basis from which the mobile technology was analysed and the goal dimensions: *Time*, *Quality*, and *Flexibility*, helped to analyse the business process improvement possibilities and to answer the research question of how mobile devices can increase effectiveness and efficiency.

In the AUDE framework, the environment is more similar to the organisational context rather than the environment context presented by DePietro, Wiarda and Fleischer (1990).

3.6 Analysis Framework

The analysis framework used in this study combines the AUDE framework with both the CSD model and the P-C CSD model. Below, each research question is restated followed by a description of how the analysis process to answer it was be conducted.

1. How can ERP-connected devices affect effectiveness and efficiency in a production environment?

Using the *Application*, and *Device* aspects of the AUDE framework made it possible to analyse ERP-connected devices. Using the goal dimensions of execution time, flexibility, and quality, presented by Hoos et al. (2014) the devices could be analysed on how they affected effectiveness and efficiency in the production environment.

2. How does the role of the production personnel affect their need for ERP-connected devices?

The *User* aspect of the AUDE framework used the P-C CSD model in order to group the different roles. By grouping similar roles and identifying their positioning in the P-C CSD model, comparisons could be made between companies and roles. To identify each role's position, questions were asked regarding the nature of their role. To find out the complexity data was gathered about the complexity of their work tasks, for specificity data was gathered about how mobile they were and how many different work tasks could they perform, and finally for dynamism to what degree their workday changed due to factors they had no control over.

3. How do the production structure and strategy affect the need, in a production environment, for ERP-connected devices?

The *Environment* component of the AUDE framework focused on the internal factors of the company. However, the external factors that affect a company may also affect the need for EPR-connected devices, an argument that DePietro, Wiarda and Fleischer (1990) support by having their environment context to analyse the external factors. By combining the two views on the environment, the CSD model by Helkiö and Tenhiälä (2013) can be used since complexity and specificity analyse internal factors and dynamism analyses the external factors. Thus, the environment aspect of the AUDE framework was analysed using the CSD model. Similar to the P-C CSD model, data was gathered to identify each company's position in the dimensions of complexity, specificity, and dynamism. The complexity of a company depends on the complexity of the products manufactured and of the work tasks, for instance, a company with products containing many subparts or that requires specialised machines or means of production would have a high complexity. For specificity the output of the processes was analysed, companies that only could produce one or few different products would classify as having high specificity. Finally, the dynamism was analysed by asking questions regarding the changes in market demand, for instance if the market changed often and rapidly, and if the changes were in volumes or type of product.

In Figure 3.3, the analysis framework based on the AUDE framework can be seen along with the models that were used to analyse each area.

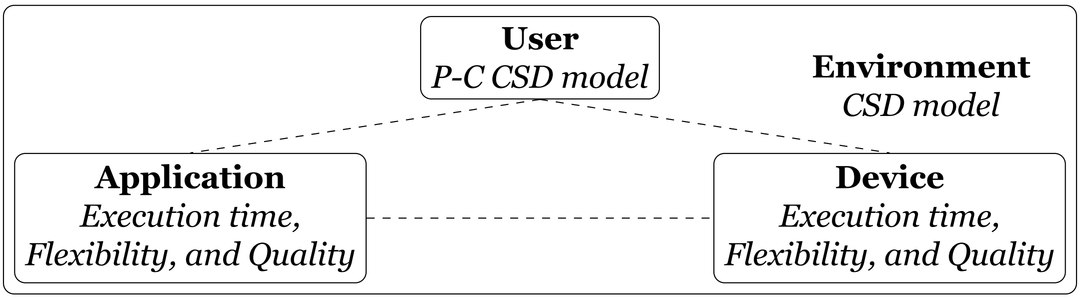

Figure 3.3: The analysis framework, based on the AUDE framework (Andersson and Henningsson, 2010)

4 Empirical Framework

In this chapter, the empirical data gathered during the interviews and production tours while visiting the companies is presented.

The data for each company is sorted under three headings, each connected to a research question. Under *Production*, the production and processes are described. These descriptions were used to analyse the production strategy and production structure of each company. *Roles* contains descriptions of the roles that were mentioned during the interviews or observed during the production tour. The analysis of each role was based on this data. *ERP-Connected Devices and Applications* contains information about the devices and applications in use at the companies, as well as those that were suggested during the visits by the interviewees. Both the applications and devices in use, as well as those suggested, were evaluated and analysed to find out how they affect the efficiency and effectiveness of the company.

Table 4.1: Descriptions of Case Companies' Production and Production Structure

Co.	Production	Production Structure
C1	Slaughter and butcher of animals	Connected line flow
C2	Manufacture of corrugated fibreboard and articles in corrugated fibreboard	Disconnected line flow
C3	Manufacture of articles in corrugated fibreboard	Disconnected line flow
C4	Manufacture of munitions	Jumbled flow
C5	Manufacture of truck equipment	Connected & Disconnected line flow
C6	Manufacture of bearings	Connected line flow
C7	Refurbish and service of forklift trucks for rental and sale	Jumbled flow
C8	Manufacture of turbines	Jumbled flow
C9	Assembly of machinery for mining, quarrying and construction	Connected & Disconnected line flow
C10	Manufacture of heat exchangers, heating units and cooling units	Jumbled flow
C11	Manufacture of electronic cables and wiring	Disconnected line flow

The eleven companies, their production and production structure can be seen below in Table 4.1. The interviewees of the study, their roles and a denotation,

Table 4.2: Interviewees by company and role

Co.	Person	Role
C1	P1-1	Production Manager
	P1-2	Foreman
C2	P2-1	Operations Manager
	P2-2	Machine Operator
C3	P3-1	Supply Chain Manager
	P3-2	Plant Manager
	P3-3	Foreman and Quality Controller
C4	P4-1	Application Manager
	P4-2	Production Manager
	P4-3	Production Planner
C5	P5-1	Business IT Manager – Supply Chain
	P5-2	Team Leader
	P5-3	Production Planner
	P5-4	Production Engineering Manager
C6	P6-1	Production Manager
	P6-2	Machine Operator
C7	P7-1	Plant Manager
	P7-2	Technical Surveyor
C8	P8-1	Production Planning Manager
	P8-2	Production Planner
	P8-3	Production Planner
	P8-4	Production Manager
C9	P9-1	Production Manager
	P9-2	Business Controller
	P9-3	Assembler
C10	P10-1	Operations Manager
C11	P11-1	Machine Operator
	P11-2	Logistic Supervisor

sorted by their company, can be found in Table 4.2. The denotation is used when referring to the interviewee in the text and is structured to help the reader to see which company the interviewee belonged to.

4.1 Company 1

The main production of Company 1, C1, was slaughter and butcher of animals using a connected line flow. The interviewees at C1 consisted of two persons: the production manager, P1-1, and a foreman, P1-2.

4.1.1 Production

The studied part of the production at C1 was the butchering of animals, followed by the packaging of the meat. The animal arrived skinned and cut into quarts, hanging from a hook in the ceiling.

At the first station, the quart was moved from the hook and a barcode on it was scanned. The quart was then cut into smaller, yet rough, pieces by a butcher. These pieces were put on a connected line that delivered the meat to the second station, to another butcher. At the second station, the butcher received ranked suggestions to what kind of meat they would cut the meat into. The butcher selected a suggestion, cut the meat accordingly and put it on another connected line. The leftovers were put on a separately connected line. The second station had a fixed limit on how much meat that could be in the queue, which occasionally meant that the first station had to wait before continuing their work.

The meat was carried away by the connected line towards packaging. In some cases, before it arrived at packaging, it was sent for a spot check by the quality controller. They conducted random spot checks with the information about what kind of meat cut it should be, but without the information about who had cut the meat. After they had judged the meat, they received information about who had cut the meat in order to give feedback to the butcher. If the meat of a single butcher did not pass the check multiple times, the quality controller had the option to check all the meat of that butcher.

If the meat was spot checked and passed, it continued on the line towards the packaging. At the packaging, it was put into different containers or packaging depending on the intended customer.

At each of the manned butcher stations, there was a fixed display connected to the ERP system. To use the system the worker had to log on to the device using a personal, physical token. Apart from the displays at the workstations, the connected line was connected to the ERP system as well. When the butcher placed the meat on the conveyor he input the cut into the ERP system, dividers will lower or raise as it travels along the line so that it ends up at the correct packing station. This way the system itself was able to control to what stations the meat arrived and furthermore it enforced the traceability required in the industry since it stored each meat's journey through the facility and who had done the operations on the cut.

4.1.2 Roles

During the interview, four roles were discussed: production manager, foreman, butcher and quality controller.

Production Manager The production manager was often stationary in the office and used a desktop computer to access the ERP system.

Foreman The foreman was often stationary in the office and used a desktop computer to access the ERP system; they were considered a support function for the production.

Butcher The butcher was stationary at a workstation, but could use any workstation by signing on with their personal token. By signing on or off, the worker could move to any station and still be able to conduct their work, which could sometimes be demanded when a station or a line got contaminated or broke down. A small subset of the butchers was more mobile and switched between the first and second stations in the butchering process, in order to minimise queues and wait times between the stations. They interacted with the ERP system using the fixed display at the workstation.

Quality Controller The quality controller was stationary at a workstation located at one of the three connected lines. They interacted with the ERP system using a fixed display at the workstation showing information about the meat they were inspecting.

4.1.3 ERP-Connected Devices and Applications

The devices along the connected line were fixed displays, which the butchers signed on to using a personal RFID token. A similar setup was used by the quality controller. P1-1, the production manager, and P1-2, the foreman, both interacted with the ERP system using computers in their offices.

P1-1, the production manager, informed that the butchers received information about their personal daily throughput at the end of the day in a text message sent to their phone.

P1-2, the foreman, were of the opinion that there were no areas where the use of other kinds of mobile devices could be used.

4.2 Company 2

The main production of Company 2, C2, was manufacture of corrugated fibreboard and articles in corrugated fibreboard using a disconnected line flow. The interviewees at C2 consisted of two persons: the operations manager, P2-1, and a machine operator, P2-2.

4.2.1 Production

At C2, the incoming raw material was rolls of paper at a width of more than two metres. These rolls were used in a machine with the capacity to manufacture a variety of corrugated paperboard. It was possible for the machine operators to alter the characteristics of the corrugation, as well as the cuts of the paperboard. The duties of the operators at this stage involved setting up the machine, monitoring, and loading new rolls of paper into the machine while it was running to avoid stops.

The corrugated paperboard was moved on pallets to other machines at which it was screen printed and folds were cut. The duties of the operators at these machines involved setting up the machine and monitoring the process. At each of these machines, the operators had access to a stationary computer through which they accessed the ERP system and the orders. At these machines, there was a panel of buttons to update the production status of the machine in the ERP system. The system switched automatically between two statuses: setting up and running.

The finished packages were moved to storage by warehouse workers using forklifts. In the forklifts, there were ERP-connected computers with barcode readers to scan barcodes off the pallets with the finished products.

4.2.2 Roles

The roles discussed during the interviews at C2 were the following: operations manager, machine operator, warehouse worker, and screen changer.

Operations Manager The operations manager was stationary in their office where a computer connected them to the ERP system and provided a real-time overview of the production.

Machine Operator The machine operator was mobile around their machine, because of its size it was necessary to be able to move around it. They interacted with the ERP system through a stationary computer at the machine.

Warehouse Worker The warehouse worker was mobile using their forklift trucks, which were equipped with ERP-connected computers. Using a barcode reader connected to the computer, they could find the pallets in the system.

Screen Changer The screens used to print were brought to and from the machines by the screen changer, who also managed the storage of them. At the storage, they accessed the ERP system to see the machine planning and status, as well as to see which screens would be needed. The screen changer was mobile in their work.

4.2.3 ERP-Connected Devices and Applications

During the interviews neither P2-1, the operations manager, nor P2-2, the machine operator, presented any applications were ERP-connected devices could be used in the production. At the time of the interview, there were no mobile devices in the production apart from the somewhat mobile forklift computers. P2-1 said that the forklift computers had slowed down the work of the warehouse workers. The warehouse workers needed to get specific pallets for orders instead of the closest one, which meant increased travel time. They had also encountered issues where the barcodes were covered up and required the warehouse worker to exit the forklift to get the barcode manually, issues that over time would hopefully disappear once the personnel were more familiar with the new processes. P2-1 still considered the forklift computers as a useful tool since it allowed them to know where each product currently was in the inventory, and overall, more detailed data regarding the inventory.

At the production tour, a direct observation was made identifying a possible application of an ERP-connected device. The application was for the screen changer to use an ERP-connected device to access data from the ERP system on the move.

The screen changer was often moving around the facility in order to transport and change screens; this could present moments where machines needed new screens but the screen changer was out on the shop floor, away from the computer. If the screen changer could access information regarding the shop floor, while mobile, the screen changer could be proactive instead of reactive. In times where there is urgency, being reactive, instead of proactive, could cause delays.

4.3 Company 3

The main production of Company 3, C3, was manufacture of articles in corrugated fibreboard using a disconnected line flow. The interviewees at C3 consisted of three persons: the supply chain manager, P3-1, the plant manager, P3-2, and a foreman who also had the duties of a quality controller, P3-3.

4.3.1 Production

C3 manufactured printed corrugated paperboards for advertisement signs, as well as printed displays in corrugated paperboard. The production varied depending on the type of product, print and the quantity of the order.

The incoming corrugated paperboard was either put into a screen printer or a digital printer. The machine operators at a screen printer had to configure the printer based on the order. At a digital printer, they had to start the printing job based on a digital file. During the execution of the orders, the operators duties mostly involved monitoring the machine.

Reporting of the order and machine status was made at stationary computers located close by the machines.

4.3.2 Roles

Five roles were discussed during the interviews and the production tour: supply chain manager, plant manager, foreman, quality controller, and machine operator.

Supply Chain Manager The supply chain manager mainly worked from their office but they used a laptop enabling them to be partially mobile.

Plant Manager The plant manager had a similar work situation to the supply chain manager.

Foreman The foreman was partially mobile and was sometimes called to the shop floor. They used a laptop to access the ERP system.

Quality Controller The quality controller had similar work tasks as the foreman. The reason for being called to the shop floor could be related to quality concerns that the machine operators discovered in their work.

Machine Operator The machine operator was mobile around their machine because of its size. They reported information to the ERP system in computers distributed among the machines.

4.3.3 ERP-Connected Devices and Applications

At the time of the interviews, C3 did not use any mobile devices in the production apart from laptops within the production management.

Although none of the interviewees saw any need for ERP-connected devices on the shop floor, they all identified the need for less physical data. Using digital data would allow the personnel to always work with the most up to date information. One example given was to only include a barcode with the shop order, which would link to the most current instruction on a digital platform. At each station the personnel would scan the barcode, which would result in the instructions being shown on a screen close by. This suggestion had its roots in the want to minimise the risk of human error and obsolete instructions.

4.4 Company 4

The main production of Company 4, C4, was manufacture of munitions using a jumbled flow. The interviewees at C4 consisted of three persons: the application manager, P4-1, the production manager, P4-2, and the production planner, P4-3.

4.4.1 Production

The production at C4 was conducted in a hands-on manner, with the exception of some tests which were automated but still required a setup. The incoming materials were semi-manufactured materials which were assembled and tested. The tests took on average more time than the actual assemblage.

Because of the low order quantities, the personnel at the assembly and testing had the knowledge to work in different parts of the production.

4.4.2 Roles

During the interviews and the production tour at C4, five roles in the production were discussed. These roles were: production manager, production planner, assembler, tester, and warehouse worker.

Production Manager The production manager was mostly stationary and worked in an office setting.

Production Planner Similar to the production manager, the production planner was mostly stationary and worked in an office setting.

Assembler The duties of the assembler involved steps of the assemblage of the products and in some instances conducting tests of the products. If there were no work at the station of the assembler, or if an automated test was running, then they could go to another station to conduct other tasks.

Tester The tester carried out tests of the components of the product or the finished product. The tester was often stationed at one workstation but also moved around in the test laboratory.

Warehouse Worker The warehouse workers used forklifts to transport the materials around the production facility, the warehouse workers were mobile.

4.4.3 ERP-Connected Devices and Applications

Due to secrecy concerns required in the industry and requirements when handling some materials, C4 did not use any mobile devices. Before mobile devices could be used in parts where only secure materials were handled, absolute data security had to be ensured.

P4-1, the application manager, expressed that a drive for wanting to use mobile devices in production was to increase effectiveness and to lower the risk for faulty data. They also said that the personnel were used to mobile devices, which they used at home, and seemed to want mobile devices in the production to some degree. During the tour of the facility, an assembler noted that it would be convenient to use a smartphone to assist in the work. The assembler wanted a mobile and lightweight unit to report data into the ERP system.

Especially in the warehouse P4-1 saw a strong need for mobile devices, to log changes in inventory. The devices would have to be some kind of tablet for the system to be easy to use by the warehouse workers.

4.5 Company 5

The main production of Company 5, C5, was manufacture of truck equipment using both a connected and a disconnected line flow, for different parts of the production. The interviewees at C5 consisted of four persons: a business IT manager focused on supply chain, P5-1, a team leader, P5-2, a production planner, P5-3, and the production engineering manager, P5-4.

4.5.1 Production

In the production of C5, parts for the finished products were manufactured in automated processes where robots loaded the materials into and out from the machines. At the automated stations, the duties of the machine operator involved starting and stopping the process, monitoring the process, moving racks of new materials to the enclosed area and moving racks of finished parts from the area.

The parts were welded and painted by shop floor personnel. The processes were organised into stations on the shop floor. The final assembly was conducted on a connected line, which had been installed weeks before the visit to the facility.

4.5.2 Roles

During the interviews and the tour in the production facility the following five roles were discussed or observed: team leader, production planner, production engineering manager, machine operator, and assembler.

Team Leader The team leader was a regular shop floor worker with team leader responsibilities for their team. The team leader worked along their colleagues with welding and painting of parts. The work required the use of their hands and was limited to a particular area on the shop floor.

Production Planner The production planner worked with production planning and follow-up of the planning. They worked from a desktop computer and their work required multiple computer screens to show all data.

Production Engineering Manager The production engineering manager was responsible for the technical solutions in the production. They were often located in their office or meetings.

Machine Operator The machine operator was responsible for moving parts on racks to and from the machine, as well as setting up and starting the orders. They were sometimes stationed between two machines to control and monitor both machines. Apart from the moving of products, they were stationary at the machine.

Assembler The assembler worked with product assembly at a connected line. All tools and resources needed were found at the stations at the line. The products were moved automatically after a fixed takt time.

4.5.3 ERP-Connected Devices and Applications

The shop floor personnel at C5 reported their information in the ERP system on computers located on the floor. Some information was automatically sent to and from the machines on the shop floor.

P5-4, the production engineering manager, discussed the possibility to use smart watches, a wearable device located on the wrist, as a means to get instant notifications for workers with tasks that demand the use of their hands. They also wanted more information to be sent from the machines about the operations status and failures.

P5-1 and P5-2, the business IT manager and team leader respectively, were interested in having notifications about machine failures and when maintenance was required. P5-2 was optimistic about using mobile devices on the shop floor, first and foremost to increase quality, traceability, and to eliminate errors. The reasoning was that a mobile device would allow the machine operators and assemblers to input what they had done into the ERP system, wherever they were, in an easy to use application. This would remove paper based reporting, and allow the machine operators and assemblers to report their work more often. At the same time, they did not deem tablets as a valid solution because of their big size.

P5-2 was sceptic about digitising the work instructions and blueprints because of the amount of data they contain. The size of the device is a limitation.

P5-3, the production planner, commented that it could be interesting to get warnings through notifications on a mobile device when the production was starting to fall behind schedule, to be able to start replanning the production. For instance if the manufactured items per hour would fall beneath a certain value, a notification could be sent as a warning, alerting the production planner that given the current throughput the production would fall behind.

4.6 Company 6

The main production of Company 6, C6, was manufacture of bearings using a disconnected line flow. The interviewees at C6 consisted of two persons: the production manager, P6-1, and a machine operator, P6-2.

4.6.1 Production

The process of manufacturing the bearings was highly automated. The warehouse workers moved material to the first machine; the material went through several steps inside the machines where it was heated, hardened, and cooled. The process of moving the material to the next step in the process was done automatically by the machines and once the material exited the machines, the warehouse workers moved it to an inventory space. The role of the machine operators was mainly to supervise the machines and respond to alerts. It took some time for the material to go through the machines so compared with that there was not much time spent setting up the machines.

The market was mature and there were no major changes in the products offered. The demand fluctuations in volume had been slow and quite predictable.

4.6.2 Roles

Three roles were discussed during the interviews: warehouse worker, production manager, and machine operator.

Warehouse Worker The warehouse workers used forklifts to transport the materials around the production facility, the warehouse workers were mobile.

Production Manager The production manager were stationary and mostly worked in an office setting.

Machine Operator The machines in the facility were large and there were few machine operators working at the same time which meant that the machine operators had to cover a large area. They monitored the machine, as well as conducted re-occurring maintenance on the machine.

4.6.3 ERP-Connected Devices and Applications

The warehouse workers used an ERP-connected device in their forklifts.

P6-2, the machine operator, was positive to the idea of using ERP-connected devices in the facility. The proposed idea was that a mobile device could show information regarding the machines, e.g. where in the machine, the material was and other variables in the machines. It was also suggested by P6-2 that work instructions for the regular maintenance could be accessed through a tablet.

P6-1, the production manager, did, however, say that he was not positive to the idea of mobile devices on the shop floor, saying that a paper based solution would be more appropriate in the production environment. P6-1 said that paper are more lightweight and easy to carry than mobile devices, and that the production environment might not be suitable for small electronic devices.

4.7 Company 7

The main production of Company 7, C7, was to refurbish and service forklift trucks for rental or sale using a jumbled flow. The interviewees at C7 consisted of two persons: the plant manager, P7-1, and a technical surveyor, P7-2.

4.7.1 Production

C7 got forklift trucks delivered to them, either rentals being returned or used forklifts. Once delivered the forklifts were classified by the technical surveyor according to how much they should be refurbished or repaired, this data was put into the ERP system along with documentation and pictures of the forklift. Each forklift got sent to a technician's work area where there could be several trucks already being worked on. This way the technician could order required parts for one forklift while working on another forklift, waiting for the parts to arrive.

There were a great variety of models and sizes on the forklifts, with varying amount of errors and faults. This made it difficult to standardise the processes. However, the technicians usually did similar repairs to all models, e.g. check the battery. The business unit did not control which forklifts got sent to them. The market was moving towards more short rentals as opposed to longer rentals, which increased the rate of forklifts that got delivered.

4.7.2 Roles

Three roles were discussed during the interviews: technician, technical surveyor, and plant manager.

Technician The technicians were stationary, they performed their work at their work area. The technicians were the ones who repaired and refurbished the forklifts.

Technical Surveyor The technical surveyor classified the forklifts as they arrived, the data was written on paper and brought to the office to be put into the ERP system. The technical surveyor also walked around the facility to inspect the forklifts and update necessary data, for instance if the forks had been changed to a wider set. This meant that the technical surveyor was mobile.

Plant Manager The plant managers work was stationary and mostly worked from the office.

4.7.3 ERP-Connected Devices and Applications

C7 was, during the case study, implementing a tablet to support the technical surveyors work. With the tablet, the technical surveyor could input data into the ERP system without needing to return to the office. The reason for this implementation was that it expedited the input of data, and it removed any errors that happened due to bad handwriting and misinterpretations of written data.

4.8 Company 8

The main production of Company 8, C8, was manufacture of turbines using a jumbled flow. The interviewees at C8 consisted of four persons: the production planning manager, P8-1, two production planners, P8-2 and P8-3, and the production manager, P8-4.

The production facilities of this particular company encompassed a large area, with construction and assembly personnel working in many buildings. The work of the personnel interviewed mainly focused on one particular building, which became the focus of this case study.

4.8.1 Production

Turbines consist of a diverse and large amount of parts, the building in which the case study focused on manufactured parts related to the blades in the turbine. The production was mainly structured as a jumbled flow; parts were produced in batches in each operation and transported to the next station once the batch was complete. Lead times for a complete turbine could be upwards to two years. With one year remaining, the turbine was connected to a specific customer order. Customers did not demand new variations of turbines. However, the demand volume could fluctuate. In the past, lowered demand had caused suppliers of parts to go bankrupt and caused a supplier shortage once the demand rose again which created a situation where C9 not only had to consider their own situation, but also the situation of the suppliers when the market shifted.

Instructions about how to perform the operations were located close by the machine operators' stations, close to these instructions were a list of which order to manufacture the parts in the order queue. If there were any changes to the order queue, these had to be printed out and put at each of these areas. Due to high requirements of traceability, once a batch was completed the machine operator manually inputs each items serial number into the ERP system.

4.8.2 Roles

Four roles were discussed during the interviews: production planning manager, production manager, production planner, and machine operator.

Production Planning Manager The production planning manager did stationary work in an office setting.

Production Manager The production manager was partly mobile and walked around the production facility. However, the ERP system was accessed through a computer in the office.

Production Planner The production planner worked in an office directly connecting to the shop floor. Much of the work was performed at a stationary computer but sometimes the production planner walked around the shop floor, to gather information and update instructions.

Machine Operator The machine operator was stationary to their work area.

4.8.3 ERP-Connected Devices and Applications

P8-2, one of the production planners, was of the opinion that barcode readers could improve the work of the machine operators, instead of manually inputting serial numbers, which could cause mistypes and errors, a barcode reader would increase throughput and reduce errors.

One issue that the production planners, P8-2 and P8-3, had noted was that certain information that travelled through the hierarchy did so by word of mouth. One type of information was the amount of items produced in one shift; this information often transformed into a higher or lower amounts as it travelled. A solution to this would be to digitise this information and send it directly to a smartphone or another device.

During the production tour, P8-2 commented that if the work instructions and blueprints were sent out digitally to the machine operators, it would save much time. It was suggested that a big screen could be placed at the workstations of the operators to show the instructions and blueprints.

4.9 Company 9

The main production of Company 9, C9, was assembly of machinery for mining, quarrying and construction using a connected line flow for the main part of the assembly and a disconnected line flow for the rest. The interviewees at C9 consisted of three persons: the production manager, P9-1, a business controller, P9-2, and an assembler, P9-3.

4.9.1 Production

The production at C9 had both a connected line flow for assembling the larger machinery and a disconnected line flow for assembly of some of the parts that would be part of the larger machinery. The connected line flow consisted of two lines, one for large and medium sized machinery and one for medium and small sized machinery. The assembly instructions, printed on paper, followed the machinery as it progressed along the line. When an operation was done, it was reported using a stationary computer close to the assembly area, after which both the instructions and machinery were moved one step down the line. The products were modular, and the customer ordered standard products with the option of adding customisation. The company acted on a global market; however, the demand was quite regular with small variations.

4.9.2 Roles

There were five roles discussed in the interviews: production manager, business controller, assembler, warehouse worker, and quality controller.

Production Manager The production manager was often stationary in the office and mostly used the ERP system for managing invoices.

Business Controller The business controller was often stationary in the office. The ERP system served as decision support and to monitor if the assembling was done on time.

Assembler The assembler worked at one station along the assembly line and was thus quite stationary to their work area.

Warehouse Worker The warehouse worker used forklifts to transport the materials around the production facility. The warehouse worker was mobile.

Quality Controller The quality controller was called when there was a machine breakdown. The quality controller went to the machine, took pictures for documentation and reported it to the maintenance crew.

4.9.3 ERP-Connected Devices and Applications

The warehouse workers were using ERP-connected devices in the form of computers in the forklifts. These computers helped the warehouse worker in reporting their work when they delivered or moved material, and it also told them where they could find the material.

P9-3, the assembler, noted that if the assemblers had access to a mobile device with a camera, they could manage the documentation and reporting of machine breakdowns.

P9-2, the business controller, said that it would be interesting if tablets could be used to show relevant data for decision support. The problems discussed during the interview was how to choose what data that was relevant and how it would best be presented on the screen. C9 traced some key performance indicators already, however, on a small display like a tablet or smartphone it was mentioned that at most a couple of the indicators should be shown.

4.10 Company 10

The main production of Company 10, C10, was manufacture of heat exchangers, heating units, and cooling units using a jumbled flow. The interviewees at C10 consisted of one person: the operations manager, P10-1.

4.10.1 Production

C10 manufactured a set of different kinds of heat transfer units, which were divided into industrial products and ventilation products. All the industrial products were customised, whereas only some of the ventilation products were.

The production was divided into multiple parts depending on the product, especially the size of the product, as well as the process.

The processes and products on the market were very similar. The way C10 tried to compete was by targeting the companies close to their geographical location, and by providing competitive offers. The demand followed the economic cycle and could be predicted fairly easy.

4.10.2 Roles

During the interview, three roles in the production were discussed: production manager, machine operator, and assembler.

Production Manager The production manager did stationary work in an office setting.

Machine Operator The machine operator was stationary to their machine. Their tasks differed depending on what kind of machine they worked at. Some machinery required mainly supervision from the operator and others required a more hands-on approach.

Assembler The assembler was stationary to their assembly area.

4.10.3 ERP-Connected Devices and Applications

At some workstations, the information was reported to the ERP system using a computer, while at others it was reported using barcode scanners connected directly to the ERP system.

Much information about the orders was reported on paper which followed the order through the production. At the end of each day, the information from the order was manually transferred from paper into the ERP system.

During the interview, P10-1, the operations manager, discussed the possibility to use mobile devices. They had dismissed the idea because of the dirtiness of the production, which might damage or limit the functionality of a mobile device. Instead, they were interested in a solution where large screens would be used to show blueprints in the production. By using screens with digital blueprints, the risk of having outdated physical blueprints in the production would be diminished.

P10-1 also talked about the how notification on mobile devices could be used to send relevant information to production personnel. However, they pointed out the importance for the personnel to be able to disconnect from work when going home.

4.11 Company 11

The main production of Company 11, C11, was manufacture of electronic cables and wiring using a disconnected line flow. The interviewees at C11 consisted of two persons: a machine operator, P11-1, and a logistic supervisor, P11-2.

4.11.1 Production

The production at C11 was semi-automated in the sense that the machine operators set up the machines before an order and monitored it during the execution. There were different kinds of machines at C11, but most machines operated in this manner.

Both P11-1 and P11-2 mentioned during their individual interviews that the most critical part of the production was the incoming material because of variations in its quality and properties. Because of these variations, the machines had to be set up in different ways to obtain the best result.

4.11.2 Roles

The following three production roles were discussed during the interviews: machine operator, warehouse worker, and logistic supervisor.

Machine Operator The work of the machine operator was mainly to set up the machine and supervise. The process from start to finish could take a long time depending on the length of the wiring. Thus, the machine operator often walked around and assisted their colleagues when they had the time.

Warehouse Worker The warehouse worker used forklifts to transport the materials around the production facility. The warehouse worker was mobile.

Logistic Supervisor The logistic supervisor usually worked in an office setting and were not mobile.

4.11.3 ERP-Connected Devices and Applications

Close by the machines, computers with access to the ERP system were located. In the ERP system, the orders were listed, sorted by priority.

On the computers, information from the intranet could be accessed. The information most often access was documentation about how the machines should be set up depending on the material and product.

During the interview, P11-2, the logistics supervisor, talked about using mobile devices in the production and warehouse. They suggested that it could be used to read barcodes or RFID tags, which in turn could be used to mark products in the production.

At the time of the interviews, C11 had implemented a machine monitoring system that fetched information both from the machines and the ERP system. The monitoring system was accessible as a website for devices within the intranet.

Analysis 5

The analysis chapter contains the analysis of the empirical data based on the analysis framework. The chapter is organised into three sections corresponding to each of the research questions.

The analysis of the empirical data was conducted using the analysis framework presented in section 3.6. The analysis was structured by first analysing the suggested and discovered applications and ERP-connected devices, by using the goal dimensions. This analysis served the purpose of identifying how applications and ERP-connected devices affect the effectiveness and efficiency in a production environment, i.e. answering the first research question.

The roles that were discussed during the interviews was analysed and positioned in the P-C CSD model. The applications and ERP-connected devices that were deemed beneficial according to the analysis above were used together with the P-C CSD model. This was done to identify to whom the applications and ERP-connected devices would be beneficial which would answer the second research question, how the role affected the need for ERP-connected devices.

Finally, the last part of the analysis was performed by analysing the applications and ERP-connected devices in connection to the companies' positioning in the CSD model. Similar to how the P-C CSD model was used, this part of the analysis was done to answer the third research question: how do the production structure and production strategy affect the need for ERP-connected devices?

5.1 ERP-Connected Devices and Applications

Several opportunities for ERP-connected devices and applications were discovered during the interviews and observations. Each application was analysed using the goal dimensions and placed in the table: Table 5.1, along with its intended user role. All of the suggested applications or those in use improved at least one of the goal dimensions, which might not be too surprising since the suggestion often came from persons familiar with the work processes, i.e. the personnel in the companies.

The results from the goal dimensions analysis laid the groundwork for a statement regarding the applications effect on effectiveness and efficiency. From the interviews and goal dimension analysis, the device or devices most fitting for the application were suggested as well. These results are presented in Table 5.2.

Table 5.1: ERP-Connected Applications and Goal Dimension Analysis

Application	Status	Co.	Role	Time	Flexibility	Quality
Receive feedback to their workstation regarding their performance or quality of their manufactured items.	In use	C1	Butcher	No change in execution time.	No change in flexibility.	The quality would improve since the shop floor personnel would get notified quicker about errors in their work processes, thus become faster at correcting these errors.
Send productivity results to the shop floor workers' cell phones at the end of the day.	In use	C1	Butcher	Does not influence the production time, as it is sent after hours.	Does not affect any flexibility.	At C1, the personnel was evaluated and paid based on their productivity results. P1-1, the production manager at C1, said that it gave the personnel extra motivation when they got the daily feedback.
Send and receive data using ERP-connected devices with barcode readers in forklifts.	In use	C2, C6, C9	Warehouse Worker	Data can be sent and accessed anywhere and at anytime, which removes the time necessary to go physically to a stationary computer to fetch it.	With a stationary computer in the forklift, the warehouse workers could receive updated instructions, improving the material handling flexibility.	P2-1, an operations manager, indicated that the quality of the data in the ERP system had improved after implementing forklift computers. The company could use more detailed information in the system.
Access to the ERP system with laptops for managers.	In use	C3	Manager	Does not affect the execution time.	Does not provide any additional flexibility.	By having access to real-time data, the managers can make decisions that reflect the current situation, compared to if they used paper, the decisions would reflect a point in the past.

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Table 5.1: ERP-Connected Applications and Goal Dimension Analysis *(continued)*

Application	**Status**	**Co.**	**Role**	**Time**	**Flexibility**	**Quality**
Scan a barcode on paper per order to fetch work instructions and display them on a nearby screen.	Suggestion	C3	Machine Operator, Assembler	It would not reduce execution time compared to sending the instructions by paper.	Would provide both labour and machine flexibility for a machine operator, but only labour flexibility for an assembler. Up-to-date information would be available more quickly for the personnel to react to.	The tasks would be performed in the same way regardless of whether the instructions were displayed on a screen or a paper. Thus, the quality would not change.
Get notifications regarding certain events, e.g. machine errors.	Suggestion	C5, C10	Any	The time elapsed from when an event happened to when the right person was notified would decrease.	The labour flexibility would be increased by instantly providing data to the individual worker.	Does not affect the quality.
Send maintenance requests containing pictures.	Suggestion	C9	Assembler	It would decrease the time to report information when maintenance is needed.	Does not affect any flexibility.	The ability to send a picture adds to the quality of the maintenance request.
Input data from production into an ERP-connected device.	Suggestion / In use: C1 & C10	C1, C4, C5, C7, C8, C10, C11	Assembler, Machine Operator, Technical Surveyor, Butcher	Would reduce the time between when the data is created and when it is put into the ERP system.	Does not affect any flexibility.	An often mentioned reason for using a device to input data as soon as possible was that it would reduce errors. For instance, if the handwriting is careless it may be misinterpreted. If the data is directly put into the system, these sources of errors are removed and the quality of the process is increased.

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Table 5.1: ERP-Connected Applications and Goal Dimension Analysis *(continued)*

Application	**Status**	**Co.**	**Role**	**Time**	**Flexibility**	**Quality**
Show machine status.	Suggestion	C5, C6, C8, C11	Machine Operator	In companies where the machine operators had a supervising role, having access to the machine status would allow them to be away from the machine and still be aware of its status. This would remove the time spent walking to the machine and inspecting it.	Would not affect the flexibility.	Would not affect the quality.
Show blueprints and work instructions on an ERP-connected device.	Suggestion / In use: C1	C1, C5, C6, C8, C10	Machine Operator, Butcher	The execution time of the machine operators' work tasks would not be impacted in any significant way.	The labour and machine flexibility would change by reducing the time between when a change is made to blueprints and instructions and when that information reaches the machine operators. However, if this data and instructions rarely change, the impact on the flexibility would be lower.	Pros and cons were identified by the interviewees. Blueprints may require larger sheets than there are screens on mobile devices. Similar remarks were made about the work instructions needing larger sheets or screens. Too small screens would result in a decreased quality as details could be missed. A benefit would be up-to-date information.
Show status of, and data from, the production on an ERP-connected device.	Suggestion	C5, C9	Business Controller, Production Planner	Does not affect the time needed to perform the task at hand.	In the case of the production planner, the routeing flexibility would be affected as they would more easily access data concerning the state of the orders and the machines. Other flexibilities would not be affected.	By having access to up-to-date information, better decisions can be made. Therefore, the quality is improved.

Table 5.2: ERP-Connected Applications and Devices, and their effect on effectiveness and efficiency

Application	Suggested Device	Effect on effectiveness and efficiency
Receive feedback to their workstation regarding their performance or quality of their manufactured items.	At the time of the interviews, stationary touch screens were in use at C1. For this application, it is useful to have a handsfree device in order to perform the tasks without disrupting the workflow.	The application was in use at C1 and it allowed them to raise the quality of the items produced without any significant drawbacks.
Send productivity results to the shop floor workers' cell phones at the end of the day.	C1 used, at the time of the interviews, smartphones to distribute personal performance data. The personal nature of the data and the fact that the data is sent during after hours makes it necessary to send to a devices type that most of the employees own.	The application was in use at C1. The data sent to the personnel was productivity values that their pay was based on and that they could affect. However, whether receiving this data every day, compared to receiving it once a month with their pay, would increase their motivation is difficult to prove.
Send and receive data using ERP-connected devices with barcode readers in forklifts.	When discussing this application, many of the companies used stationary computers in their forklifts with a barcode reader, which seemed to be the best solution.	Since all three of the measured goal dimensions were improved, this application had a clear and positive effect on effectiveness and efficiency.
Access to the ERP system with laptops for managers.	Since the managers often worked in an office, a laptop would provide them with the benefits of a stationary computer and the option of carrying it with them if necessary.	Using real-time data could improve the effectiveness of the decisions made. The managers were seldom mobile which makes it questionable whether this application would be used to support mobility.
Scan a barcode on paper per order to fetch work instructions and display them on a nearby screen.	Using a barcode reader connected to a nearby screen, either stationary screen or mobile device would be the most suitable.	The improved flexibility would most likely only be noticeable in companies manufacturing customised products. The effect of this suggestion would likely be highly dependent on the production structure.
Get notifications regarding certain events, e.g. machine errors.	Notifications do not require a large screen and most people carry a smartphone with them. Therefore, a smartphone would be the device suggested.	The effects would probably be positive as the application improves two of the goal dimensions.
Send maintenance requests containing pictures.	Smartphones would give the opportunity to both take pictures and send maintenance requests, and a smartphone would be small enough to be unobtrusive in their work.	The application would improve both the quality and the time, but has no effect on the flexibility. Because of the overall improvement of the dimensions, the effects would increase.

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Table 5.2: ERP-Connected Applications and Devices, and their effect on effectiveness and efficiency *(continued)*

Application	**Suggested Device**	**Effect on effectiveness and efficiency**
Input data from production into an ERP-connected device.	At C1 and C10, the function was controlled using a barcode reader or mounted touchscreens with the size of tablets, but the use of tablets was a common request overall. The different choice of devices may have varied based on the production.	Based on the reduced time and the quality incentives expressed during the interviews, the positive effect of the application seems to be outweighing any negative effects.
Show machine status.	Smartphone or tablet would be fitting when the user is mobile since it is easy to carry. Depending on the amount of information a tablet might be necessary to display all of the required information.	The increased effect on effectiveness and efficiency would be small as there are only positive effects on the time dimension.
Show blueprints and work instructions on an ERP-connected device.	The size of work instructions and blueprints could vary, making a wall-mounted screen a safer option but a tablet might work as well with the option of zooming on the device.	The effects could be both positive and negative depending on the situation when implementing the solution and what devices are used. Big blueprints on mobile devices would not be feasible, but on a larger wall-mounted screen they would more likely have positive effects. Work instructions, on the other hand, appears to be feasible on both kinds of device and would have a positive effect.
Show status of, and data from, the production on an ERP-connected device.	A laptop or tablet would provide the mobility and the necessary screen size to be able to show the data.	The application would improve one or two of the goal dimensions depending on the role of the user. The benefits of the application may, therefore, vary more on the situation at hand.

Due to aspects and factors specific to certain companies for some of the suggested applications, it was not possible to present one result that applied to all of the companies where the applications were suggested. However, the applications and devices that could be deemed beneficial were the ones showing a clear improvement regarding effectiveness and efficiency. In this case, the applications and the motivation for whether or not they were beneficial enough to analyse in regards to the roles, production strategy and production structure can be found in Table 5.3.

Table 5.3: ERP-Connected Applications and Motivation for Whether or Not to Analyse Each of Them

Application	**Motivation**
Receive feedback to their workstation regarding their performance or quality of their manufactured items.	The application did only provide a noticeable improvement on one goal dimension and was suggested by only one company. The company that used the solution was the only company in the study using a purely connected line flow. The production structure seemed to be an important part of the application. Since the application only provided a few improvements on efficiency and effectiveness and seemed to be a corner case in this study, the application was not further evaluated in this study.
Send productivity results to the shop floor workers' cell phones at the end of the day.	This application may improve one of the goal dimensions but only anecdotal evidence was given to support this claim. The probability that this application would be beneficial for a company is low, which is why no further analysis was made regarding this application.
Send and receive data using ERP-connected devices with barcode readers in forklifts.	This application improved all of the goal dimensions, it was also in use at several of the companies and had shown improvements to their work processes. This application was thus deemed beneficial to do further analysis on.
Access to the ERP system with laptops for managers.	This application and its suggested device only provide improvements to one goal dimensions. It is also questionable if one can consider the laptops as mobile or mobility-supporting devices since they are mostly used as stationary devices in this case. No further analysis on this application was done.
Scan a barcode on paper per order to fetch work instructions and display them on a nearby screen.	This application improved only one goal dimension: flexibility. As the application only was suggested by one company, the application might not be demanded by other companies. The application itself is to remove paper and use a digital medium instead. This application was not further analysed, but a similar application seen below was.
Get notifications regarding certain events, e.g. machine errors.	Improvements were shown in two of the goal dimensions. The device used is common, and there are no specific demands that must be met for this application to be useful. Thus, this application was further analysed.
Send maintenance requests containing pictures.	The application improves two of the goal dimensions. It would also utilise aspects specific to mobile devices, i.e. the ability to take pictures using smartphones. This makes it an interesting application, and further analysis was done.
Input data from production into an ERP-connected device.	Since it improved two of the goal dimensions and it was suggested in a majority of the companies it was chosen to be further analysed.
Show machine status.	Though it was suggested in several companies, the effects of it would not be great since it only affected one goal dimensions. The machine would also need to sense its status and transmit it to the ERP system. The application would also only be useful if the machine operator is mobile and away from the machine. The amount of demand put on other hardware and processes was why this application was not further analysed.
Show blueprints and work instructions on an ERP-connected device.	This application improves one or two goal dimensions depending on the device used. Given a large wall-mounted screen is used for blueprints and a smaller device for work instructions the application improves two dimensions and with this assumption the analysis was conducted.

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Table 5.3: ERP-Connected Applications and Motivation for Whether or Not to Analyse Each of Them *(continued)*

Application	**Motivation**
Show status of, and data from, the production on an ERP-connected device.	This application improves two of the goal dimensions: flexibility and quality. As the application focuses on roles in the production management team, the application might be used in companies independent of their production type. Since the possibilities of the application seemed adequate, the application was further analysed.

The choice was made to have *device in forklift to send and receive data* as its own application even though it is partially similar to the input data application. The data sent and received by a warehouse worker is different from data created in the production, and highly specific to inventory management. The device of having a stationary computer inside the forklifts would also make the device only usable by warehouse workers since they are the only ones using forklifts. Thus, the low possibility to make the warehouse workers processes and devices generalisable it was deemed most suitable to separate it into its own application and device.

In total, six of the applications was deemed beneficial enough to further analyse. These applications and most fitting devices were:

1. Send and receive data using ERP-connected devices with barcode readers in forklifts.
2. Input data from production into the ERP system using barcode readers and tablets.
3. Get notifications to the person's smartphone.
4. Show status of, and data from, the production on a laptop or tablet.
5. Send maintenance requests using a smartphone.
6. Show blueprints and work instructions on a tablet or wall-mounted screen.

5.2 Roles

To analyse the roles of the companies, the roles were grouped together for all companies. For each of the roles, a descriptive analysis that served as a basis for how they should be classified according to the personnel-centric CSD model was produced. Based on this classification the roles were sorted, and their needs were compared to each other. Some of the discussed roles were similar to each other and were classified in the same group according to the P-C CSD, but they had different titles, e.g. production manager, plant manager, and operations manager. The tasks may have differed, but overall the way they worked were similar enough to justify grouping them together in order to make the analysis easier to grasp. The role of quality controller was split into two since the work processes differed too much between the companies to be able to specify a position in the P-C

CSD model that satisfied all the quality controllers. Instead, the quality controller was split into a mobile and a stationary quality controller to properly reflect the differences in the roles.

To improve readability, the positioning in both the CSD and P-C CSD model will sometimes be shortened, e.g. low-high-medium corresponding to a low complexity, high specificity, medium dynamism.

A complete list of the roles discussed can be found in Table 5.4 with the number of companies at which each role was discussed, and with what similar role, if any, it was grouped. The list of roles, their analyses and classifications can be found in Table 5.5.

Table 5.4: The discussed roles with the number of companies at which they were discussed and with what similar role, if any, it was grouped.

Role	**No. of Co.**	**Grouped with**
Machine Operator	7	
Production Manager	6	
Warehouse Worker	5	
Assembler	4	
Production Planner	3	
Mobile Quality Controller	2	
Foreman	2	
Plant Manager	2	Production Manager
Stationary Quality Controller	1	
Butcher	1	
Operations Manager	1	Production Manager
Screen Changer	1	
Supply Chain Manager	1	Production Manager
Tester	1	
Team Leader	1	Foreman
Production Engineering Manager	1	Production Manager
Technician	1	Assembler
Technical Surveyor	1	
Production Planning Manager	1	Production Manager
Business Controller	1	Production Manager
Logistic Supervisor	1	Production Manager

Table 5.5: Role Descriptions and Analysis

Role	Description	Comp.	Spec.	Dyn.
Machine Operator	Often stationary at their machine, with tasks that are repeated, thus the specificity was high. There were differences in how they performed their tasks between the companies. Some machine operators mainly supervised the machines, and others had a hands-on approach. Overall the complexity of their work can be seen as low since they did not have any responsibilities apart from those for their own machine. There were few factors outside of their influence that affected their work, with the exception of machine breakdowns which would halt the work of the machine operator, the dynamism was low.	Low	High	Low
Production Manager	Often stationary in their office. The tasks they perform seemed to be recurring, with the exception of events that required their attention at the shop floor. Since the production manager can be quite mobile when necessary, as well as changing their work task at a moments notice to respond to events, the specificity was medium. The work day of production managers appeared to be pretty structured, but they could be affected by other factors such as the shop floor status, the dynamism is medium. The role of the production manager can be seen as quite complex, with many responsibilities in managing the production facility. Thus, the complexity was set to high.	High	Medium	Medium
Warehouse Worker	Moved around in warehouse area and sometimes in the production area. The tasks were limited to duties of moving materials and products to and from the warehouse. Due to the extreme mobility, not having a stationary point and almost always being mobile, points towards a low specificity. The area in which they were needed was affected by factors out of their control. They did, however, always perform the same tasks each time. Thus, the dynamism is medium.	Low	Low	Medium
Assembler	Often stationary at their workstation, with the exception of C4 where the assemblers were mobile. Due to the nature of assembling, the assemblers performed hands-on work, work tasks that were repeated. Using a similar argument that was made for machine operators, the complexity can be seen as low due to the low range of responsibilities and the recurring pattern in their work task. Because of the repeating work tasks and the stationary work they did, the specificity was high. The outside factors that could influence their work are quite low pointing towards a low dynamism.	Low	High	Low

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Table 5.5: Role Descriptions and Analysis *(continued)*

Role	Description	Comp.	Spec.	Dyn.
Production Planner	The work of the production planner had similar characteristics to a production manager. Being that the production planner's work was stationary in an office setting, both the recurring tasks and the limited mobility suggests a high specificity. The task of a production planner was to schedule orders, and the tasks were recurring, but the planners did have responsibilities over the production processes so a medium complexity was deemed the most fitting. The orders usually came from the sales department, the orders would also need to be replanned in some cases, there are thus outside factors and dynamism is medium.	Medium	High	Medium
Mobile Quality Controller	The mobile quality controller differed in some ways from the stationary quality controller. The mobile quality controller inspected both items and machines, and fit into a medium complexity. Being mobile and with a wider variety of things to check the specificity was medium. The dynamism was medium as well since the quality controller was affected by the shop floor workers.	Medium	Medium	Medium
Foreman	The foremen spent time both in their office and in the production, and their tasks stayed the same over time. Because of their mobility, these two aspects pointed to a medium specificity. The complexity of the foremen was medium since they bore the responsibility for some of the shop floor personnel and therefore the production. Their dynamism was medium because the nature of their work was affected by the production.	Medium	Medium	Medium
Stationary Quality Controller	The stationary quality controller was in charge of controlling products as a step in the production. The stationary quality controller focused on controlling a range of items, which made a medium complexity fitting. Being stationary and with a fixed range of items to control, the specificity was high. However, what to control changed depending on the performance of the shop floor workers making the dynamism medium.	Medium	High	Medium
Butcher	The butchers were quite stationary to their workstation. The work tasks were mostly repetitive due to the limited choices that exist when butchering an animal. The butchers did, however, get the additional responsibility to judge the material whether it could produce the desired product, this made it a medium complexity. Few outside factors impacted their work. Thus, having a low dynamism.	Medium	High	Low

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Table 5.5: Role Descriptions and Analysis *(continued)*

Role	Description	Comp.	Spec.	Dyn.
Screen Changer	The screen changer was in charge of delivering and changing screens for the printers. By only managing this task, the complexity was low. However, the screen changer was mobile in his work, describing a low specificity. The screen changer's work was highly dependent on when the printers needed new screens which made the work highly influenced by this outside factor. Thus, the dynamism was high.	Low	Low	High
Tester	The tester was in charge of both manual and automatic testing, on a broad range of components, indicating a medium complexity. The tester was mobile in some parts of their work and stationary in others, with the recurring nature of the task the specificity was medium. Each order contained many components to test but with a limited amount of orders, which made the work of the tester easier to plan and with little influence from outside factors. Thus, the dynamism was low.	Medium	Medium	Low
Technical Surveyor	The technical surveyor had several responsibilities and was in charge of classifying the forklifts so they got the correct reparations. Therefore, the technical surveyor had medium complexity. The technical surveyor was mobile, and the work tasks could shift a bit during the work day, which is why the specificity was low. Some of the work was dependent on outside factors like a new customer order, but some of the work could be planned. Thus, the dynamism was medium.	Medium	Low	Medium

5.2.1 Send and Receive Data in Forklifts

This application was used in several companies and by one role in particular: the warehouse worker. The warehouse worker had a low complexity, low specificity, and a high dynamism and was the only role having this specific combination in the P-C CSD model. This makes it difficult to test whether other roles in the same position could use the forklift application.

Since the application was used mainly to manage inventory and the warehouse, it was unlikely that another role would enjoy any benefits from this application. Overall, the work processes of a warehouse worker were very specific to their role, finding applications that would support a warehouse worker as well as other personnel might prove difficult.

5.2.2 Input Data into the ERP System

The application to input data into the ERP system was used in C1 by the butchers using stationary touchscreens, and by C10 using barcode readers. In the interview with P8-2, a production planner in C8, it was brought up that using barcode readers was a device they wanted to input data into their ERP system. Several other companies noted that tablets would probably be the best solution.

The intended roles for this application were assembler, machine operator, technical surveyor, and butcher. All these roles, except technical surveyor, were the roles filled by most personnel in each company and were the ones adding direct value to the products. Both assembler and machine operator had a low complexity, high specificity, and low dynamism. Butcher had similar values, except a medium complexity instead of a low.

Suggestions of devices for machine operators and assemblers were either tablets, which provided a large screen to input values, or barcode readers when the values were tied to a barcode. With a high specificity the work tasks were recurring, and the personnel had a low mobility, suggesting that the data sent would often be similar. This was further supported when looking at the dynamism; their work did not get affected significantly by outside influences, making a rigid system like a barcode reader sufficient. There were no other roles with a high specificity and low dynamism to test whether this application would be usable by other roles. However, since it was in use or suggested for all three of the roles with high specificity and low dynamism, it is probable that roles with those values, and either medium or low complexity, would benefit from this application.

The technical surveyor, on the other hand, had a very different positioning in the P-C CSD model, with a medium complexity, low specificity, and a medium dynamism. For this role, the application served the purpose of supporting the technical surveyor's mobility. The work of the technical surveyor mainly involved updating and inputting data to the ERP system. Spending much of the time mobile a tablet was most suitable for the tasks. No other role had the same values in the P-C CSD model, some roles shared at least two of the three values, but overall the application was not suitable for any other roles.

The role of a technical surveyor did not exist anywhere else other than C7, and no other role had similar work processes and responsibilities. There may be a use for this application for other roles where data reporting and mobility is important, but since this role seemed to be unique in this study, it was difficult to generalise the findings to other roles.

Every company either had machine operators, assemblers, or butchers. Due to how common these roles were and the suggestions regarding this application, it would be possible for this application to be beneficial in many companies where these roles are present.

5.2.3 Receive Notifications

The application of receiving important notifications to a person's smartphone was discussed at two companies, but during the interviews, there was no specific role to which this application would be the most beneficial. The idea was that smartphones are a common item to carry on your person which would make the financial side easier for the company when implementing notifications. However, these notifications would work for every role, but using notifications for different events.

In C5 the machine operators were slightly more mobile when compared to machine operators in many other companies and due to the size of the facility it would be difficult to know their location when an event occurs, this spawned the idea of sending a notification whenever there was an important event regarding their machine. Managers, production planners, quality controllers, their notifications would centre around events that required their attention. The question for this application does not revolve around who would need it, rather what data each role would be notified of.

5.2.4 Show Status and Data from Production

Showing status and data from the production floor was something that business controllers and production planners wanted. This application would help them as decision support and to plan for the future.

The business controller was part of the manager role group and had a high complexity, medium specificity, and medium dynamism. Being part of the manager group, the business controller had similar work processes to the other roles in the group, and the need to have access to updated data would seem to be shared as well. Their tendencies to seldom be mobile meant that this application with a device would rarely act as a mobile or mobility-supporting device. The times managers were mobile a laptop or tablet would suffice. It was mentioned in a few interviews that a laptop was all that a manager needed, though the application was not always discussed.

The production planners had a medium complexity, high specificity, and medium dynamism. A positioning shared with the stationary quality controller. The production planners had a need for up to date data in order to correctly reschedule orders and ensure that the production went as planned, similar to the managers the production planners were seldom mobile and the mobility-supporting effect would be small. The stationary quality controller on the other hand, did not have a need for data in their work. Thus, the medium-high-medium position did not seem to be an indicator for a need of this application.

Personnel in the high-medium-medium position that was interviewed, such as managers, did have a need for this application. Due to the amount of interviewed personnel in this position it could be said that it was an application that other roles would find useful given that they are positioned the same. The medium-high-medium position, where the production planners were found, did not appear to be a position where the need for this application could be generalised.

5.2.5 Send Maintenance Requests

At C9, the assembler that was interviewed, P9-3, noted that it would be a good idea to be able to send maintenance requests using a smartphone. This would allow the assembler to attach a picture to make the job easier for the personnel managing maintenance, and a smartphone is an item that he always had on his person reducing the cost of implementing this application.

Assembler and machine operators both had a low complexity, high specificity, and low dynamism. During the interview stage, it was only an assembler that thought of this application; this interview was in the later stages of the case studies which made it difficult to test whether it was a common desire to send pictures with maintenance requests. However, many of the machine operators and assemblers in other companies used their smartphones and called the maintenance crew whenever something broke down or needed attention. Using an application to send a picture with the request would not be all that cumbersome when they already have the device and use it. Even if the machine operators and assemblers themselves do not see the benefit, the maintenance workers would probably appreciate a picture of the error.

There were no other roles in the low-high-low position, and it would seem that this application would be of little use to other roles. The machine operators and assemblers were the ones noticing the need for maintenance and contacting the appropriate personnel. Any role with a low-high-low positioning which works on the shop floor would probably find this application beneficial.

5.2.6 Show Blueprints and Work Instruction

To show blueprints, work instructions or both on ERP-connected devices was suggested at five companies: C1, C5, C6, C8, and C10. At C1 work instructions were already sent to the butchers on fixed touchscreens. At the other four companies, it was suggested by or for machine operators. It would allow them to access work instructions on a mobile device and blueprints on a wall-mounted screen, acting as a mobility-supporting device. Having the work instructions on the go would allow them to move around the facility, while having the blueprints on a wall-mounted screen would allow them to move less, as they would not need to fetch the blueprints.

Butchers had a medium complexity, high specificity, and low dynamism, while machine operators had a low complexity, high specificity, and low dynamism. Assemblers shared the same classification as machine operators, while butchers were alone of having its particular classification.

Assemblers could probably use the application in a similar way as machine operators, who also work on the shop floor. In their case, having the work instruction on a mobile device could be interesting as it might be changed and having it digitally would ensure that it is the latest version.

The application seems beneficial for roles in the low-high-low position, while it is difficult to give a definite answer for the medium-high-low position. It is likely that other roles on the shop floor with the low-high-low position would find this application useful.

5.3 Production Structure and Production Strategy

In order to analyse how the need of ERP-connected devices vary, based on the production structure and production strategy of the company, the production structure and production strategy for each company was analysed using the CSD model. The analysis and classification for each company can be seen in Table 5.6.

The table is followed by the analyses of the selected applications in relation to the production structure and production strategy.

Table 5.6: CSD classifications

Co.	Complexity	Specificity	Dynamism
C1	**Low** – The processes were not complex and had not changed in a long time. It could take a while to learn to do the work efficiently but the animals anatomy never changes, so there would not be any new processes that needed to be learnt.	**High** – As previously stated, the anatomy of an animal does not change so the variations are limited, e.g. if the bone is left in or cut out. The output could not be changed more than just marginally.	**Low** – Due to the limitations of what could be produced from an animal the demand for new products were pretty much non-existent. The demand did vary over the year based on seasonal events, such as at Christmas when ham is consumed to a greater degree, but it was easy to forecast these demand changes.
C2	**Low** – Corrugated paperboard is a simple product. There were slight variations that could be applied in colour and thickness but they did not make the process more difficult. A lot of the work was mostly acting as a monitor and reporting malfunctions, starts and stops in production. The workers could change the settings on machines at their own discretion if they thought another setting would produce a better product.	**High** – The changes in settings were minor with the result still being the same. The output from the processes would always be similar to each other.	**Low** – The demand in volume did not fluctuate. The market did not demand any new products apart from the occasional change in what colour they preferred the corrugated paperboard to be.
C3	**Low** to **Medium** – The company bought their corrugated paperboard and added print and punches it into the correct shapes. There was some complexity in that there were seldom products that are recurring; each order was customised and customers rarely order the same thing twice.	**High** – The processes produced corrugated paperboard with print on. The prints were either done digitally away from the shop floor, or through the use of screens. The end products were similar to each other and the customers could not demand anything other than variations in images and punches.	**Medium** – The market was changing its demand towards more frequent orders with less volume in each order. This affected the manufacturing process by increasing the amount of setup time with the machines. This change in demand made the digital print more appropriate than the screen press. If this trend would continue the company might be forced to invest in more digital press machines.
C4	**High** – The products had a research and development time of about eight years followed by two years where the products were manufactured and sold, meaning that the total production time consisted of about 80 % R&D time. The products were varied and complex, making it difficult to have a modular production except in smaller product families.	**Low** – The processes used could manufacture diverse products.	**High** – Customers often demanded customised products. Customising the products was both costly economically and made the manufacturing process take a longer time.

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Table 5.6: CSD classifications *(continued)*

Co.	Complexity	Specificity	Dynamism
C5	**Medium** – The products were standardised, but there were multiple products and production steps.	**Low** – Processes could be used to produce different output and the components could be used in several different products.	**Low** – The changes in demand and development of new products were slow, leading to a stable market.
C6	**Low** – The products were in a mature stage and few improvements and changes were made. Most of the production was automatised.	**High** – The processes could be slightly changed to alter the characteristics of the material but the end result was still similar.	**Low** – The changes in demand were slow and only concerned the volumes.
C7	**Medium** – The forklift trucks that arrived varied a lot and the issues that needed to be repaired also differed. These factors made it difficult to standardise the work but the varieties of trucks and problems were limited making the set of operations limited.	**High** – The processes were formed so that the forklift truck could be restored to a better state, the output was thus entirely dependent on what forklift truck that was the input.	**Medium** – The division did not have any control over what new forklift trucks they would receive making it difficult to forecast. The rental was also moving towards more short-term rentals instead of long-term, further increasing the uncertainty.
C8	**High** – Turbines are complex products. Their lead times could stretch up to two years. They only manufactured one family of products and spare parts within that family.	**Medium** – Parts were manufactured to a standard core product approximately one year before the customer order decoupling point was reached and the product was connected to an order, after which customisations and customer adjustments were made before the product was finalised.	**High** – The demand experienced fluctuations in volume, but not in the sought after products. Previously, when demand had dropped the production have been slowed down or halted, a sudden change that some suppliers had not been prepared for and then become bankrupt. The turbine product is a niche product, and new suppliers could be hard to find.
C9	**Low** – The production was modular, using a standard product to which the customer could add customisations. No parts were manufactured inside the shop; the production was just assembling already made parts into the finished product.	**Medium** – There were two lines in the assembly. One line where large and medium-sized products were assembled and one line where medium and small-sized products were assembled.	**Medium** – The market was mature, but they were selling to a global market which led to them needing separate market strategies depending on the markets.
C10	**Medium** – On average the orders contained 1.6 articles, with customisation this almost made it into individual projects.	**Medium** – They produced a few set of articles with a lot of customisations. However, according to the production manager, they were essentially the same products.	**Low** – The market did not demand any larger product developments. It took a long while to phase out old products.

Continued on the next page

Table 5.6: CSD classifications *(continued)*

Co.	Complexity	Specificity	Dynamism
C11	**Low** – The cores of the cables were purchased and a layer of coating was put onto the cable. What may have increased the complexity a bit is that there could be different cores and coatings which require different machine setups.	**High** – Different coatings could be used but in the end, there would still be a cable.	**Low** – They and their demand appeared to follow the economic cycle.

5.3.1 Send and Receive Data in Forklifts

The application was in use in three companies: C2, C6 and C9. Two of these companies, C2 and C6, were classified as having low complexity, high specificity, and low dynamism. C9, on the other hand, was classified as having low-medium-medium in the CSD model. Although the different classification, they were both located close by the B-plane in the CSD model, see Figure 3.2, which entailed good product performance.

The production and process structure at the companies varied. The processes were more automated in C2 and C6 while the main process at C9 was assembly, being a hands-on process. The companies used connected or disconnected line flow or a combination of the two.

The warehouse workers were discussed and existed in multiple companies, and they were somewhat located away from the production. Because of this, the potential for using mobile devices in forklift trucks within the warehouse does not seem to be limited to a specific production structure or strategy.

5.3.2 Input Data into the ERP System

This application was in use in C1 and C10 while sought after in five other companies: C4, C5, C7, C8 and C11. The classification on the CSD model different completely among all companies except two, which shared a low-high-low classification.

The production at C1 and C10 differed, they used connected line flow and jumbled flow respectively. There does not exist any strong connections between the production strategy or structure, which seems to indicate that the application could be applicable in companies with other types of production.

5.3.3 Receive Notifications

The application was suggested at C5 and C10. Both used different structures in the manufacturing: C5 used both connected and disconnected line flow while C10 used jumbled flow. Their CSD classifications were medium-low-low for C5 and medium-medium-low for C10, which was similar.

The production strategy and structure, themselves, do not seem to influence the need for the application.

5.3.4 Show Status and Data from Production

At both C5 and C9, this application was suggested. Their structures used both connected and disconnected line flow. Each CSD classification of their production strategy was medium-low-low and low-medium-medium.

Although the companies share the same combination of production structures, there does not seem to be any obvious connections between the production and the application. In this case was the users not present on the shop floor, which might also weaken the link between the application and the production strategy.

5.3.5 Send Maintenance Requests

The application was suggested at C9, where, as mentioned in the previous subsection, they used both connected and disconnected line flow in the production. Their CSD classification was low-medium-medium.

Because the application was only asked for at one company, the application can not be linked with certainty to a specific production strategy or structure.

5.3.6 Show Blueprints and Instruction

This application was suggested at C5, C6, C8, and C10, and in use at C1. Two of the companies: C1 and C6, shared the CSD classification low-high-low, while the other three had three different classifications. Two of the companies: C8 and C10, shared the jumbled flow production structure, while two of the other companies: C1 and C6, used connected line flow, and the fifth company: C6, used both connected and disconnect line flow in different parts of the production.

Since most companies had different production strategy and production structure, its is difficult to link the application to a specific configuration.

6 Conclusions

In this chapter, the answers to the research questions are presented and the conclusions of the study are drawn.

The purpose of this study was to identify how the use of ERP-connected mobile and mobility-supporting devices could affect processes among shop floor and production management personnel in large manufacturing companies. Empirical data was gathered from eleven companies; this data was analysed using the analysis models identified in the theoretical framework, presenting us with the conclusions to our three research questions.

1. How can ERP-connected devices affect effectiveness and efficiency in a production environment?

The interviewees at the case companies and the authors of this study identified several applications and ERP-connected devices. Using the goal dimensions of quality, time, and flexibility, the effect on the effectiveness and efficiency was measured. Five applications improved only one dimension, five applications increased two dimensions, and one application increased all of them. The most effective application was the input to the ERP system and receiving of data while mobile in a forklift truck.

The ERP-connected devices suggested for these applications were smartphones, tablets, laptops, barcode readers, and forklift truck computers. All of the identified applications and ERP-connected devices affected the effectiveness and efficiency in a positive way, though only six in a significant way.

One of the applications, sending maintenance requests, is an application that Thun (2008) has done further research into. The conclusion in the report by Thun (2008) was that mobile devices had the potential of improving maintenance activities, where one of these activities was to send maintenance reports. In this study the idea of using mobile devices to send maintenance requests was identified by shop floor personnel, i.e. by people with practical experience, Thun (2008) identified the same idea from a theoretical perspective. This lends further credibility to our result regarding the send maintenance request application.

Similar to what Thorvald, Högberg and Case (2014) found in their research, that easier and more flexible access to the information system reduces errors, could be found among several of the companies. C7, for instance, implemented an ERP-connected tablet in order to remove the errors that would occur due to the extra steps of writing and interpreting written data. Other companies, such as C8, noted that going for digital data instead of written would remove error sources and thus increase the overall quality in the production environment.

The findings show that ERP-connected devices can improve effectiveness and efficiency, no ERP-connected devices or applications were identified that decreased or had no effect on effectiveness and efficiency. However, during interviews it surfaced that using devices that were not a good fit for an application could be harmful to the process. This hints that negative effects can be found, but in the analysis each application was paired with its most suited device, possibly circumventing these sorts of negative effects.

2. How does the role of the production personnel affect their need for ERP-connected devices?

When the applications and ERP-connected devices were identified, the interviewees specified which role they thought would benefit from them. Roles who had the same positioning in the personnel-centric CSD model were tested to see if they too would benefit. The results were mixed. Personnel who were closest to the shop floor and identified as low-high-low in the P-C CSD model, i.e. the roles of assemblers and machine operators, had similar needs. Similarly the personnel in management positions, high-medium-medium, also had similar needs to each other. For the other roles, no clear linkage could be found between their needs and their positioning in the P-C CSD model, only that their needs differed from other roles.

Different roles had different needs for ERP-connected devices. This was not too surprising since several academic papers divide the users into roles. For instance Andersson and Henningsson (2010) discuss that there are typical uses of IT within certain roles. In cases where applications and devices are discussed specific roles are often the users. In the study by Er and Kay (2005) it is the role and characteristics of a doctor that is discussed, in other studies it is operators discussed (Åkerman et al., 2016), field service technicians (Valiente and Westelius, 2007), or managers (Turbide, 2014). This suggested that the role had effects, which were confirmed in our study.

The roles who were positioned in either the low-high-low or the high-medium-medium had similar needs to other roles in the same position.

Being able to generalise need between different roles was not something that was found in the literature. The closest could be in the white paper by Turbide (2014), where he discuss managers generally. This would confirm the result of being able to generalise the needs in the high-medium-medium position, which in our case was managers.

3. How do the production structure and production strategy affect the need, in a production environment, for ERP-connected devices?

During the interviews and the production tours, data concerning the production, its structure and the production strategy was gathered. The data was used to classify each company according to the CSD model and thereby analyse their production strategy.

The production strategy of each company was used, together with the aforementioned identified applications, to compare the companies to each other and to try to find similarities between the companies.

Based on the analysis of the six applications together with the production strategies of the companies that used or showed interest in the applications, the production strategy and production structure does not have a clear effect on the need for ERP-connected devices in manufacturing companies. If it exists, it is too weak be apparent in the selection of companies used in this study.

The decision to study the effect of the production structure and production strategy was made since we, the authors, thought it would be an important aspect. Since this research question was grounded in assumptions from our side, reaching an inconclusive result may be a reflection of our previous knowledge base regarding production environments, which at the start of this study was shallow.

Discussion 7

This chapter contains the discussion concerning the how the study has been conducted and recommendations for further research.

In the research by Hoos et al. (2014), the goal dimension of cost is disregarded. For this study, the choice was made to disregard cost as well. This was due to the fact that a cost analysis would require calculations on data that would be hard to get and that the results would be difficult to generalise. The ERP-connected devices and applications in this study all improved at least one of the goal dimensions; the question arises whether the beneficial effects would offset the implementation and support costs that would be incurred from these devices and applications. Gerwin (1993) mentions that cost is often a factor that gets left out when studying the impact of increased flexibility, seeing as it is a recurring appearance since it also appears in the framework by Hoos et al. (2014) and this study, it is pertinent that further research is done regarding the cost aspect. The case companies in this study had varying degrees of implementation regarding ERP-connected devices, ranging from full implementation with support to those that did not have any. This made it difficult to generalise a cost dimension due to the many factors that affect the cost. Further research could identify the implementation costs for some of the applications and devices that were discovered in this study, in order to fully analyse all four goal dimensions.

The first of the research questions were phrased in a way that opened up for the possibility of negative or no effect at all on effectiveness and efficiency. During the study no ERP-connected device or application was found that had a negative effect on the goal dimensions. This could very well be due to allowing the personnel and interviewees to identify applications; it is probable that they would identify applications that would aid them in their daily work. Though the results of this study show that positive effects can be found, the fact that no harmful applications were found does not prove that they do not exist. It is also important to consider whether the personnel would accept the devices, one interviewee noted that a paper based system would be preferable, hinting that some personnel would be reluctant to use the suggested devices.

One reason for why the results turned out to be inconclusive could be due to the tools used in the analysis. The CSD model was deemed to be useful in analysing the production strategy and production structure of the companies. Two companies that produced similar products in the same material, C2 and C3, had very different processes and overall strategy, which is shown as they had different positioning in the CSD model. C1, C2, and C11 manufactured entirely different products and used entirely different material. However, the processes and strategies utilised on the shop floor were similar, and the companies got the same positions in the CSD model. The CSD model thus proved to be a valid analysis tool to differentiate deceivingly similar companies, while still generalising companies with similar processes and strategies, in a satisfactory way. The CSD model by Helkiö and Tenhiälä (2013) thus proved to be a useful analysis model to analyse the production strategy. However, in this study, a model or framework that analysed other aspects in the production environment might have resulted in a conclusion that would not end up being inconclusive.

Due to limited resources, only companies within a certain geographical area could be visited. These companies were active in different industries, although all were manufacturers of some kind. The closeness of the companies could affect the results, for instance, if there was a cultural aspect that was present in this geographical area which influenced the results. Further research could delve deeper in one specific industry, trying to find characteristics dictating their needs for ERP-connected devices, preferably with companies spaced farther apart. When looking at the model by Hayes and Wheelwright (1979), there was one process structure which this study did not analyse, which was the continuous flow structure. It would have been preferable to study a company with a continuous flow structure, or a couple of companies with continuous flow, to see if the results can be generalisable to that type of structure.

A factor that might have affected the study is the fact that the authors did not have prior knowledge in all the industries they included in the study. This in turn might have led to misinterpretations of the data and further on in the analysis. These concerns could have had a further impact if the companies provided incorrect information during the interviews, which could have resulted in flawed conclusions. This factor was combated during the study by being aware of its potential existence and by critically reviewing the interviews and the other empirical data.

One aspect of this study to consider is whether other researchers would end up with the same conclusions using the same methodology and analysis framework. The personnel-centric CSD model was created during this study by us, the authors. How to use the model has been described, and a reader can see how it has been used to analyse different roles, giving a reader guidelines concerning its use. The model was tested on many different roles, though mostly machine operators, assemblers, and managers. Other roles that were discussed only a few times are susceptible to errors that would make their positioning wrong. For instance, if the roles differed greatly between companies, or if a company that was studied had a role working in a unique way. A high amount of interview subjects in each role would be more likely to end up with an average positioning in the role or with enough data to be able to separate roles into two like it was done in this study regarding stationary and mobile quality controllers. Further research regarding the P-C CSD model should focus on finding a way to assess roles quantitatively, and do a quantitative study to test the validity and reliability of this model and possibly improve upon it.

The CSD model provides guidelines for how the model should be used. It was also tested quantitatively by the authors Helkiö and Tenhiälä (2013), which might make it easier for researchers to use. Due to its more descriptive user guide, it is likely that the results are easier to replicate.

Finally, the applications and devices analysed in this study were identified by the interview subjects. If this study were to be replicated, their applications and devices might differ from those in this study if they too let the interview subjects do the identifying. However, further research could use our applications and devices as topics of discussion, to test whether other persons identify the same benefits and potential consequences of using the applications.

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A Interview Questions

Translated from Swedish.

A.1 Start Interview

- What is your job title?
- For how long have you worked at the company and in your current role?
- What are your work tasks and processes?

A.2 Facility-Specific Questions

- How many of the employees work in the production?
- How would you describe the production?
- Do you know of any critical parts of the production? Time, quality, process?
- What are the duties of the shop floor personnel?

A.3 Production Strategy and Market

- How much do your production and/or product differ from that of your competitors?
- What is the change in the market like regarding customer needs, demand, etc.?
- What sort of changes? (Volume flexibility, Product mix flexibility)
- How easily can you adjust to these changes?

A.4 Product and Process

- What do you produce?
- How many production steps are needed in order to produce a finished product?
- Do you customise your products for your customers? In which case, how?
- Which production steps do you have in this facility?
- How long time does it take to teach new personnel the processes and the duties?
- How do you teach new personnel?
- Can a process or a task be carried out in a different way? (Strict procedure or flexible)?
- To what degree can the machines be used in the manufacture of different kinds of products or orders?
- To what degree can the resources/material be used in the manufacture of different kinds of products or orders?
- Do you have any bottlenecks in the production?
- Are the operators at designated machines? Alternatively, do they rotate, in which case how often?
- Are all processes carried out at machines? (Reporting, measuring, etc.).

A.5 Mobile App Usage Areas

- Would you use/allow mobile devices for work on the shop floor?
- How is information, e.g. about machine failures, reported? How do you get notified about machines failures?
- How is information received? How fast is new information noticed? (Also information from external sources).
- Do you have any ideas for how mobile devices could be used in the production? What requirements would apply? Do you see any potential problems?
- Do you see any other applications for mobile devices at the company as a whole?
- If you use mobile devices, how are they used and for what?

Ask for consent to contact them for follow-up questions. Ask for an e-mail address. End the interview and stop the recording.